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Assoc. Prof. Eng. KISS Imre, PhD.
UNIVERSITY POLITEHNICA TIMISOARA,
FACULTY OF ENGINEERING HUNEDOARA

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Fascicule 1
[January – March]
tome XV
[2022]

ACTA Technica CORVINIENSIS
BULLETIN OF ENGINEERING

ISSN: 2067-3809

TABLE of CONTENTS

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
Tome XV [2022],
Fascicule 1 [January – March]

The ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering, Tome XV [2022], Fascicule 1 [January–March] includes original papers submitted to the Editorial Board, directly by authors or by the regional collaborators of the Journal.

Also, the ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering, Tome XV [2022], Fascicule 1 [January–March], includes scientific papers presented in the sections of:

- **IIZS 2021 – XI International Conference on Industrial Engineering and Environmental Protection**, organized by Department of Mechanical Engineering, Department of Environmental Protection and Department of Industrial Engineering in Exploitation of Oil and Gas, Technical Faculty Mihajlo Pupin Zrenjanin, University of Novi Sad (SERBIA), in cooperation with partners University Politehnica Timisoara, Faculty of Engineering, Hunedoara (ROMANIA), University St. Kliment Ohridski, Technical Faculty, Bitola (MACEDONIA), Aurel Vlaicu University of Arad, Faculty of Engineering, Arad (ROMANIA), University of East Sarajevo, Faculty of Mechanical Engineering East Sarajevo (BOSNIA & HERZEGOVINA) and University of Giresun, Faculty of Engineering, Giresun (TURKEY), in Zrenjanin, SERBIA, in 07–08 October, 2021. The current identification numbers of the selected papers are the **#3–6**, according to the present contents list.
- **The International Conference on Applied Sciences – ICAS 2021**, organized by University Politehnica Timisoara – Faculty of Engineering Hunedoara (ROMANIA) and University of Banja Luka, Faculty of Mechanical Engineering Banja Luka (BOSNIA & HERZEGOVINA), in cooperation with Academy of Romanian Scientists (ROMANIA), Ministry for Scientific and Technological Development, Higher Education and Information Society of the Republic of Srpska (BOSNIA & HERZEGOVINA), Academy of Sciences and Arts of the Republic of Srpska (BOSNIA & HERZEGOVINA), Academy of Technical Sciences of Romania – Timisoara Branch (ROMANIA), General Association of Romanian Engineers – Hunedoara Branch (ROMANIA) and Association Universitaria Hunedoara (ROMANIA), in Hunedoara, ROMANIA, 12–14 May, 2021. The current identification numbers of the selected papers is the **#10,** according to the present contents list.
- **ISB–INMA TEH' 2021 – International Symposium (Agricultural and Mechanical Engineering)**, organized by Politehnica University of Bucharest – Faculty of Biotechnical Systems Engineering (ISB), National Institute of Research–Development for Machines and Installations Designed to Agriculture and Food Industry (INMA Bucharest), Romanian Agricultural Mechanical Engineers Society (SIMAR), National Research & Development Institute for Food Bioresources (IBA Bucharest), National Institute for Research and Development in Environmental Protection (INCDPM), Research–Development Institute for Plant Protection (ICDPP), Research and Development Institute for Processing and Marketing of the Horticultural Products (HORTING), Hydraulics and Pneumatics Research Institute (INOE 2000 IHP) and "Food for Life Technological Platform", in Bucharest, ROMANIA, between 31 October – 1 November, 2021. The current identification numbers of the selected papers are the **#15–20,** according to the present contents list.

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Fascicule 1

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[1,2.]Alireza DARVISHI, [1,3.]Aria DANESHMAYEH, [2,4.]Alihosein SALEHI, [2,4.]Mahdi AHMADI

EFFECT OF DOUBLE AUSTENITIZATION TREATMENTS ON THE MICROSTRUCTURE AND HARDNESS OF 11.7% CHROMIUM AND 1.4% CARBON STEEL (FMU–11)

[1.] Graduate School of Materials Engineering, Azad University, Saveh Branch, Saveh, IRAN
[2.]Department of Technology, Ravanshir Steel Factory, Takestan, IRAN
[3.]Department of Production, Ring Khodro Pars Factory, Takestan, IRAN
[4.]Department of Production, Ravanshir Steel Factory, Takestan, IRAN

Abstract: In this study, the effect of double austenitization (DA) and single austenitization (SA) on the microstructure and hardness of FMU–11 steel, which is used to make the cement mill, was investigated. To obtained maximum hardness; FMU–11 steels are used in a quenched and tempered condition. This involves heating the material to the austenitizing temperature (850–1100ºC), quenching at a suitable rate to form martensite, and tempering to increase the toughness and reduce the retained austenite content. In this investigation, four samples as SA and four other samples as DA was heat–treated at 900, 950, 1000, and 1050 ºC, respectively. The microstructure of the samples was studied using an optical microscope and then scanning electron microscopy (SEM) was applied for higher magnification studies. The hardness measuring for the samples heat–treated in different cycles. The results showed that the DA compared to SA heat treatment will reduce the size of the carbides but will increase retained austenite. However, the hardness decreases as the quenching temperature is increased from 900 to 1050 ºC

Keywords: double austenitization, heat treatment, cement mill, microstructure, hardness

INTRODUCTION

FMU steels are high carbon– high chromium steels that are widely used in cement mills. These steels are air–hardening types with maximum dimensional stability during heat treatment and give high hardness and wear resistance. The heat treatment methods recommended for high chromium martensitic steels continue:

≡ Austenitization between 950 and 1100ºC followed by quenching in the air;
≡ Tempering between 200 and 300ºC for high strength, medium–toughness, and resistance also between 600 and 700 ºC for medium–strength, high toughness [1, 2].

An optimum combination of high strength and high toughness in the steel can be achieved only under carefully controlled heat treatment conditions. Earlier studies revealed that austenitizing at a lower temperature of 950ºC did not allow a large number of alloy carbides to go into the solution, leading to the achievement of lower strength and toughness. Moreover, a high austenitizing temperature of 1100ºC or higher, notwithstanding helping in a dissolution of alloy carbides, resulted in an increase in prior austenite grain size besides increasing the δ–ferrite, as well as retained austenite content. Hence, double austenitization (DA) can be applied to obtain the benefits of both treatments. The advantages of DA treatment were reported on other steels [1–9]. The present study has therefore been taken up to evaluate the effects of single austenitization (SA) and Double austenitization (DA) treatments on the microstructure and hardness of FMU–11 steel. The objective of the present study was to explain the mechanisms concerning how the size of the carbides is affected by microstructure through mainly DA treatment for FMU–11 steel.

EXPERIMENTAL PROCEDURE

— Material – specimen preparation

Test samples used in the current study, sectioned with the dimensions of 25 mm × 25 mm ×150 mm, were prepared from a high carbon–high chromium steel (FMU–11) with the chemical composition determined by the Hilger spectrometer, as shown in Table 1. The steel was melted using an induction furnace and then poured into a silica sand mold.

Table 1. Steel Composition.

Element	Composition (%)
C	1.4
Si	0.38
Mn	0.69
Cr	11.71
Mo	0.29
V	0.039

— Heat Treatment

Before the heat treatment, the surface of the samples was coated with cupric sulfate ($CuSO_4$) to prevent oxidation and de–carburization. Due to the low heat transfer coefficient of this steel [10], the samples were heated to 650°C, with a heating rate of 70°C/h and after keeping them there for 30 minutes, they were isothermally treated at different temperatures and times as given in Table 2 and 3. At these temperatures, the samples were kept for 0.5 minutes per mm of thickness, followed by a direct quenching process in the compressed air environment and then tempered in 250°C for 1 h.

— Hardness Testing

The hardness of all the samples measured at 10 Kg minor load and 150 Kg major load using a Vickers hardness tester according to ASTM standard E384 [11].

Table 2. Single Austenitisation (SA)

Sample	Austenitisation	Tempering
T1	900°C	250°C
T2	950°C	250°C
T3	1000°C	250°C
T4	1050°C	250°C

Table 3. Double Austenitisation (DA)

Sample	Austenitisation	Tempering
H1	900°C	250°C
H2	950°C	250°C
H3	1000°C	250°C
H4	1050°C	250°C

— Metallographic Techniques

The light microscopy specimens were prepared based on the ASTM standard E3 [12]. The chemical etchant used to reveal matrix and carbides in hardened steels was 4% Picral. The time of etching varied following different heat treatments. The SEM samples were prepared by mounting in a conductive polymer Polyfast, to minimize the effect of charging.

— Microstructure Imaging

Nikon's high–resolution MA200 Microscope with the camera was used for the examination of the microstructure of specimens. The Tescan Vega–3 LMU a high–resolution scanning electron microscope (SEM) that uses a field–emission electron source was used for imaging.

— Volume Fraction of phases Measurement

The volume fraction of retained austenite and carbides (primary and secondary carbides) in the steel matrix was calculated by using CLEMEX image analyzer software.

RESULTS AND DISCUSSION

— Optical and SEM Microscopy

The optical micrographs of the single heat–treated samples are shown in Figure 1 – T(1–4), and those of double heat–treated shown in Figure 2 – H (1–4). The volume fraction of carbides and retained austenite shown in table 4.

Table 4. Carbide & Retained Austenite Volume Fraction with 2% STD dev

Sample	Carbide Volume Fraction (%)	Retained Austenite (%)
T1	11	4.7
T2	7.9	6.3
T3	5.4	9.5
T4	5.7	11
H1	5.5	9.9
H2	4.7	12.9
H3	4.6	17.1
H4	4.1	19.8

The number of carbides decreased with increasing austenitization temperature from 900 to 1050°C. It was also observed that the DA treatment helped in taking most of the carbides into the solution. The size and number of undissolved carbides were lower in the double treated steel sample compared to the single treated ones. The packet size of martensite laths was also observed to have increased marginally on raising the austenitizing temperature. The retained austenite content increased from 4.7% when austenitized at 900°C to 11% at 1050°C. On DA treatment the retained austenite content of the steel further increased to 19.8%. No significant change in the volume fraction of retained austenite was noticed on tempering the samples at 250°C as compared to the as–quenched condition.

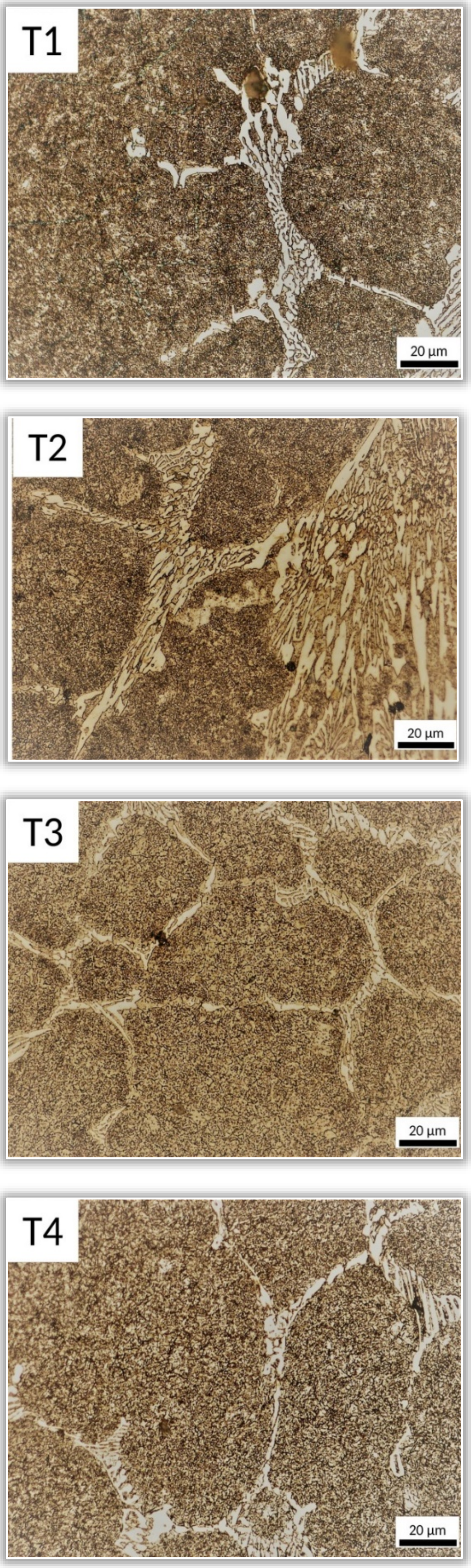

Figure 1. Optical Micrographs of Single Austenitisation T1–T4

The double austenitization treatment helps carbide dissolution. Careful selection of austenitization temperature (single or double) helps maintain a constant volume fraction of retained austenite. The volume fraction of retained austenite increases with an increase in single austenitization temperature and also further increases with the DA treatment. The retained austenite remains stable on tempering the steel at 250°C. Such carbides are decreased after austenitization at 1050°C owing to the higher solubility of carbon in austenite at this temperature. These undissolved carbides provide abundant nucleation sites for austenite nucleation during the second austenitization treatment, resulting in finer carbides.

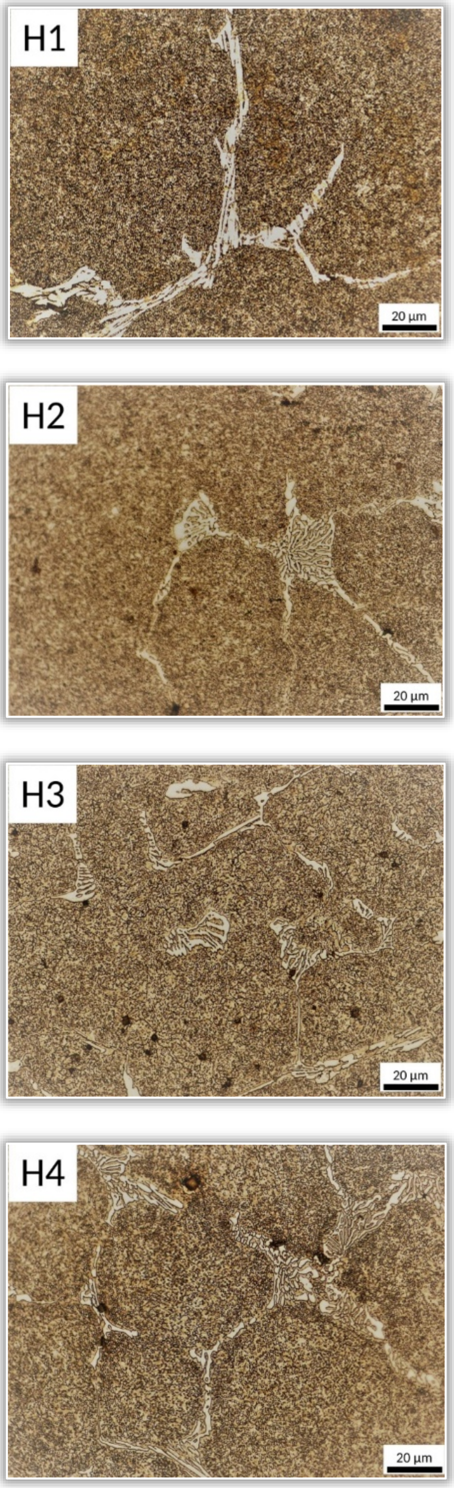

Figure 2. Optical Micrographs of Double Austenitization H1–H3

The SEM images in Figure 3 show that the only difference between the two samples, T3 and H3, was the fine–grained carbides. During the double austenitization at 1000°C, the primary carbides were decomposed and during the cooling and tempering, they were converted into fine–dispersed carbides in the structure. Specimens in both the conditions exhibited typically lath martensite and interlath contiguous films of retained austenite.

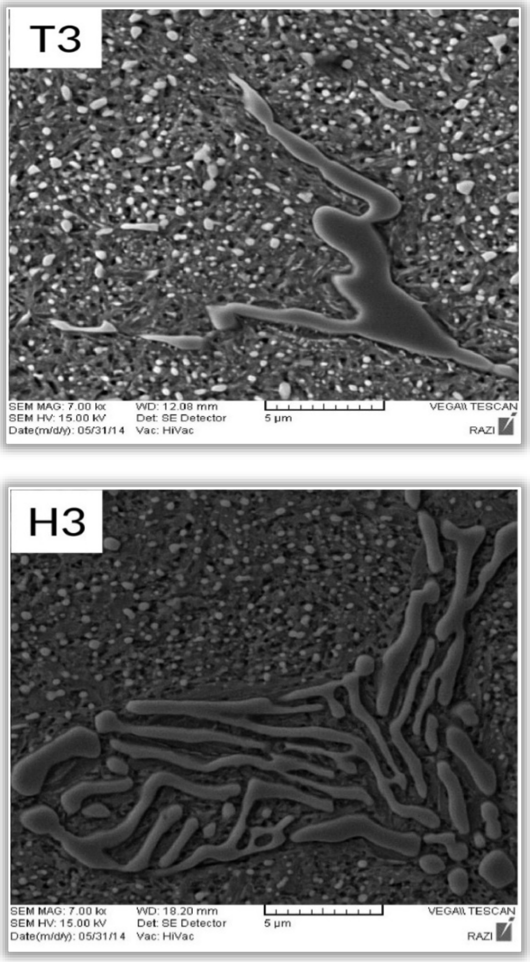

Figure 3. SEM Images of Single Austenitization T3, Double Austenitization H3

— Hardness

On increasing the first austenitization temperature from 900 to 1050°C, the hardness increased from 50 to 58 HRC while in the case of double austenitization the hardness decreased from 58 to 48 HRC. Differences in hardness on tempered samples quenched from various austenitization treatments are given in Table 5. The increase in the hardness with increasing austenitization temperature is because of the rise in the carbon content of the austenite transforms to martensite on quenching. The limited decrease in the H treated samples (compared to that of SA) could be attributed to the slightly higher retained austenite content of the DA treated samples and the decrease in carbon content due to carbide precipitation during second–stage austenitization as was assumed before [1]. Thus the second austenitization in DA temperature should be below the first austenitization (much below solubility of carbides) else it will have a negative effect on hardness.

Table 5. Hardness Values with ±1 STD dev

Sample	Hardness (HRC)
T1	50
T2	56
T3	57
T4	58
H1	58
H2	55
H3	53
H4	48

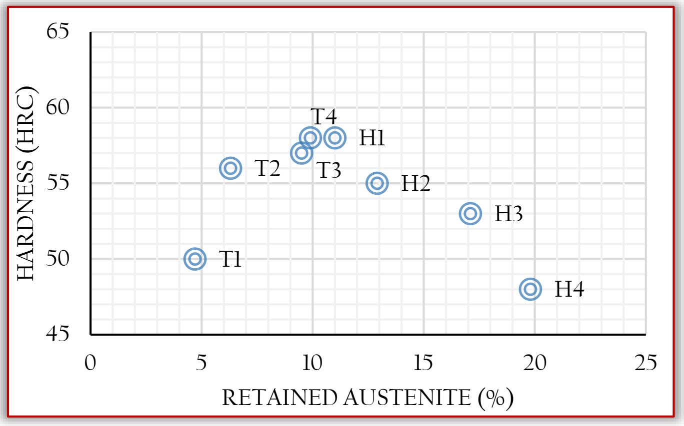

Figure 4. Graph depicting comparison of single and double heat treatments.

CONCLUSIONS

The following conclusions can be drawn based on the present study:

≡ As seen from the graph (Figure 4) of hardness and retained austenite, DA treatment offers relatively better properties as compares to SA treatment.

≡ Undissolved carbides decrease following high temperature (1050°C) single austenitization as compared to low temperature (900°C) single austenitization treatment.

≡ Few undissolved carbides remained in the steel after DA treatment.

≡ The retained austenite increases with an increase in single austenitization temperature from 900 to 1050°C.

≡ Carbide dissolution has a significant effect on grain refinement and hardness. Carbide dissolution in the first austenitization enhanced hardness. An increase in the re–austenitization temperature hurts dissolution of carbides has resulted in a decrease in hardness.

≡ Retained austenite content increases following single austenitization at 1050°C as compared to 900°C, while DA treatment further increases the retained austenite content.

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[1]Samuel SULE

PROBABILITY-BASED DESIGN OF A SOLID TIMBER COLUMN SUBJECTED AXIAL COMPRESSION AND BENDING

[1]Department of Civil and Environmental Engineering, University of Port Harcourt, Port Harcourt, Rivers State, NIGERIA

Abstract: In this paper, the results of the probability-based design of a solid timber column of softwood specie and Strength Class C24 at predefined safety levels under axial compression and bending in accordance with the design rules of EC-5 (1995) are discussed. Different values of coefficient of variation (10%, 15%, and 20%) of the column strength in compression and bending were considered in order to obtain adequate cross sectional dimensions at predefined safety levels. The First Order Reliability method was invoked to check the safety of the designed section using a MATLAB program. It was found that economical column cross sectional dimensions were achieved at lower target safety index. It was also found that the results obtained from the failure of the column due to axial compression were more economical in terms of material consumption compared to the results obtained due to column failure in bending. However, the results obtained all satisfied the design criteria in compression and bending.
Keywords: Probability based design, solid timber column, predefined safety levels, first order reliability method, design criteria, EC-5

INTRODUCTION

The major objective of structural design is the fulfillment of certain performance criteria that relate to safety and serviceability of the structure or structural element (Ogork and Nakore, 2017; Abubakar, 2006; Ranganathan, 1990). Structural problems are non-deterministic in nature (El-Reedy, 2013; Abejide, 2012). In consequence, the use of partial safety factors cannot guarantee the required safety levels as it fails to explicitly consider the probability of failure associated with some performance criteria of the structure (Afolayan and Abubakar, 2003). The violation of ultimate and serviceability limit states of engineered structures may lead to loss of lives and damage of properties worth millions of naira (Sule and Benu, 2012; Sule and Benu, 2019). Hence there is a need to accurately determine the limit state to enhance efficient design. However, the attainment of a limit state is always difficult due to uncertainties inherent in the resistance and load parameters. According to Melchers (1999), the failure of structures may not be related directly to the predicted normal loading or strength. It may result from human error, negligence, poor workmanship or neglected loading. The variability of material properties, fluctuation of loads on structures and uncertainties of the design models cause the performance of the structure to fall below expectation.

A probabilistic approach always provides a rational way of dealing with such uncertainties that are inherent in structures by using statistical approach. A probabilistic design aims at finding the optimal solution that satisfies the prescribed performance criteria (Afolayan, 2002; Afolayan and Abubakar, 2003; Salisu et. al, 2009; Afolayan, 2005). In this paper, a probability-based design of a pin-ended solid square timber column of square cross section under axial compression and bending is carried out using EC-5 design rules.

The variability of the strength of column in axial compression and bending at varying values of load ratio were considered in the probabilistic design of the column cross sectional dimensions. The safety of the designed cross sections was checked at predefined safety level using First Order Reliability procedure coded in a MATLAB language.

PERFORMANCE CRITERIA

The performance criteria are derived in accordance with the EC-5 design rules for timber structures. A pin-ended solid square timber column under axial compression and bending (Figure 1) is considered in this study.

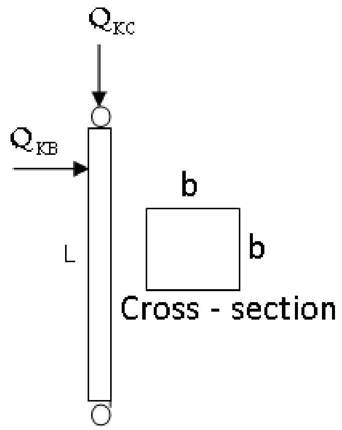

Figure 1. A pin-ended square timber column under axial compression and bending

— Compression criterion

The design compressive stress in column parallel to grain is given by:

$$\sigma_{c,d} = \frac{Q_C}{A} = \frac{Q_C}{b^2} \qquad (1)$$

where $\sigma_{c,d}$ = design stress, A = cross- sectional area, b = cross sectional dimension of the column, Q_C = compressive load on column

The factored compressive load on column is given by:

$$Q_C = Q_{KC}(1.4\alpha_C + 1.6) \qquad (2)$$

Therefore, the compressive strength parallel to the grain is given by:

$$f_{c,d} = \frac{K_{mod}\, f_{c,k}}{\gamma_m} \qquad (3)$$

where K_{mod} = modification factor for duration of loading and moisture content, Q_1 = short term axial load, γ_m = partial safety factor for the material property based on EC-5, $f_{c,k}$ = characteristic value of the compressive strength based on timber strength class, α_C = load ratio under axial compression

Applying equations (1), (3) and (4), the limit state function in axial compression is given by:

$$g(x) = \frac{K_{mod}\, f_{c,k}}{\gamma_m} - \frac{Q_K(1.35\alpha + 1.5)}{b^2} \qquad (4)$$

— Bending criterion

The applied bending stress parallel to grain is given by:

$$\sigma_{m,d} = \frac{M}{Z} \qquad (5)$$

The induced bending moment on beam under uniform loading is given by:

$$M = \frac{Q_L L^2}{8} \qquad (6)$$

From applied structural mechanics, the section modulus of a solid square section is given by:

$$Z = \frac{b^3}{6} \qquad (7)$$

Applying equations (5), (6) and (7), the load induced bending stress parallel to grain is given by:

$$\sigma_{m,d} = \frac{0.75 Q_L L^2}{b^3} \qquad (8)$$

where Q_L = short term lateral load that causes bending, b = cross sectional dimension of column

The factored applied lateral load is given by:

$$Q_L = Q_{KB}(1.4\alpha_B + 1.6) \qquad (9)$$

According to EC-5, the design bending strength parallel to grain is given by:

$$f_{m,d} = \frac{K_{mod}\, f_{m,k}}{\gamma_m} \qquad (10)$$

where $f_{m,k}$ = characteristic value of the bending strength

Applying equations (8), (9) and (10), the limit state function in bending is given by:

$$g(x) = \frac{K_{mod}\, f_{m,k}}{\gamma_m} - \frac{0.75 Q_{KB}(1.4\alpha_B + 1.6)L^2}{b^3} \qquad (11)$$

MATERIALS AND METHOD

The First order reliability method is used to obtain the design points on the failure surface. Let the failure surface in x-space be given by:

$$g(x) = g(x_1, x_2, \ldots, x_n) = 0 \qquad (12)$$

The vector of the random variables in x-space is given by:

$$x = [x_1, x_2, \ldots, x_n]^T \qquad (13)$$

The normalized random variables $y_1, y_2, \ldots, y_n$ are introduced using an appropriate one to one linear mapping in the form of $x = L(y)$ such that $y = L^{-1}(x)$. The corresponding design points in y-space are then defined by the transformation:

$$x = L(y), \quad y = L^{-1}(x) \qquad (14)$$

Consequently, equation (12) maps equation (14) into:

$$h(y_1, y_2, \ldots, y_n) = 0 \qquad (15)$$

The function h is defined by:

$$h(y) = g[L(y)] \qquad (16)$$

Equation (16) is the failure function in normalized coordinate. The minimum distance between the origin and the failure surface in normalized coordinate is the reliability index, β.

The reliability index, β is given by:

$$\beta = \min\left\langle \sqrt{\sum y_1^2 + y_2^2 + \ldots + y_n^2} \,\middle|\, h(y_1, y_2, \ldots, y_n) \right\rangle = 0 \qquad (17)$$

The values of the design variables that minimize the distance from the origin to the failure surface subject to $h(y_1, y_2, \ldots, y_n) = 0$ are obtained by iteration scheme.

The design is adequate when:

$$\beta = \min\left\langle \sqrt{\sum y_1^2 + y_2^2 + \ldots + y_n^2} \,\middle|\, h(y_1, y_2, \ldots, y_n) \right\rangle \approx \beta^T \qquad (18)$$

The flowchart that shows the design procedure and statistics of the basic variables are shown in Figure 1 and Table 1 respectively.

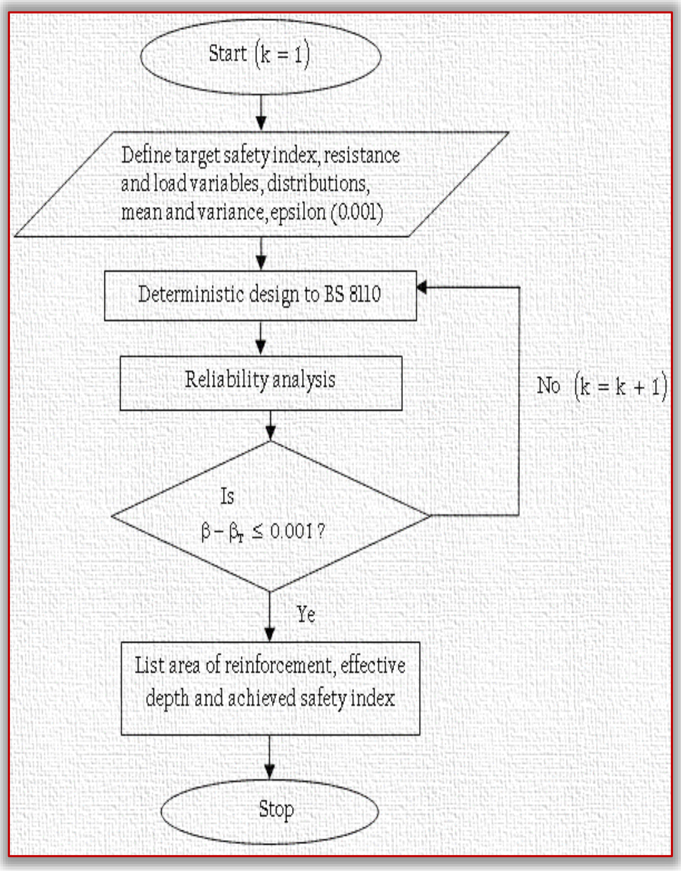

Figure 2: Flowchart showing the reliability based design procedure

Table 1: Statistics of the basic variables

S/N	Random variable	Mean	Standard Deviation	Coefficient of Variation	Type of Probability Distribution
1	Q_{KC}	65,000N	1950N	0.030	Gumbel
2	Q_{KB}	3.25N/mm	0.975N/mm	0.30	Gumbel
3	K_{mod}	0.90	0.135	0.15	Lognormal
4	L	3000mm	30mm	0.01	Normal
5	b	300mm	3mm	0.01	Normal
6	$f_{m,k}$	24N/mm^2	3.6N/mm^2	0.15	Lognormal
7	$f_{c,k}$	21N/mm^3	3.15N/mm^3	0.15	Lognormal
8	γ_m	1.30	0.195	0.15	Lognormal
9	α_C	Varying	Varying	0.30	Fixed
10	α_L	Varying	Varying	0.30	Fixed

Source: (Benu and Sule, 2012)

RESULTS OF THE PROBABILITY-BASED DESIGN

The results of the probability-based design of a pin-ended solid square timber column of strength class C24 obtained at different values of target safety indices are presented in table 1 to 4 respectively.

The axial and lateral load ratios were varied for each performance criterion in the design process while other relevant parameters were kept constant. The values of the cross sectional dimension that satisfy the specified safety index, the coefficient of variation of the column and load ratio was determined. The design was found to be adequate at load ratio value of 0.2, 0.3, 0.4 and 0.5 respectively, for the two performance criteria considered as the value of the implied safety index and the value of the predefined target safety index coincided (Eurocode 0, 2002).

From Table 1 to 4, it can be seen that economical cross sectional dimensions were obtained at lower target safety index. It can also be seen that increase in load ratio (both in axial compression and bending) and coefficient of variation produces a corresponding increase in the cross sectional dimensions of the column.

The results obtained showed that the results obtained due to failure of the column in axial compression are more economical in terms of material consumption than those obtained due to column failure in bending.

Table 1: Column dimension for axial and lateral load ratio of 0.20

Failure criteria	Target Safety Index	Coefficient of variation of column strength in compression and bending		
		10 %	15%	20%
Compression	2.0	125	132	143
	2.5	135	147	163
	3.0	150	169	195
	3.5	167	193	241
	4.0	189	229	320
Bending	2.0	175	180	190
	2.5	186	196	208
	3.0	201	215	234
	3.5	217	237	270
	4.0	240	265	323

Table 2: Column dimension for axial and lateral load ratio of 0.30

Failure criteria	Target Safety Index	Coefficient of variation of column strength in compression and bending		
		10 %	15%	20%
Compression	2.0	129	138	148
	2.5	140	153	169
	3.0	158	175	204
	3.5	173	201	250
	4.0	196	245	340
Bending	2.0	180	185	195
	2.5	192	201	213
	3.0	207	220	240
	3.5	223	242	276
	4.0	245	272	340

Table 3: Column dimension for axial and lateral load ratio of 0.40

Failure criteria	Target Safety Index	Coefficient of variation of column strength in compression and bending		
		10 %	15%	20%
Compression	2.0	134	143	153
	2.5	145	158	175
	3.0	162	182	215
	3.5	180	208	260
	4.0	205	255	365
Bending	2.0	185	190	200
	2.5	196	205	218
	3.0	213	226	247
	3.5	228	248	282
	4.0	250	282	350

Table 4: Column dimension for axial and lateral load ratio of 0.50

Failure criteria	Target Safety Index	Coefficient of variation of column strength in compression and bending		
		10 %	15%	20%
Compression	2.0	137	147	158
	2.5	150	163	181
	3.0	168	190	220
	3.5	185	215	267
	4.0	210	262	280
Bending	2.0	188	195	202
	2.5	200	210	223
	3.0	216	230	255
	3.5	233	253	288
	4.0	256	286	347

However, the values of the cross sectional dimensions produced at varying values of load ratios are all found to be adequate as they satisfied the two performance criteria.

CONCLUSION

A computer program developed in MATLAB language has been developed to automate the probabilistic design of a pin-ended solid timber column under axial compression and bending designed in accordance with EC-5 (1995) design rules.

The design point of the First Order Reliability method was invoked to check the safety level of the designed section. It was shown that the results obtained due to failure of the column in axial compression are more economical in terms of material consumption than those obtained due to column failure in bending. It was also shown that higher column cross sectional dimensions were obtained at higher safety index. However, the values of the cross sectional dimensions produced at varied load ratios of 0.2, 0.3, 0.4 and 0.5 all satisfied the performance criteria in axial compression and bending.

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[1.]Stanko P. STANKOV

BIG DATA IN WATER SUPPLY AND SEWERAGE SYSTEMS

[1.]University of Niš, Faculty of Electronic Engineering, Department of Automatic Control, Aleksandra Medvedeva 14, 18000 Niš, SERBIA

Abstract: Digitization in the field of water supply and sewerage is associated with the concept of processing extremely large amounts of data (big data) and processing and analysis of these data (data mining). In essence, the significance of the mentioned data for water supply and sewerage systems is huge, but in order to understand their role, it is necessary to assess the possibility of using and applying these data. In conditions in which data from various sensors and equipment in the field of kai and data related to customer needs are permanently obtained, the amount of this data increases significantly. Replacing classic water meters with smart ones also significantly increases the amount of information. New trends in the management and supervision of water supply and sewerage systems enable operators to make maximum use of this data, and management to undertake activities at the tactical and strategic level. Modern SCADA (Supervisory Control and Data Acquisition) systems significantly contribute to the rapid detection of infrastructure failures, reduction of losses by detecting leaks, overflows in tanks. Based on the collected data, operational efficiency is improved, opportunities for proactive maintenance of water and sewage resources are identified, as well as preparation for long–term investments.
Keywords: data, acquisition, control strategy, supervision

INTRODUCTION

Information related to the needs of clients in the water supply and sewerage sector is one of the most important data, which can be used to predict the required amount of water for a certain part of the water supply area in order to achieve optimal efficient network control. In the individual sense, the data can indicate whether there is a leaking in a particular client [1]. The information acquisition from the water meter can be used to detect zones in which e.g. pressure control and in which unusually high consumption occurs. The data can also be used for the implementation of complex algorithms that calculate in which regions the lowest revenues are achieved during the exploitation of water by customers [1], [2].

The data obtained, especially from smart water meters, can be useful in many ways. This data is collected for a month or more and is mainly used to bill users. By increasing the frequency of collecting this data via smart water meters, the amount of this information increases by an order of magnitude. The temporal character of the data is extremely important, since medium–term information is vital for the daily activities of the water supply system, and long–term data play a role in creating a control strategy [3].

The analysis of operational data in the field of water supply and sewerage leads to the knowledge of current situations. This data has great potential for the big data sector. Knowledge of the situation is crucial for operators in management and control centers and for maintenance services to respond in a timely manner.

Operational data enables the identification of risks related to a specific consumer or a specific zone in which efficiency is relatively low, while process optimization would lead to savings for both the company and the client. Operational data is usually used on a daily basis or within a week. In the long run, data on parameters and process values can be indicators of the periodicity of maintenance of specific equipment and indicate the need for investment in order to improve the existing infrastructure [4], [5].

SUPERVISION AND EFFICIENCY

In companies whose activity is the development, construction and maintenance of water supply and sewerage systems, there are a large number of sensors and automation elements in the field that send large amounts of data to supervisory control centers with a high frequency. These data are of interest for the functionality of water supply and sewerage systems, and data analysis provides an opportunity to optimize operation, preventive, current and investment maintenance of the systems themselves, correction of management algorithms to increase efficiency and reduce operating costs. Operators in the management system can e.g. to reduce the dosing of activated carbon in wastewater treatment plants, precisely by analyzing the large amount of data coming from the sensors in the filter fields [6].

Due to the fact that the activated granular coal changes in a timely manner, the concentration of trihalomethane is maintained in the allowed range. Further improved efficiency can extend equipment life. With the help of quality data, you can e.g. in wastewater treatment plants, reduce the dosage of chemicals and maintain the essential parameters of the treated water (e.g. pH value). In this way, reducing the amount of chemicals can limit or delay the deterioration of the most important equipment of these plants [7].

PREDICTIVE ANALYSIS OF DATA

Water and sewage systems can have a significant benefit from the large amount of data generated by various equipment, especially when creating predictive models that lead to more precise and detailed results. The application of big data in water and sewage systems is reflected in the preparation of predictive maintenance strategies [7].

IoT sensors, which are an integral part of the equipment, provide information on key parameters such as temperature, vibration, speed, level, etc. Algorithms for big data analysis find a correlation that allows a fault prediction to be made very quickly for a particular device operating in a mode outside the nominal range. Predictive maintenance strategy can increase the service life of equipment and increase the efficiency of maintenance programs, which allows to avoid costly delays by timely signaling the potential failure of a particular device.

Some modern supervisory control systems can turn off a certain device, which is on the edge of failure, with the appropriate message, light and sound signaling [8]. Big data can combine inside information with information from third–party sources to improve the quality of the predictive model. It is possible e.g. combine data from multiple wastewater treatment plants, which allows for thorough analysis to detect trends and forecast inlet flow balances and enables operators to take appropriate action. Improved procedures for the acquisition, processing and use of large amounts of data can be of great importance for companies whose activities are water supply and sewerage. Wastewater treatment plants in this sector often have problems with depreciation and equipment that is difficult to maintain due to extreme operating conditions and inaccessibility [9].

Precisely on the basis of big data, it is possible to act preventively and perform the necessary interventions in a timely manner, which preserves the equipment and avoids costly delays. Water supply and sewerage systems began to use the benefits of big data relatively late, which increases the reliability and optimization of services provided to customers. Some of the big data solutions available on the market enable integration with sensor and communication technologies, modeling procedures and SCADA systems.

With the accelerated application of advanced computer systems, cheap sensors that measure various process quantities and parameters, data is collected and sent to control devices. Cost–effective data warehousing systems and water companies can get much more real–time information at reduced costs, and in some cases, data from hitherto unavailable zones [10]. Smart technologies such as big data allow operators to optimize customer service.

According to the analyzes, despite the fact that the road is relatively long, the water supply and sewerage sector has taken the right direction in its further development. However, in order to fully justify investments in smart technologies, it is necessary to have a clear idea and vision of organizational and strategic goals, while implementing and adapting business plans.

The main task and ultimate goal of the system for data collection, processing and analysis in companies dealing with water supply and sewerage problems is to provide quality services in the field of information, which facilitates the work of operators and helps managers develop new opportunities for cost monitoring and risk management improving all service levels [11–13].

Implementation of intelligent systems so–called AMI (Advanced metering infrastructure) in the field of water supply and sewerage is growing. Smart grid solutions are widely represented in electricity distribution companies, and they are also finding their way into the water supply sector, so that today we can talk about intelligent networks in water supply [14].

SMART TECHNOLOGIES

Smart technologies are aimed at solving key challenges in the water supply and sewerage sector, such as water and energy losses, lack of water resources on a global level, management of current and operating costs, etc. There is already a wide range of reliable intelligent devices on the market, such as AMR (automatic meter reading) and complete solutions that can be applied in solving problems related to water supply and sewerage. This is also the case with the more recent AMI technology, which is increasingly available in financial terms [14].

AMI INFRASTRUCTURE

AMI infrastructure is an automated two–way communication between a measuring device (e.g. a water meter) with an IP address and a water supply company.

The basic idea for the application of AMI applications in utility systems is to obtain basic real–time data on water needs, status and energy consumption of installed equipment in the water supply and sewerage system, based on which forecasts can be made about accidents, downtime, and losses in system, etc. [14]. Both water supply systems and customers benefit from the introduction of intelligent technologies. The key is in the data that AMI systems operate with.

Possibilities for monitoring and analyzing the behavior of water supply networks and equipment, as well as identifying various problems justify serious investments in the construction of intelligent water infrastructure. In the future, data from intelligent measuring devices and sensors will be increasingly used in the water sector not only in solving operational tasks such as registration, localization and troubleshooting (leaks, failures, etc.) but also in strategic goals such as reducing operating costs, predictive maintenance of devices and equipment, improving the quality of services, efficient forecasting of infrastructure investments, etc. [15].

AMI PLATFORMS IN FUNCTION OF INCREASING THE EFFICIENCY OF WATER SUPPLY SYSTEMS

Thanks to AMI systems, the need for manpower is reduced, data acquisition related to users and account generation is fully automated and remote. Based on the data collected from smart water meters, the processes of water storage, transport and distribution, timely detection of water leaks and reduction of losses can be improved.

Two–way communication enables better provision of services to users through precise and adequate calculation of consumption, as well as efficient preventive, current and investment maintenance of resources. The systems for segmentation and analysis of customer bases that are the basis of modern AMI platforms can help identify the needs and requirements of customers of water companies, as well as activate various programs that will reduce losses in water supply [14]. Based on these capabilities, water utility companies can achieve various goals related to efficient management, optimization of equipment operation, planning, forecasting and proactive control of capital investments.

WATER SUPPLY SUPERVISION

Nowadays, the application of supervision and control of water supply is increasing, in urban and rural areas, where individual users and industrial consumers have an insight into water consumption. Because water resources are limited, there are two main objectives of monitoring:

- reducing water losses and
- rationally control of needs [6], [7].

Although various strategies and programs are applied in the world to reduce water losses, primarily through the use of modern supervisory control systems, water losses due to irrational use and leaks in various places are a very serious problem in the water supply system. The European Environment Agency gives a forecast until 2030. That the need for vision, on a global scale, will increase by as much as 40 % [8], [9].

SENSORS IN FUNCTION OF EFFORTS TO REDUCE WATER LOSSES

With the technological development of sensors and with the reduction of their price, they become an integral part of supervisory control systems in water management.

Wireless sensor networks can be implemented both independently and as part of complex platforms for water resources control in individual, commercial – business and industrial facilities [6], [7]. Modern supervisory control systems used in plumbing systems are connected to flow sensors usually in the range of 0.15 to 60 L/min. The sensors send data to the center, which activates an automatic alarm, if the flow has certain values higher than the set threshold. This allows operators to register local leaks and undertake appropriate overhaul activities on the water supply network to combat water loss.

According to Libelium, a Spanish supplier of sensor technology and IoT applications, the use of sensor technology in water management in Japan saves $ 170 million annually [16]. In the floors of individual buildings, shopping and business centers and in various industrial facilities, sensors are installed that can register the existence of leaks in water pipes. In open water supply networks, soil moisture sensors installed at an appropriate distance from each other can signal a drastic increase in soil moisture, which is a warning of possible water leakage and a signal to optimize irrigation.

Strategic deployment of sensors in the entire area of water supply provides sufficient data necessary for the functionality of the supervisory control system. The data is sent wirelessly and at certain intervals to the control center where it is processed and analyzed. They can also be applauded on a cloud server or over the Internet where they are publicly available to citizens or industry.

WATER SUPPLY SYSTEM – EXAMPLE

An example of a complex water supply system, which consists of a number of technical – technological units is the water factory Mediana 2 in Nis.

The supervisory control system is based on programmable logic controllers and operator panels, which are interfaces between the operator and the plant. The control system is also connected to the SCADA computer in the control room (CR). Nominal factory mode is automatic. For special purposes, individual technical units can be switched to manual control mode, which is suitable for testing equipment during overhauls and maintenance. The block diagram of the factory management is shown in Figure 1.

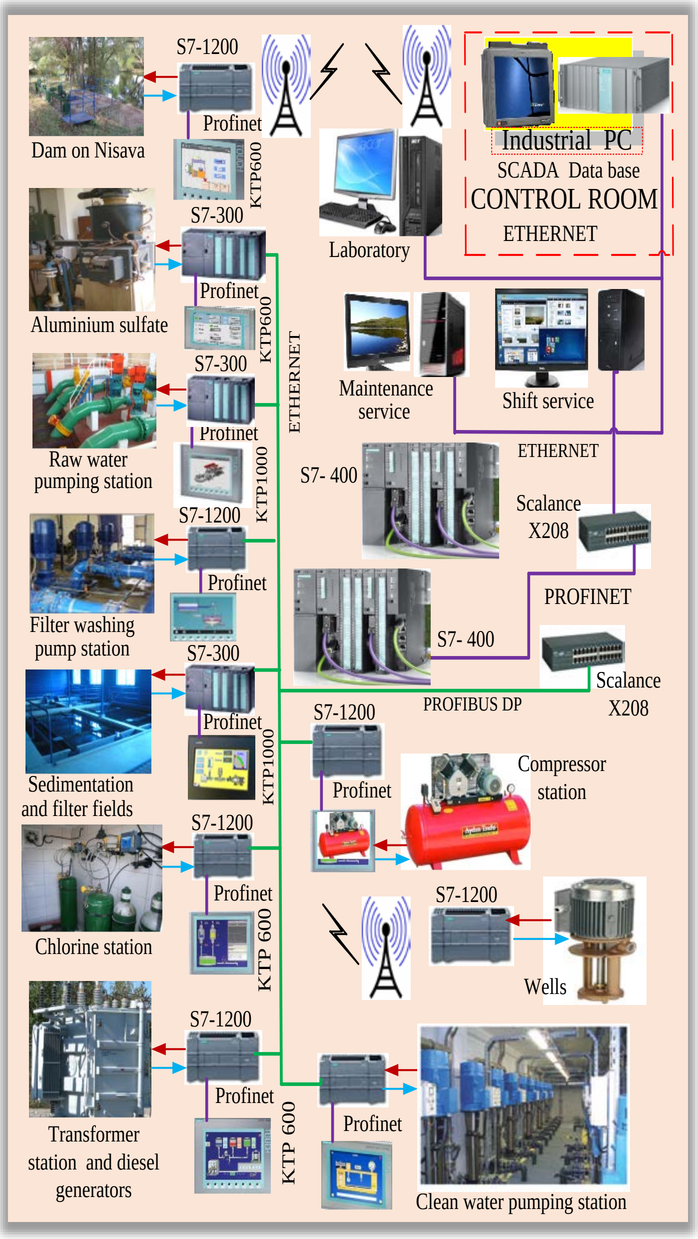

Figure 1. Block diagram of supervisory control of Mediana 2 water supply system

A large amount of data is generated, acquision and processed here [6], [7]. Basically, the control of the Mediana 2 water supply system is a central supervisory control system installed in CR.

The system architecture is based on a master–slave configuration consisting of PLC controllers:
- the master PLC is Simatic S7–400 (redundant pair);
- S7–300 (Al sulfate preparation and dosing plant, PS of raw water, sedimentation and filter fields, PS for washing of filter plant, clean water pump station);
- S7–1200 (transformer station, diesel generator, dam, system for mechanical water purification – mechanical rakes and sieves; compressor station, chlorine station) [6], [7].

Each local controller is connected to the operator panel KTP communication protocol PROFINET. The connection of the master controller to the slave controllers and servers was done via the ETHERNET network. A real–time database server has been installed in CR, which distributes data to workstations – clients (CR, maintenance service, chemical laboratory, management) [6], [7].

SCADA is organized in the form of menus and submenus, showing the functionality of the system with certain animations (e. g. operation of pumps, electromotor valves), the change of a quantity in real time in the form of a trend graph or in digital form (level values, flow, turbidity, residual chlorine, etc.), reaching the limit values is signaled as an alarm message with sound and light signaling. The main tasks set before the SCADA system are:
- acquisition of real–time digital and analog data from all objects connected to the system (a large number of tags);
- archiving relevant information obtained on the basis of collected data in a relational database;
- presentation of real–time and archived data via synoptic screens, trends, charts and tables;
- real–time control and supervision of water intake, mechanical water purification, chemical preparation, well plants, pumping stations.

The master redundant tandem system of PLCs S7–400 in conjunction with a SCADA computer in CR dictates communication with all remote stations, sends queries, commands and accepts and archives all messages arriving from controled objects [6 – 9].

DISPLAY OF FILTER WASHING PUMP STATION

Figure 2 shows one SCADA screen of a pump station (PS) for washing filters. It is one of a number of technical units of the Mediana 2 water supply system. Within this PS there are 3 pump units whose power is 75 kW – two working pumps and one spare which, if necessary, works in alternation with the main pump [6], [7].

The pumps are powered via frequency inverters. Each inverter at the input has semiconductor fuses and compact switches with the possibility of remote shutdown in case of failure or blockage of a particular pump.

The control of the PS for filter washing is from the PLC system which, based on the obtained sequence and the state of openness/closure of individual valves in the filter fields, includes and gives permission for switching on the drive of a certain pump. Pumps provide a set flow value in the discharge line to the filter fields. A flow meter (Fp) is installed on the pressure pipeline. The maximum set flow is 125 L/s. The flow rate information (analog signal 4–20 mA) is input to the analog input of the PLC from where, according to the number of active pumps and the selected operating mode, the reference flow values for each of the pump units are transmitted as analog values to the inputs of frequency inverters.

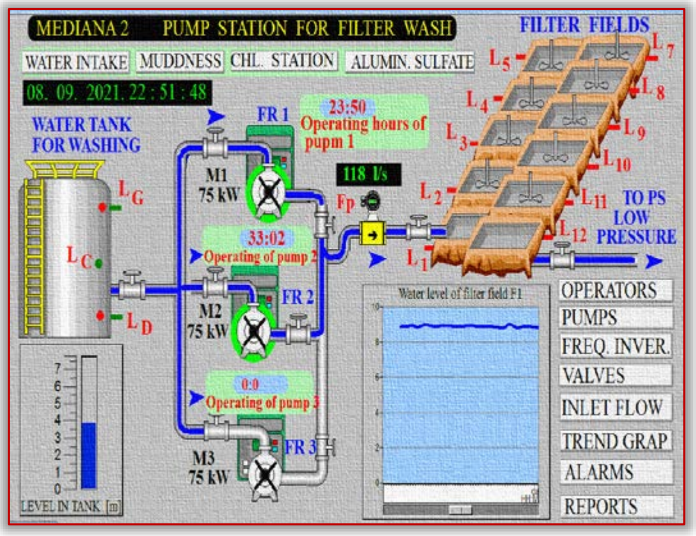

Figure 2. SCADA screen in CR of water pump station, for filters washing

Protection against dry running of PS pump units is via built–in hydrostatic probes for continuous level measurement. Control of the operation of the PS for filter washing and regulation of the flow of washing water in the discharge line was realized using the Siemens S7–1200 PLC [6 – 9].

CONCLUSION

It is obvious that an extremely large amount of data is generated in water supply and sewage systems. The paper describes the control – monitoring system based on PLC and SCADA configuration with decentralized distributed control of technological units, which are integral parts of the water factory.

The control units perform program control of the plants and regulation of technological quantities and parameters such as levels, flow, speed, pressure, pH value, turbidity, dosing of aluminum sulfate, chlorine, etc. Various situations in the work of installed machines and devices are considered and they are protected from technological and electrical accidents. Graphical display of components using dynamic screens allows the operator to monitor the process.

The transformer station and diesel generator, dam, mechanical water purification process, preparation and dosing of aluminum sulfate, chlorine dosing, processes in filter fields, sedimentation tanks, raw water pumping stations, filter washing water and clean water are controlled. The control system identifies changes in the state of the process, diagnoses and evaluates errors, enables prediction of the behavior of control objects in the conditions of changing input variables and generates optimal values of control signals in order to achieve the prescribed water quality. In addition, the system performs the acquisition, processing and archiving of data related to the values of process quantities and the state of the installed equipment. It is possible to create and print shift and periodic reports on the functionality and availability of individual technological units and the course of production, based on which analyzes and necessary corrections are made in order to increase efficiency. Alarm states that occur in case of failures or exceeding the set values of certain quantities are also monitored.

The proposed supervisory control system enables:

- periodic reading of characteristic sizes and working hours of devices and equipment,
- archiving of changes on all digital and analog inputs and outputs of control units,
- long–term archiving of all actions of the operator,
- assigning flexible work schedules.

Visualization of controlled objects with graphical and tabular display of relevant physical values and parameters is of great importance for the maintenance sector. On the SCADA system screen, through dozens of intuitive screens, there is an insight into the functionality of the water factory, and the appearance of alarm signals enables faster localization of faults, which significantly increases the efficiency of maintenance. Light and sound signaling of reaching critical values (alarms) is enabled, during which appropriate control logic activities take place.

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ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
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[1.]Milan IVANOVIĆ, [2.]Hrvoje GLAVAŠ

ADVANTAGES OF BIOGAS POWER PLANTS IN ENERGY TRANSITION OF PANNONIAN COUNTRIES – BENEFITS FOR THE LOCAL COMMUNITY

[1] Panon – think tank for strategic studies, Osijek, CROATIA
[2] Josip Juraj Strossmayer University of Osijek, Faculty of Electrical Engineering, Computer Science and Information Technology, Osijek, CROATIA

Abstract: This paper points out the benefits for the local community from the construction of biogas power plants (BgP) – which are no from using other renewable energy sources. Benefits from BgP for local community are: additional income to local farmers, higher level of agro technologies in the village, strengthening social cohesion, ecological disposal of rural waste, electricity and heat production, organic fertilizer, hiring local labor and better quality of life for all inhabitants. In paper presented and important elements for planning the construction of biogas power plants.
Keywords: Biogas power plants, Energy transition, Local community, Renewable energy sources, Smart village

INTRODUCTORY NOTE

The energy transition is a pathway toward transformation of the global energy sector from fossil–based to zero–carbon by the second half of this century. At its heart is the need to reduce energy–related CO_2 emissions to limit climate change. Renewable energy and energy efficiency measures can potentially achieve 90% of the required carbon reductions. [1]

Biogas plants are not adequately represented in the energy transition plans of the new EU members, nor in the EU candidate countries. Stakeholders for wind and solar power plants strongly influence decision makers in the investment policy in the energy sector through (in) transparent processes. Intensified construction of wind farms and large solar systems in the Pannonian countries is essentially detrimental to many local communities and the national economy and energy transition of these countries – because national credit lines, RES funds and preferential tariffs are used; all of which minimizes investment in other renewable energy.

On the other hand, biogas plants (BgP) – which do not have structured interest groups (because there are not so many opportunities to earn without work in this sector) are unfairly neglected – are put in the background. This paper therefore points to the advantages of biogas power plants – particularly important for villages in Pannonia – a natural area for biogas power plants in rural areas. In addition, the Pannonia areas have problems with: unfavorable demographic trends, insufficient economic development based on agriculture, and an unfavorable situation with local waste management.

Research data, as well as the work of members of Panon think tank Osijek show that biogas plants have the most favorable effects on the development of rural local communities and the GDP of the national economy – through investment, intermediate consumption and employment of domestic labor and putting into service national resources. This will be illustrated by the example of the Republic of Croatia. [2–6]

The benefits of biogas power plants are multiple for both the local community and the national economy. From this title, this analysis is conducted on two levels: local and national.

BENEFITS OF BIOGAS POWER PLANTS FOR THE LOCAL COMMUNITY

The construction of biogas power plants contributes to a number of local development goals; raising the standard of living and quality of life in villages, raising the organizational and technological level of life and business in villages, employment of young people and other benefits – as shown in Figure 1.

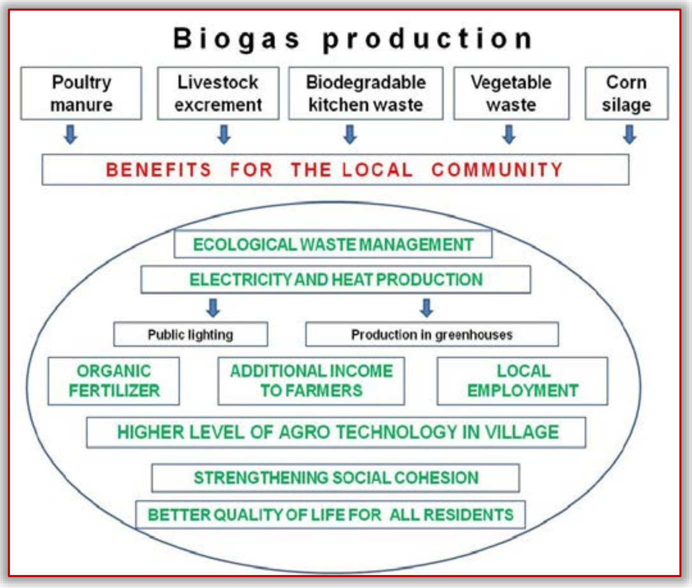

Figure 1. Benefits to the local community from the construction of biogas power plants

Biogas is produced in rural areas from poultry manure and livestock excrement, biodegradable kitchen waste and green biomass (vegetable waste and silage). In urban areas, it is also produced from sewage sludge and biodegradable municipal waste.

So the benefits to the local community are:

— Ecological disposal of rural waste

In most rural areas, the ecological disposal of waste from rural production (poultry manure and livestock excrement) and bio–degradable kitchen waste has not been effectively addressed. Rural households solve this traditionally – by disposing of their property. A small number of rural households, which own a larger number of livestock, dispose of livestock manure in their backyards – in their private compost bins and, later, use this organic fertilizer on their arable land. However, such a traditional method is not sanitary (stench, rats, insects, pigs, poultry, etc.) and endangers the quality of life of owners and neighbors and emits greenhouse gases (methane, etc.). In contrast, transporting such waste to a local biogas plant is a much more efficient way of disposing of rural waste.

— Electricity and heat production

Biogas power plants produce electricity that can be: (a) delivered to the national electricity system – for a fee (if there is a contract and the BgP is connected to the electricity grid) or (b) used locally – for public lighting, local water supply, for communal, social or educational facilities. E.g. many rural municipalities in the area of Slavonia and Baranja have problems with the financing of public lighting, and in many villages of these municipalities the public lighting is turned off after midnight. Therefore, with the construction of BgP, it is possible to solve the local electricity supply of communal facilities.

In the process of electricity production in BgP, waste heat is generated which can be used for heating business and social spaces, for drying agricultural products or for heating greenhouses and hothouses. E.g. in the area of Slavonia and Baranja, several biogas power plants supply heat for the hydroponic production of tomatoes in greenhouses (on 4 ha in Kneževi Vinogradi) or for the production of vegetables and flowers in greenhouses (in village Ivankovo and Tomašanci). [3]

— Additional income to local farmers

For the operation of BgP in the fermenter – in addition to livestock manure and organic kitchen waste – green biomass (vegetable waste and corn silage) is used in the amount of 40 to 60 percent in each cycle of BgP – which lasts about 29 days. This means that it is necessary to deliver tens of tons of silage for each cycle of BgP operation – depending on the installed BgP capacity and the model of structuring the input raw materials. In this way, local farmers earn additional income, because – silage is the calculated input cost in the production of BgP.

— Organic fertilizer

At the end of each BgP cycle (depending on the installed capacity), tens of tons of digestate remain – a high–quality organic fertilizer – which is used to fertilize agricultural land or is commercially packaged and sold in retail chains. It should be noted that according to the quantities of waste delivered (after the completion of the cycle in BgP) each local supplier of livestock manure receives the appropriate amount of digestate for use on their agricultural land; e.g. as it is applied in the municipal BgP (power 2 MW) in Dunaujvaros, Hungary.

— Hiring local labor

Given the significant share of construction work in the construction of BgP – there is a high probability that for several dozen local construction workers there will be work from one to two years – depending on the installed capacity of BgP.

When the BgP construction is completed, the BgP crew is hired – which is not numerous – from 3 to 5 employees with secondary technical education and one engineer? The importance of employing local technical staff should be pointed out here – which at the same time contributes to a higher level of technical competence of the local community.

— Higher level of agro technologies in the village

The existence (business) of BgP in each rural community contributes to increasing the level of application of modern agro technologies in the village – as opposed to traditional habits and customs. In this way – a regular rhythm of business is introduced in the village, a certain organization of business and social and business relations is introduced – in the wake of the concept of a smart village.

— Strengthening social cohesion

Planning and organization of the implementation of the BgP project and its construction, as well as the functioning of the plant itself, requires the agreement and cooperation of all local private, business and social entities and local self–government bodies. These are often significant challenges in practice, but basically – these processes contribute to strengthening social cohesion in the community; mutual trust of residents, their trust in local authorities and local organization and work on a joint project are strengthened.

— Better quality of life

Realization and operation of BgP – ultimately brings a better quality of life for all residents in the village; there are fewer unpleasant odors and stench in the settlement, there is more order and more organized business life, local farmers have additional earnings, part of the local workforce is employed and a higher level of technical and agro culture is achieved in the community.

PLANNING THE CONSTRUCTION OF BIOGAS POWER PLANTS

Planning the construction of a biogas power plant (location and capacity) starts from local potentials; important are – number of households, number of poultry, number of small livestock (sheep, goats), number of pigs and number of cattle – according to the model shown in Figure 2; i.e. a larger number of inhabitants and livestock allows the construction of higher–capacity BgP. The most common built capacities of biogas power plants in developed EU countries are 1 and 2 MW per locations where there is a large livestock production and a larger number of inhabitants, and power plants of lower power (300 to 500 kW) are built–in smaller villages.

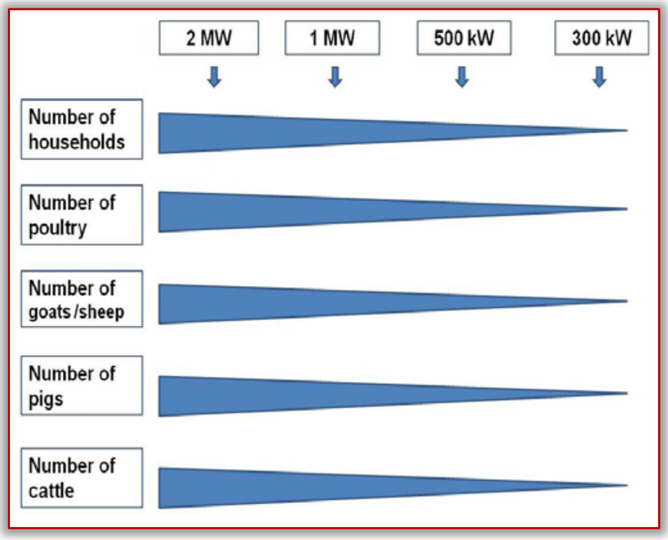

Figure 2. Elements for planning the construction of biogas power plants

We also graphically presented the model of financing the construction of BgP (Figure 3). Large business systems of agricultural production (LBS), national energy efficiency fund (NEEF), national energy market operator (NEMO), large private agricultural producers (LPAP) will participate in financing and crediting the construction of large BgP (1 MW of power and more). In construction of small capacity BgP in addition to the above entities (with a smaller share) will also finance: joint small agricultural producers (JSAP), local government (municipality), individual households in the local community (household) and regional government (county);

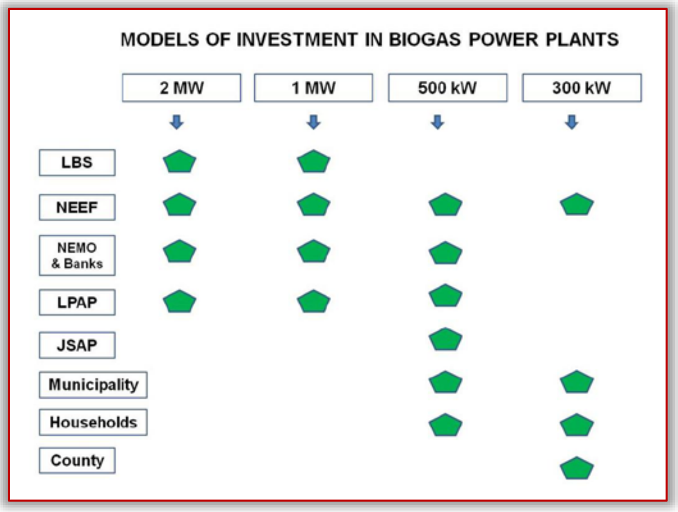

Figure 3. Investment models in biogas power plants

It should be noted here that the first biogas power plant in Croatia was built in 2009 in the agricultural cooperative Osatina near the village of Ivankovo (not far from Vinkovci), and in the following years another 38 biogas plants with a total capacity of 41.7 MWel were built and put into operation; of that number, 24 power plants (installed capacity 29,986 MWel and 30,292 QMW) were built in the Slavonia region (from these 15 BgP was built in the Osijek–Baranja County). It is significant that a large number of these plants in the region were designed, built and put into operation (connection to the power system) by Slavonian experts from Belišće, Osijek, Slatina, Sl. Brod, Vinkovci and Vukovar [4]. Figure 4 shows the newly built BgP (300 kW) in Hrastin village (about 20 km from Osijek) and Figure 5 shows the locations of the built BgP in the region of Slavonia until the end 2019.

It should be noted here that the first biogas power plant in Croatia was built in 2009 in the agricultural cooperative Osatina near the village of Ivankovo (not far from Vinkovci), and in the following years another 38 biogas plants with a total capacity of 41.7 MWel were built and put into operation; of that number, 24 power plants (Installed capacity 29,986 MWel and 30,292 QMW) were built in the Slavonia region, and 15 BpE was built in the Osijek–Baranja County. It is significant that a large number of these plants in the region were designed, built and put into operation (connection to the power system) by Slavonian experts from Belišće, Osijek, Slatina, Sl. Brod, Vinkovci and Vukovar [5]. Figure 4 shows the newly built BpE (300 kW) in the Hrastin village – about 20 km from Osijek and Figure 5 shows the locations of the built BgP in the Slavonia region.

Figure 4. Biogas power plant (300 kW) in the Hrastin village

Figure 5. Locations of biogas power plants in the area of Slavonia and Baranja region (as of 2019)

CONCLUSION

The construction of biogas power plants in rural areas of the Pannonian countries contributes to a number of local development goals;

- Raising the standard of living and quality of life in the village,
- Possibility of additional earnings for local farmers,
- Ecological disposal of livestock and rural waste,
- Raising the organizational and technological level of business in the village,
- Youth employment and
- Raising social cohesion in the village.

In this paper, models for decision–making and construction of BgP are also proposed.

Examples from rural areas of Austria, Croatia and Hungary prove the importance and benefits of building biogas plants.

Note: This paper was presented at IIZS 2021 – The XI International Conference on Industrial Engineering and Environmental Protection, organized by Technical Faculty "Mihajlo Pupin" Zrenjanin, University of Novi Sad, in Zrenjanin, SERBIA, in 07–08 October, 2021.

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[1.]Milan IVANOVIĆ, [2.]Hrvoje GLAVAŠ

ADVANTAGES OF BIOGAS POWER PLANTS IN ENERGY TRANSITION OF PANNONIAN COUNTRIES – BENEFITS FOR THE NATIONAL ECONOMY

[1.]Panon – think tank for strategic studies, Osijek, CROATIA
[2.]Josip Juraj Strossmayer University of Osijek, Faculty of Electrical Engineering, Computer Science and Information Technology, Osijek, CROATIA

Abstract: This paper points out benefits for the national economy from construction of biogas plants (BgP) – especially important for countries of the Pannonia Plain. Research data show that BgP has the most favorable effects on GDP of the national economy – compared to other renewable sources. Benefits from BgP for the national economy are: reducing CO_2 emissions and municipal waste disposing, fewer imports of electricity, gas, and oil, significantly better economic performance in energy sector, balancing functioning of the national electricity system, hiring domestic companies and activating domestic resources and use of biogas in transport.
Keywords: Biogas power plants, Energy transition, National economy, Pannonian countries, Renewable energy sources

INTRODUCTORY NOTE

In the paper "Advantages of biogas power plants in energy transition Pannonia countries – Benefits for the local community" we pointed out the unfavorable position of biogas power plants (BgP) in government structures (stronger interest groups for wind and solar power plants) and the benefits of the local community from the construction of BgP.

In this paper we pointed out benefits to the national economy – especially important for the countries of the Pannonian Plain. Research data show that BgP has the most favorable effects on the GDP of the national economy – compared to other renewable sources – through investment, intermediate consumption and employment of domestic labor and the activation of national resources. This will be illustrated by the example of the Republic of Croatia [1–5].

BENEFITS OF BIOGAS POWER PLANTS FOR THE NATIONAL ECONOMY

The national economy and energy sector have a number of very significant benefits from investing in the construction of biogas plants compared to other renewable sources – as shown in Figure 1.

— Climate change – meeting EU obligations

Each EU member state has committed itself to reducing CO_2 emissions and disposing of municipal waste, in order to mitigate climate change. It should be emphasized here that these are not unimportant and only formal obligations imposed from above – but a civilization and planetary obligation to prevent catastrophes for humanity. As much as wind and solar power plants are neutral in terms of greenhouse gas emissions, so is the disposal of livestock manure in BgP – especially in cattle breeding due to methane emissions.

There is special issue of disposal, i.e. recycling of municipal waste; e.g. Croatia should have separated and recycled 50% of municipal waste by 2020. But this has not been achieved; the rate of separate collection of municipal waste in Croatia in 2020 was 41%.

According to the current practice Croatia will pay penalties until the assumed obligations are fulfilled as paid by Bulgaria, Greece, Hungary, Italy and Poland (about ten million € per quarter). [3]

— Fewer imports of electricity, gas, and oil

The production and use of biogas contribute to the reduction of imports of fossil fuels. E.g. in the last 10 years, the Republic of Croatia has imported between 30 and 40% of electricity and the same amount of natural gas. A significant increase in the production of biogas and electricity from BgP has a positive impact on reducing national energy dependence, i.e. reducing import of these energy sources. [4]

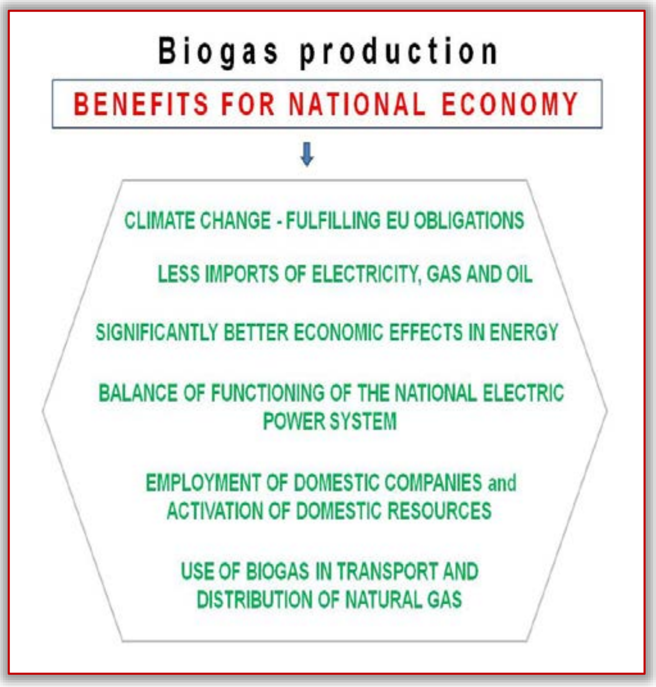

Figure 1. Benefits to the national economy from the construction of biogas power plants

— Significantly better economic performance in energy

The largest impact on GDP and employment in Croatia among renewable energy sources (RES) is achieved by GDP; as shown in Tables 1 and 2. Also – with BgP, investments per MW in electric power plants are lower.

Table 1. Investment channels – effects on € 1 million value of total investments. Source: [6]

Power plant type Indicator	Wind farms	Solar	Biomass	Biogas	Small hydropower
GDP (000 €)					
Direct effect	739,1	973,6	188,9	215,8	916,3
Indirect effect	193,3	17,5	671,5	608,0	73,3
Induced effect	91,0	7,4	336,5	183,5	35,3
Total effect	1023.3	998,6	1197,0	1007,3	1025,0
Number of employees in terms of annual labor input					
Direct effect	0,6	0	11,7	8,6	6,0
Indirect effect	6,5	0,5	37,8	33,3	2,5
Induced effect	3,6	0,3	13,1	7,2	1,4
Total effect	10,7	0,7	62,7	49,1	9,8

Table 2. Intermediate consumption channel – effects on € 1 million value of total investments. Source: [6]

Power plant type Indicator	Wind farms	Solar	Biomass	Biogas	Small hydropower
GDP (000 €)					
Direct effect	130,0	238,4	217,1	240,9	235,9
Indirect effect	94,2	181,0	178,1	212,9	200,6
Induced effect	120,5	216,9	199,9	220,3	210,7
Total effect	344,6	636,3	595,1	674,1	647,3
Number of employees in terms of annual labor input					
Direct effect	6,1	8,2	9,8	11,9	11,6
Indirect effect	3,2	6,5	6,5	6,6	6,1
Induced effect	5,0	8,5	8,6	9,0	8,3
Total effect	14,3	23,2	24,9	27,5	26,0

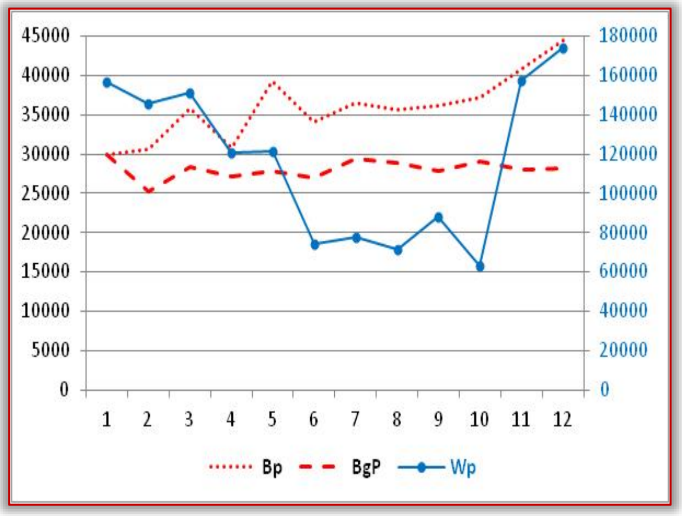

Figure 2. Production of electricity from renewable energy sources in Croatia in 2019 – by months [7]

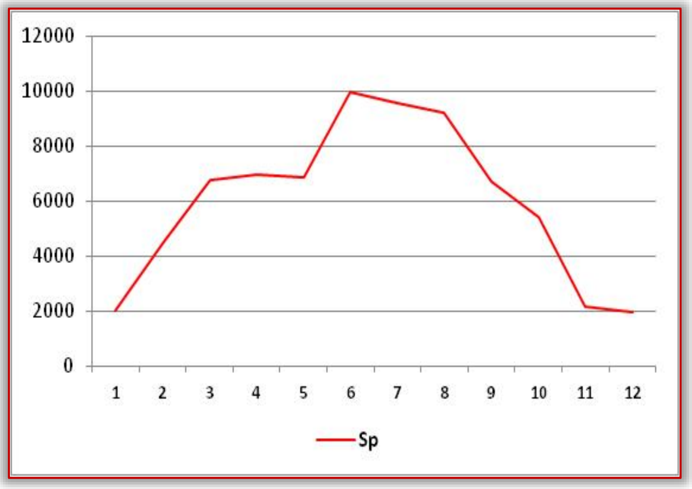

Figure 3. Production of electricity from solar power plants in Croatia in 2019 – by months [7]

— Balancing the functioning of the national electricity system

Biogas plants do not have daily and seasonal oscillations in production – such as hydro, solar and wind power – which contributes to balancing the functioning of the country's electricity system. E.g. Figures 2 and 3 show the monthly oscillations in the production of electricity in the power system of the Republic of Croatia from renewable energy sources. Balanced production of BgP and biomass power plants (Bp) is observed in contrast to wind power plants (Wp) and solar power plants (Sp).

— Hiring domestic companies and activating domestic resources

Data on investments in renewable and energy sources in Croatia in the period from 2009 to 2016 show that about 80% of the total investment costs in biogas plants are realized by the domestic economy, unlike wind farms and other technologies where imports of equipment and materials and foreign costs h contractors amount to over 80 percent. Figure 4 shows the BgP complex (2 MW) "Biointegra" Slatina – built by domestic contractors with domestic construction materials and a significant part of domestic equipment.

Figure 4. Biogas power plants (2 MW) "Biointegra" Slatina, Croatia [8]

USE OF BIOGAS IN TRANSPORT AND DISTRIBUTION OF NATURAL GAS

Finished biogas (biomethane) in developed EU countries has been used for years as a fuel in road transport or as a supplement in the distribution of natural gas. To use biogas as a fuel for road vehicles or in the natural gas distribution network, additional processing is needed – removal of CO2 and sulfur. The treated biogas (now biomethane) is compressed to the gas network pressure level and can be placed in the natural gas network distribution system. In the developed European countries, in the past decade, there has been strong growth in the construction of biogas capacity and the use of biogas, and especially strong growth in the capacity for biogas refining, i.e. biomethane production; Figure 5 shows the annual growth rates of the number of biogas and biomethane plants in Europe. [9][10]

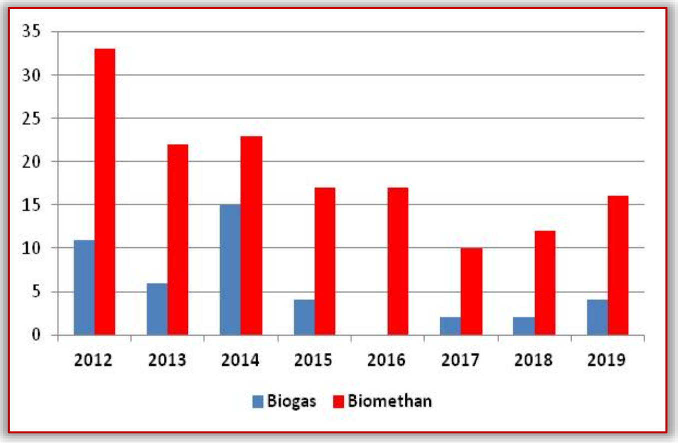

Figure 5. Annual growth rates of biogas and biomethane plants in Europe (%) [10]

Unfortunately, no biogas refinery has been built in the Republic of Croatia, and according to available information, it is not in the plans.

CONCLUSIONS

Our considerations – on the example of the Republic of Croatia – showed:

- That BgP have the most favorable effects on the GDP of the national economy – compared to other renewable sources – through investment, intermediate consumption and employment of domestic labor and activation of national resources.
- Importat benefits for the national economy are to: reducing CO_2 emissions and municipal waste disposing; fewer imports of electricity, gas, and oil; significantly better economic performance in energy; balancing functioning of the national electricity system; hiring domestic companies and activating domestic resources; and Use of biogas in transport
- European developed countries are achieving strong growth in biogas capacity building and biogas use, and especially strong growth in biogas refining capacity (biomethane production).
- States in the Pannonian area should pay special attention to investments in renewable energy sources and objectify the eco–friendly, ecological and energy effects of certain forms of renewable energy sources, and not be subject to the influence of interest lobbies without a critical approach.

Note: This paper was presented at IIZS 2021 – The XI International Conference on Industrial Engineering and Environmental Protection, organized by Technical Faculty "Mihajlo Pupin" Zrenjanin, University of Novi Sad, in Zrenjanin, SERBIA, in 07–08 October, 2021.

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[1.]Vladimir ŠINIK, [2.]Željko DESPOTOVIĆ, [3.]Branko RADOVIĆ, [1.]Mića ĐURĐEV, [1.]Miloš JOSIMOVIĆ

PROBLEMS RELATED TO THE ELECTRIC POWER SYSTEM OF WIND FARMS AND NEW TENDENCIES IN THEM

[1.]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, SERBIA
[2.]Institute „Mihajlo Pupin" Belgrade, SERBIA
[3.]Institute for Protection and Ecology of Republika Srpska, Banja Luka, BOSNIA & HERZEGOVINA

Abstract: Wind farms supply real power variations into the upstream grid, and at the same time, in some types of wind generation systems, the reactive power consumption is related to the real power production. These power variations cause voltage variations with consequences for the electrical power system and the customers. On the other hand, the increasing use of power electronics in wind generation systems introduces voltages and current harmonics into the power system. As wind energy is a non–controllable energy source, it can cause problems with voltage stability and transient stability. The first part of the paper presents the problems of electricity production using wind farms. In the second part of the paper, new tendencies in the realization of wind farms are given. Power systems are complex systems that evolve over years in response to economic growth and continuously increasing power demand. In order to make energy economically available with reduced carbon emission using renewable energy sources, the structure of the modern power system has become highly complex.
Keywords: Wind farms, power systems, connecting wind farms

INTRODUCTION

The annual energy production of a wind farm is not equal to the sum of the generator nameplate ratings multiplied by the total hours in a year since the wind speed is variable. The capacity factor of a wind farm is the ratio of actual productivity in a year to the theoretical maximum. The range of the capacity factor is between 20 and 40%, with values at the upper end of the range in particularly favorable sites.

The rapid development of the wind turbine industry is going in two key directions – increasing power, through increasing the diameter of the rotor, or through increasing the coverage of kinetic wind energy, and increasing efficiency conversions through the improvement of converter circuits, ie active speed regulation and setting at the point of maximum power [1]. Electricity generated from wind power can be highly variable at several different timescales: hourly, daily, or seasonally.

However, wind is always in constant supply somewhere, making it a dependable source of energy because it will never expire or become extinct. Annual variation also exists, but is not so significant. Like other electricity sources, wind energy must be scheduled. Wind power forecasting methods are used, but predictability of wind plant output remains low for short–term operation. Because instantaneous electrical generation and consumption must remain in balance to maintain grid stability, this variability can present substantial challenges to incorporating large amounts of wind power into a grid system [2], [3].

POWER SYSTEM CONNECTION ISSUES OF WIND FARMS

Unlike classical sources of energy, wind farms supply real power variations into the upstream grid, and at the same time, in some types of wind generation systems, the reactive power consumption is related to the real power production. These power variations cause voltage variations with consequences for the electrical power system and the customers. On the other hand, the increasing use of power electronics in wind generation systems introduces voltages and current harmonics into the power system. As wind energy is a non–controllable energy source, it can cause problems with voltage stability and transient stability. Due to the rapid increase in the number of wind farms connected to the grid, the increasing rate of power of single wind farm and the weakness of the upstream power grid, where the wind farm connects, the importance and necessity of the study of wind farms connected to power systems is clear [3].

The connection of wind farm to electrical power systems influences the system operation point, the load flow of real and reactive power, nodal voltages and power losses [4].

The impact of wind farm on the power system depends on the location of wind power plants relative to the load, and the correlation between wind power production and load consumption. Wind power, like any load or generation, affects the power flow in the network and may even change the power flow direction in parts of the network. The changes in the use of the power lines can bring about power losses or benefits.

Increasing wind power production can affect bottleneck situations. Depending on its location, wind power may, at its best, reduce bottlenecks, but at another location result in more frequent bottlenecks. Grid extensions are commonly needed if new generation is installed in weak grids far from load centers to make full use of the wind power. The issue is generally the same for modern wind power plants or any other power plants.

The cost of grid reinforcements, due to wind power, is therefore very dependent on where the wind power plants are located relative to the load and grid infrastructure, and one must expect numbers to vary from country to country.

With current technology, wind power plants can be designed to meet industry expectations such as riding through voltage dips, supplying reactive power to the system, controlling terminal voltage, and participating in SCADA (supervision control and data acquisition) system operation with output and ramp rate control [4, 5].

DIFFERENT WIND TURBINE TECHNOLOGIES

There are many different generator types for wind power applications in use today. The main distinction can be made between fixed speed and variable speed wind generator types. Previous solutions with asynchronous machines of cage or sliding type with constant or partially regulated operating speeds are not sufficiently energy efficient and can hardly meet the increasingly complex network requirements given in the "Rules for the operation of power systems" [5]. Also, the issues of reliability and reduction of maintenance costs, especially for offshore wind farms, are becoming increasingly important, so new solutions are being sought for more efficient use of wind energy through the growing role of power electronic converters as interfaces between generators and grid, and operation without mechanical speed multipliers. The rapid development of the wind turbine industry is going in two key directions – increasing power, through increasing the diameter of the rotor, or through increasing the coverage of kinetic wind energy, and increasing efficiency conversions through the improvement of converter circuits, ie active speed regulation and setting at the point of maximum power [1], [5].

Wind turbines started as small generator units of several tens of kW and with a symbolic role in the power system. However, they developed very quickly and in the previous decade, units of several MW became commonplace. Power generators are currently appearing on the market 6–8 MW, with the planned development of 10 MW units with a vision to increase to as much as 20 MW [6].

In a continuous effort to reduce costs, increase the reliability and efficiency of wind energy conversion systems, various solutions have been developed. In general, wind turbines can be classified as fixed and regulated speed turbines [1], [8]. Fixed speed wind turbines use a cage asynchronous generator connected directly to the grid. To start, thyristor energy converters are used in the "soft start" configuration, which are in nominal mode short–circuited. This method forces the electric machine to operate at a constant frequency and therefore at an approximately constant speed. Wind power pulsations are transmitted directly to the grid and there is no control of active and reactive power, which are typically important parameters for frequency and voltage regulation. Network connection and difficulties in complying with the "Power System Rules" are additional problems. On the other hand, these solutions are simple, robust and use existing, already developed technology, so they are affordable. An improved solution with a synchronous generator with permanent magnets and a converter circuit connected in an open stator hub, enables active damping with relatively low converter power (20% of the nominal power of the generator) [1], [8]. However, that solution remained at the level of an academic proposal and outside the interests of the industry. Fixed speed wind turbines were mainly used in the first days of using wind energy and are characterized by low power. Greater interest in the application of wind generators and stronger investment cycles, have led to the search for solutions to remove the above limitations, ie to the development of the application of structures with regulated speed. Speed–regulated turbines provide better power utilization and are easier to adapt to network needs.

Synchronous generators and asynchronous cage generators connected to the energy conversion system are used in practical embodiments of these wind turbines. In addition, sliding–reel machines, such as double–powered asynchronous generators with reduced converter power or asynchronous generators with external controlled rotor resistance, have practical applications [1], [7].

Due to the variability of wind speed, it is highly desirable that the turbine drive be of variable speed. Also, with the increase of turbine power, control parameters become more and more important, so it is necessary to implement power electronics as an interface between the wind turbine and the network. The turbine is with variable speed it improves the dynamic behavior of the turbine and enables propulsion with maximum power at a certain wind speed and control of the flow of active and reactive power. Other benefits are reduced mechanical stress, less torque and power pulsations, improved voltage quality and less noise at low wind speeds [1], [5]. Based on the use of the transmission mechanism, they can be divided into turbines with direct or indirect drive. Both solutions of a synchronous generator with a wound rotor or with permanent magnets are acceptable for direct drive, for which a full energy converter system is required. Asynchronous cage generators can also be used, also with the use of a back–to–back converter system. This system serves as an interface between the generator and the network and consists of a diode or active rectifier, a DC link and a network inverter. The generator speed is adjusted turbine speed and thus the transmission mechanism is of minor importance and can be eliminated. In wind turbine systems with multi–pole (eg 72–pole) or multi–phase configurations (for example phase 6) synchronous generators a mechanical multiplier can be eliminated [1]. This is especially true when the generator is running at low speed, ie. has a large number of poles. Such a turbine without a mechanical multiplier (transmission mechanism) is attractive due to lower cost, weight and significantly lower maintenance costs. Multiphase or multi–winding generators are interesting for research also because such a topology increases the reliability of the whole system, and with the appropriate design of switching schemes, the influence of harmonics on the network can be significantly reduced [1]. Indirect–driven turbines require a transmission mechanism to synchronize low–speed turbines with high–speed generators. Another possible classification reflects the application of converter systems based on energy electronic converters. There are wind generator systems with partially regulated speeds and full speed regulation.

In the early stage of wind power development, most wind farms were equipped with fixed speed wind turbines and induction generators. A fixed speed wind generator is usually equipped with a squirrel cage induction generator whose speed variations are limited. Power can only be controlled through pitch angle variations. Because the efficiency of wind turbines depends on the tip–speed ratio, the power of a fixed speed wind generator varies directly with the wind speed. Since induction machines have no reactive power control capabilities, fixed or variable power factor correction systems are usually required for compensating the reactive power demand of the generator. Figure 1 shows the schematic diagram of the fixed speed induction machine [3].

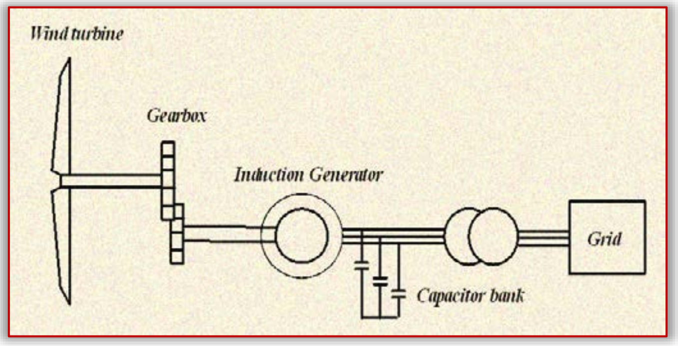


Figure 1. Fixed speed induction generator [3]

Variable speed concepts allow operating the wind turbine at the optimum tip–speed ratio and hence at the optimum power coefficient for a wide wind speed range. The two most widely used variable speed wind generator concepts are the DFIG and the converter driven synchronous generator. Due to advantages such as high energy efficiency and controllability, the variable speed wind turbine using DFIG is getting more attention. DFIG is basically a standard, wound rotor induction generator with a voltage source converter connected to the slip–rings of the rotor. The stator winding is coupled directly to the grid and the rotor winding is connected to power converter as shown in Figure 2.

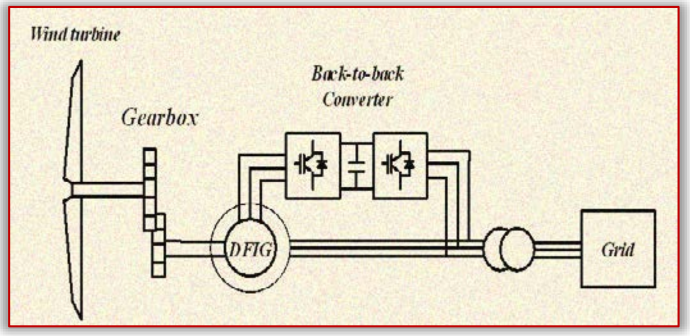


Figure 2. Double fed induction generator [3]

The converter system enables two way transfer of power. The grid side converter provides a dc supply to the rotor side converter that produces a variable frequency three phase supply to generator rotor via slip rings. The variable voltage into the rotor at slip frequency enables variable speed operation. Manipulation of the rotor voltage permits the control of the generator operating conditions. In case of low wind speeds, the drop in rotor speed may lead the generator into a sub synchronous operating mode. During this mode, DFIG rotor absorbs power from the grid [3].

This category of wind turbines uses a synchronous generator that can either be an electrically excited synchronous generator or a permanent magnet machine. To enable variable–speed operation, the synchronous generator is connected to the network through a variable frequency converter, which completely decouples the generator from the network. The electrical frequency of the generator may vary as the wind speed changes, while the network frequency remains unchanged. The rating of the power converter in this wind turbine corresponds to the rated power of the generator plus losses. The schematic diagram of the converter driven synchronous generator is as shown in Figure 3.

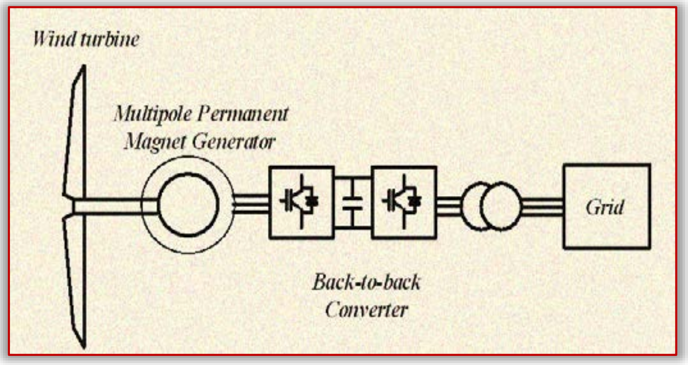


Figure 3. Converter–driven generator

A wind generator with a synchronous generator (SG) has a number of possible configurations, because SGs can produce rotor flux independently. Instead of an active rectifier on the generator side, a cheaper diode rectifier with a voltage boost converter can be used in the DC link (Figure 4). However, for higher power the voltage booster must be composed of several intertwined units or in some other way.

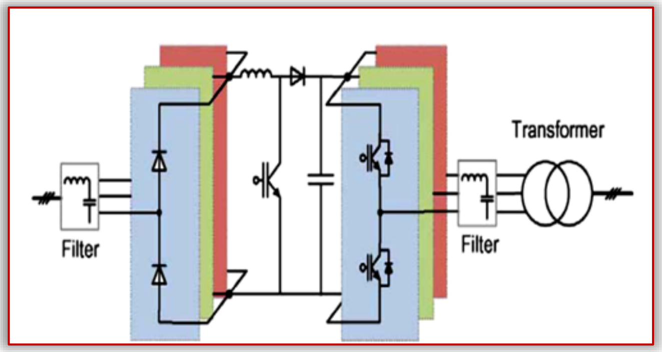


Figure 4. Converter assembly with diode rectifier, boost voltage converter and voltage rectifier [1]

Medium voltage electric generators and adequate converters are used for higher power wind generators (10 MW). The problem is the high voltage stress of the electronic switching components, however components must bind to the row.

New solutions for higher power converters include the use of multilevel converters. 3–level, 5–level inverter variants are possible, as well as combinations of these solutions in a half–bridge or bridge configuration. Figure 5 shows a solution with a 3–level rectifier and a 5–level inverter in a half–bridge configuration. In addition to the problem with the voltage fluctuation of the midpoint, which is on the way to a solution, a serious drawback is the uneven distribution of losses in the branches of the converter.

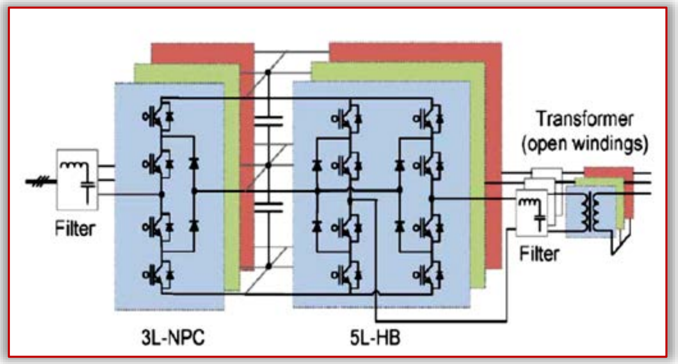
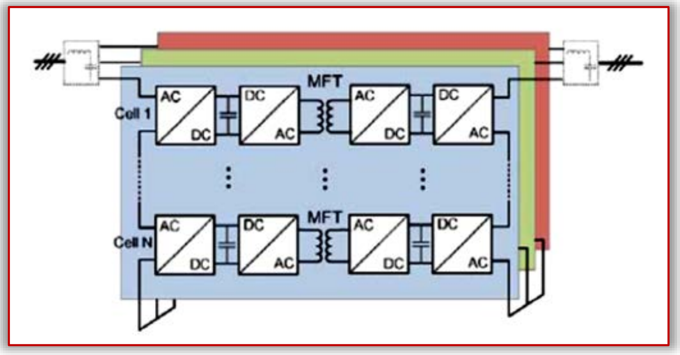


Figure 5. Dual converter with 3–level rectifier and 5–level inverter [1]

For wind generators, it is possible to use converters with several connected smaller units, which is more convenient considering the voltage levels of the switching electronic components themselves. Unlike variants with double converters, solutions with indirect or direct AC / AC converters are proposed here.



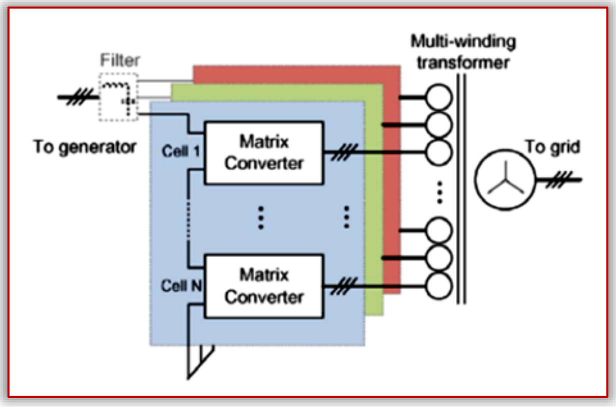


Figure 6. Indirect and direct AC / AC converters for wind turbines [1]

Figure 6 shows two possibilities: an indirect converter and a direct (matrix) converter. An indirect converter is a combination of AC / DC, DC / AC, AC / AC, AC / DC and DC / AC series–connected converters, with the AC / AC converter being in fact an isolating transformer, operating at medium frequencies. A matrix converter is a complex unit, which requires an isolating transformer with a larger number of primary windings. Other solutions are possible, which include a large number of differently parallel or series–connected converters with a large number of switches. However, due to the many components, the issue of system reliability comes to the fore, so complex analyzes of possible outages and maintenance methods are needed [1].

IMPACT OF WIND INTERMITTENT AND VARIABILITY

Uncertainty and variability are characteristics that exist in wind power, aggregate electric demand and supply resources and have always posed challenges for power system operators. Future expansion of the loads cannot be predicted accurately, generator outputs and loads fluctuate strongly in different time frames, and it can also lose energy system equipment at any time and without prior warning. Different amounts and types of operating reserves are secured by power system operators to compensate for uncertainty and variability for load reliable service and to keep the system frequency stable. There are many different terms, definitions, and rules concerning what operating reserves entail.

The real power capability that can be given or taken in the operating timeframe to assist in generation and load balance and frequency control is defined as the operating reserves. To provide voltage support systems also require reactive power reserve as well, and require certain targets for installed capacity that is often referred to as planning reserve [3].

The type of event the operating reserves respond to, the timescale of the response and the direction (upward or downward) of the response can differentiate the types of operating reserves. Unpredictable imbalances between load and generation caused by sudden outages of generating units, errors in load forecasting or unexpected deviations by generating units from their production schedules can be compensated by spinning reserve (SR).

It becomes more difficult to predict accurately the total amount of power injected by all generators into the power system, as the proportion of power produced by wind farms increases. This added uncertainty must be taken into account when setting the requirement for SR. The uncertainty on the wind power generation increases the uncertainty on the net demand that must be met by traditional forms of generation if wind power generation is considered as a negative load. Spinning reserve is intended to protect the system against unforeseen events such as generation outages, sudden load changes or a combination of both by taking the increased uncertainty into account when determining the requirements for SR [3].

CONNECTION OF THE WIND POWER PLANT TO THE NETWORK

Each power system operates in accordance with certain rules that define the obligations of existing and future users to operate and connect to the power grid [1,4]. These requirements must be met by electricity producers, consumers connected to the electricity grid and grid management companies. These rules are known as the "Rules of Procedure power system" (Grid Code).

Similar to transmission networks, the distribution network determines the requirements for connection of its users in the "Rules of operation of the Distribution Network" (Distribution Code) [1]. Compared to transmission network users, distribution network users have less power and less impact on the operation of the network, so that the requirements of the Rules of Operation of the Distribution Network are significantly easier compared to transmission. The fact is that the requirements of the "Rules of operation of the power system" are constantly adapted to the development of technology. These include fault issues, active power regulation, frequency, reactive power regulation, voltage regulation and production planning.

Wind farms are connected to the electricity grid, depending on the power: for installed power over 15 MW, farms are connected mainly to the transmission network, while for power below 15 MW they are connected to the distribution network. Since wind farms can have a significant impact on the quality of electricity and the stability of the power system, their installation, activation and operation are a significant problem. In that sense, technical ones are prescribed rules for connection of wind farms in the Rules for the operation of power systems (Grid Code). Wind turbine technology is evolving rapidly and has a lot of special functionalities compared to conventional power plants. For this reason, in many countries the requirements for joining farms wind generators have a special treatment in the form of special rules (Wind Code) [1].

CONCLUSION

The changing nature of a power system has considerable effect on its dynamic behaviors resulting in power swings, dynamic interactions between different power system devices and less synchronized coupling.

The general requirements of most of the leading Rules on the operation of the system (Grid Code) in the part of connecting wind farm farms, include the problem of failures, regulation of active power, frequencies, regulation reactive power and voltage, which are analyzed in this paper.

On the other hand, modern constructions of wind generators enable cost reductions and increased reliability. In future high–power units, quality and reliable solutions of power electronics converters will play a key role in the electrical part. Further progress and significant improvements are expected in this area.

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[1.]J.E. SANI, [1.]G. MOSES, [2.]R.K. ETIM, [1.]U.N. WILSON, [1.]A.O. BABATUNDE

STABILIZATION OF LATERITIC SOIL WITH CEMENT AND TREATED SISAL FIBRE

[1.]Department of Civil Engineering, Nigerian Defence Academy, Kaduna, NIGERIA
[2.]Department of Civil Engineering, Akwa Ibom State University, Ikot Akpaden, NIGERIA

Abstract: Lateritic soil collected at Shika Zaria was stabilized with Cement (C) and sisal fibre (SF) to determine its effect on the unconfined compressive strength. The preliminary investigation conducted shows that it falls under A–7–6 (10) classification and CL. The soil was treated with cement–sisal fibre in concentrations of 0%, 2%, 4%, 6%, and 8% and 0%, 0.25%, 0.5%, 0.75% and 1% by dry weight of soil. The Sisal Fibre was treated with Sodium Borohydride (NaBH4) (1% wt/vol) for 60 minutes at room temperature to remove the cellulose content present in the Fibre. Compaction was carried out using Standard Proctor energy and the Maximum Dry Density (MDD) decreases from 1.85Mg/m^3 for the natural soil to 1.6Mg/m^3 at 4% cement/0.25% sisal fibre treatment. The Optimum Moisture Content (OMC) increases from 18% to 24.5% at 6% cement of 0.5% sisal fibre content. The Unconfined Compressive Strength (UCS) value increased from 186kN/m^2 for the natural lateritic soil to a peak value of 1942kN/m^{2}at 4% cement /0.5% sisal fibre. This peak value is higher than the 1720kN/m^{2}criterion for adequate cement stabilization of base courses. Analysis of variance was carried out using Microsoft Excel Analysis Tool Pak Software Package. Mini–tab R15 Software was used for regression analysis. Laboratory results were used to generate reliability indices using a FORTRAN based first order reliability program. The reliability analysis carried out indicates that the reliability indices were more pronounced for MDD and OMC which are also related to the UCS of the soil evaluated. Model 1 produced successful result in coefficient of variation (COV) range 1 – 50 % that can be used to predict field UCS of lateritic soil stabilized with Cement and sisal fibre for base and sub–base materials for pavement structures.
Keywords: Lateritic soil, Cement, Sisal fibre, Unconfined Compressive Strength and Sodium Borohydride (NaBH4), Regression analysis and Reliability index

INTRODUCTION

Soil stabilization is the improvement of the original soil properties to meet specific engineering requirements. It is aimed at the enhancement of the engineering properties of deficient soils to enable them perform and sustain their intended engineering use [1]. Its objectives are: improvement of the strength of the soil and bearing capacity, decreasing permeability and water absorption, and to increase the durability under varying moisture content. Stabilization increases the shear strength of a soil or control the shrinkage–swell properties of the given soil thus improving the load bearing capacity of a sub grade to support pavement and foundation [2]. Soil stabilization can be utilized on roadways, parking areas, site development projects, airports and many other situations where subsoil are not suitable for construction.

Laterites, which are formed in tropical and sub–tropical regions of hot and humid climatic condition with heavy rainfall, warm temperature and good drainage according to Townsend [3], are very rich in iron and aluminium and occur mostly as the capping of the hill. They therefore find extensive use in numerous construction activities such as subgrade material for road construction and brick production material [4]. Most tropical laterites predominantly composed of kaolinite, non–swelling, non–expanding 1:1 clay mineral which are engineering materials [5]; some often contain swelling 2:1 clay mineral sand therefore constitute problematic engineering materials for road construction. Stabilization can be used to improve a wide range of sub grade materials varying from expansive clays to granular materials.

This process is accomplished using wide variety of additive; including lime, fly ash, and Portland cement other by–products include lime kiln dust and cement kiln dust [2].

Cement stabilized soils generally have high compressive strength but low ductility. Cement stabilization generally increases durability, shrinkage and volume stability for expansive clays but reduces the permeability for most other soils. Additives other than pozzolanas used in soil stabilization include fibres, shredded tyres and polymers and lime. Sisal fibre can also be used in addition with cement stabilize soil for construction purpose as they increase the soil ductility [6]. Also. Tanko [6] indicated that sisal fibre are bio–degradable materials because of the cellulose present in the fibre which when used for reinforcing soil can degrade at long time curing, therefore the sisal fibre used for this research work was treated with Sodium Borohydride (NaBH4) (1% wt/Vol) as recommended by [7].

Sisal fibres comes from sisal plant and from Chinese origin, the plant is repeatedly beaten and pulped to form the fibre along with other natural fibres. Sisal fibres have recently become popular in soil reinforcing due to their affordable cost, strength and availability the addition of sisal fibre increases the shear strength of soil as well as cohesion and ductility. They are important agricultural products used in the manufacture of rope. They are also used in reinforcement of polymeric or cement based composite. The production process leads to large amount of residues generation, which currently have low potential for commercial use. The length and percentage of fibre is important because being too long reduces the shear strength and percentage greater than 0.75% also reduces shear strength [6].

Therefore, this research aimed at stabilizing lateritic soil using cement and treated sisal fibre to improve the strength of the lateritic soil. This was achieve through the treatment of the sisal fiber with Sodium Borohydride (NaBH4) (1% wt/Vol) and determination of compaction characteristic, compressive strength of cement – treated sisal fiber stabilized lateritic soil and carrying out statistical analysis together with the reliability analysis of the results obtained.

MATERIALS AND METHODS

— Materials

≡ Lateritic soil: The lateritic soil sample used for this study was collected by method of disturbed sampling from a borrow pit located at Shika in Zaria Local Government Area (Longitude 7^0 36' E Latitude 11^0 4' N). The top soil was removed to a depth of 0.5m before the soil samples were taken, sealed in plastic bags to avoid loss of moisture and placed in sacks before transportation to the laboratory. The soil samples were then air–dried before lumps were broken to obtain particles passing BS No. 4 sieve (4.76 mm aperture).

≡ Cement: Cement used for the study was obtained from Dangote Portland Cement deport in Kaduna State.

≡ Treated Sisal Fibre: Sisal fibre was gotten from Central Market in Kaduna metropolis in Kaduna State. A length of 3.5cm sisal fibre was used.

— Methods

The soil was subjected to tests in accordance with [8], for the natural soil and [9] for the treated soil samples.

≡ Index properties: Index tests were carried out on the natural soil in according to [8] and [9].

≡ Oxide composition: The oxide composition of Cement was determined at defense industry cooperation of Nigeria (DICON), Kaduna, Nigeria, using the method of X–Ray Fluorescence (Nuclear Energy Test). The Properties of sisal fibre and the tensile and elongation test was carried out at Standard Organization of Nigeria (SON) at Kawo New Extension Kaduna. The test was carried out by inserting three strand of the sisal fibre into the test machine and the tensile and elongation value was recorded as recommended by [6]. This ensures that the peak value of strength gain in sisal fibre stabilized soil was obtained at 3.5cm length. The sisal fibre was soaked in a solution of Sodium Borohydride containing 1% wt/Volume and allowed for 24 hours to extract the cellulose contained in the sisal fibre. The treated sisal fibre was allowed to dry at room temperature before been used together with cement to stabilize the soil.

≡ Compaction: Tests involving moisture–density relationships carried out for untreated and cement – treated sisal fibre treated specimen using the Standard Proctor energy level. The Standard Proctor effort consists of the energy derived from a 2.5kg rammer falling through 30cm onto three layers, each receiving 27 blows.

≡ Unconfined compressive strength: Lateritic soil was treated with both cement and treated sisal fibre in stepped concentrations of 0, 2, 4, 6 and 8% as well as 0, 0.25, 0.5, 0.75, and 1.0 %, respectively. Thoroughly mixed air–dried soil – Cement – Treated sisal fibre mixtures were compacted at Optimum Moisture Contents (OMC) and compacted using standard Proctor (SP) energy. The compacted samples were extruded from the standard 1,000 cm^3 mould using a cylindrical steel mould with height of 76mm and internal diameter of 38 mm. The specimens were sealed in polythene bags and kept in the humid room at a constant temperature of 25 ± 2^{0}C for 7 days curing period so as to compare the result with the standard UCS value of 1720kN/m^2 as recommended by [10]. The specimens were then placed in a load frame driven at a constant strain of 0.10 %/min until failure occurred. Three specimens were used for each test and the average result was taken.

≡ Set up of regression and reliability analysis procedures

Laboratory results measured from all experiments were used for the regression and reliability analysis. Measured soil variables were classified as dependent and independent variables. The UCS was dependent variable while C, SF, MDD and OMC are called the independent variable. A regression model was developed using Minitab R15 to predict the unconfined compressive strength from the measured laboratory results.

Statistical analysis was carried out on the obtained results using analysis of variance with the Microsoft Excel Analysis Tool Pak Software Package. The regression equation developed was used as a limit state function for the reliability analysis. The regression model was incorporated into a FORTRAN based program, FORM 5 to produce the reliability index for each variable, one at a time within a range of coefficient of variation (COV) between 1 and 100% while the original values for other variables were allowed to remain constant. The UCS, MDD and OMC values were assigned lognormal distributions while C and SF values were assigned normal distributions. The various data for the reliability analysis are contained in Table 1.

Table 1: Input data for reliability based design for six independent variable using FORM 5 from laboratory measured strength.

S/no	Variables	Distribution type	Mean e(x)	Standard deviation s(x)	Coefficient Of variation Cov (%)
1	UCS	Lognormal	598.2	330.5	55.25
2	C	Normal	4.0	2.887	72.18
4	SF	Normal	0.5	0.361	72.20
5	MDD	Lognormal	1.674	0.0524	3.13
6	OMC	Lognormal	20.80	2.116	10.17

RESULTS AND DISCUSSION

— Index Properties of the Natural Soil

The index properties of the natural soil used are summarized in Table 2. The oxide composition of the lateritic soil and cement used are shown in Table 3 and Table 4 respectively. The property of the sisal fibre used is shown in Table 5. The soil belongs to the CL group in the Unified Soil Classification System [11] or A–7–6(10) soil group of the AASHTO soil classification system [12].

Table 2: Properties of the Natural Soil

Property	Quantity
Percentage passing BS No 200 sieve, %	57.5
Natural Moisture Content, %	20.76
Liquid Limit, %	48.00
Plastic Limit, %	27.27
Plasticity Index, %	20.73
Linear Shrinkage, %	7.87
Free Swell, %	19.09
Specific Gravity	2.73
AASHTO Classification	A–7–6(10)
USCS	CL
Maximum Dry Density, Mg/m^3	1.85
British Standard Light	
Optimum Moisture Content, %	18.0
British Standard Light	
Unconfined Compressive Strength, kN/m^2	189
British Standard Light	Reddish Brown
Colour	

Table 3: Oxide composition of lateritic soil [13]

Oxide	Concentration %
SiO_2	47.1
Al_2O_3	17.40
K_2O	0.48
CaO	0.17
TiO_2	3.69
V_2O_5	0.070
Cr_2O_3	0.035
Fe_2O_3	19.04
MnO	0.054
CuO	0.065
ZrO	0.966
L.O.I	10.3

Table 5: Properties of the sisal fibre [13]

Property	Quantity
Natural Humidity, %	14.48
Average Diameter, mm	0.13
Water Absorption, %	340
Specific Gravity, g/cm^3	0.22
Tensile Strength, N/mm^2	
One Strand	10.60
Two Strands	24.45
Three Strands	30.60
Elongation at Break, mm	5.58
Colour	Shiny white

Table 4: Oxide composition of cement [13]

Oxide	Concentration %
CaO	73.05
SiO_2	14.42
Al_2O_3	3.48
Fe_2O_3	3.38
MgO	1.30
Mn_2O_3	0.03
Na_2O	0.00
SO_3	2.99
P_2O_5	0.11
Cr_2O_3	0.01
SrO	0.46
ZnO	0.00
Cl	0.15
TiO_2	0.21
L.O.I	–

— Compaction Characteristics

The variations of the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) of lateritic soil – sisal fibre mixtures with cement are shown in Figure 1 and 2, respectively.

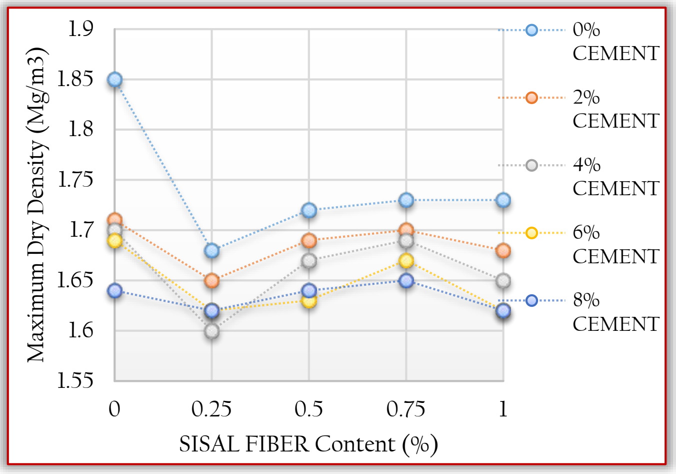

Figure 1: Variation of maximum dry density of lateritic soil – sisal fibre content mixture with cement content

The MDD shows a general trend of decreasing in MDD value from 0% sisal fiber to 0.25% sisal fiber and thereafter increases with increase in sisal fiber content up to 1% sisal fiber for all cement contents considered.

The MDD decreased from 1.85 to 1.6Mg/m^3 at 0.25% sisal fibre/4% cement contents. The reduction may be due to the effect of cement (with high calcium oxide) on the workability of the stabilized soil and also attributed to sisal fibre having low density as compared to the density of the soil. This also reduces the average unit weight of the solids in the mixture and making compaction difficult because the sisal fibre occupy more space thereby creating voids within the mixture.

The trend of decreasing MDD with admixture contents was reported by [14 – 17]. Other probable reasons for the drop in MDD may be due to the flocculated and agglomerated clay particles.

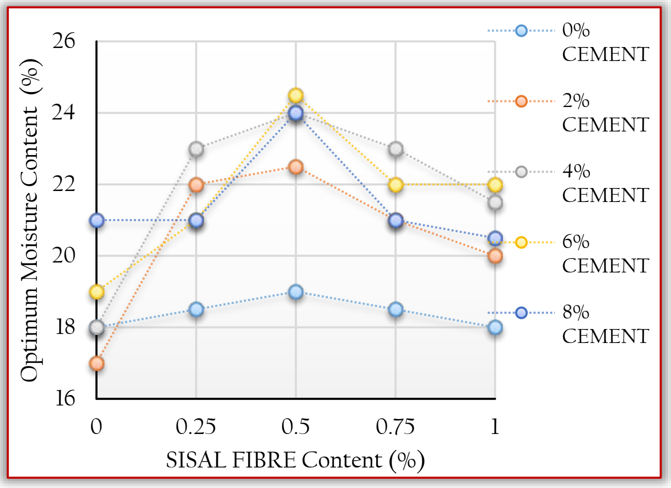

Figure 2: Variation of optimum moisture content of lateritic soil – sisal fibre content mixtures with cement content

The OMC increased generally for all the cement contents with increasing sisal fibre content up to 0.5% sisal fibre content. Thereafter there was a general decrease in OMC as the sisal fibre content increased. The OMC increased from 18% to 24.5 % at 0.5% sisal fibre/6 % cement. Upon further increase in the fibre content, the OMC reduced as the sisal fibre content increased. This means that the fibre, which naturally had a high water absorption rate, caused an initial increase in OMC from the plain state of the soil to 0.5% content of the fibre by dry weight of soil and thereafter reduced the OMC with increasing aspect ratio and percentage content. Similar trends were observed by [14, 15] who used laterite soil and black cotton soils respectively

— Unconfined Compressive Strength

The variation of unconfined compressive strength (UCS) of lateritic soil – sisal fibre mixtures with cement for 7 days curing periods is shown in Figure 3. The UCS value for 0% and 2% cement peaks at 0.75% sisal fibre while at 4%, 6% and 8% cement peaks at 0.5% sisal fibre content which correspond to the maximum dry density values peaked at 0.5% sisal fibre. This can be attributed to the fact that at higher percentage of sisal fibre it absorbed the moisture present in the mix meant for cement hydration reaction, thereby reducing the extent of hydration leading to lower strength value.

The peak 7–day UCS values of 1942, 1757 and 2343kN/m^2 were obtained at 4%, 6% and 8% cement from a natural value of 189kN/m^2. These UCS values met the conventional 1720kN/m^2 for adequate cement stabilization of base courses specified by [10]. Prabakar and Srindhar, [14] obtained the highest deviator stress values at 0.75% and at 3.5cm fibre lengths. Santhi and Sayida [15] obtained their peak at 0.50% fibre inclusion.

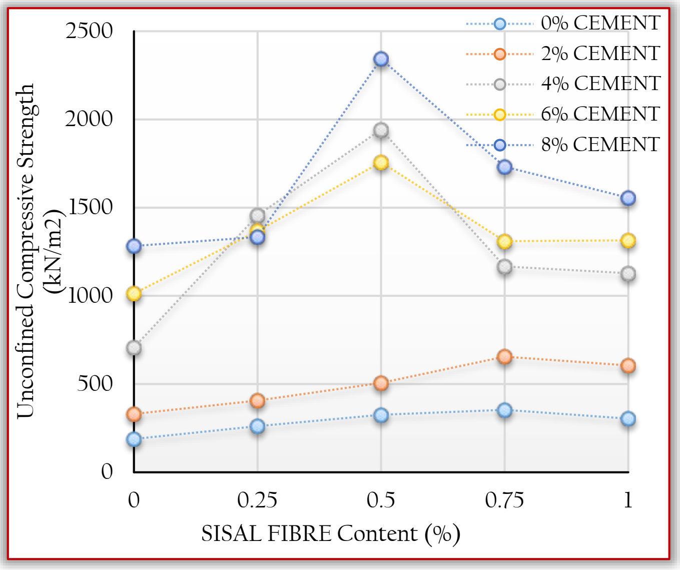

Figure 3: Variation of unconfined compressive strength of lateritic soil –sisal fibre content mixture with cement content

— Regression analysis for unconfined compressive strength

Researchers like [18–19, 13] have successfully used regression models in many geotechnical engineering applications. The regression model (see Eq. (1)) used for this analysis was developed from laboratory results and used for predicting UCS from measured UCS values in the laboratory. Results show that the effect of the several independent variables considered (C, SF, MDD and OMC) on the dependent variable UCS of the treated soil were statistically significant.

The coefficient of determination value (R^2) of 88.9% which was obtained which is equivalent to correlation coefficient (R) value of 94.3% indicates that there is a very strong association between UCS and the independent variables considered.

All the independent variables have positive coefficients in the regression model which indicate that an increase in each of the independent variables will lead to a corresponding increase in the UCS values of the treated soil and vice versa. The possible explanation to this model entails the need to monitor these independent variables for a SF treated lateritic soil with Cement as admixture for use as sub–base/base material or for any geotechnical application.

A plot of predicted UCS values from the model plotted against the measured UCS values measured from the laboratory shows a strong correlation between the UCS values obtained in the laboratory and the predicted values from the regression model using a Third order polynomial relationship with approximate coefficient of determination value (R^2) of 0.889 which was equivalent to correlation coefficient (R) value of 0.943 (see Figure 4).

$$\text{UCS} = -3650.09 + 94.18\text{C} + 400.75\text{SF} + 1677.76\text{MDD} + 41.47\text{OMC} \quad (1)$$
$$R^2 = 88.9\%$$
$$R = 94.3\%$$

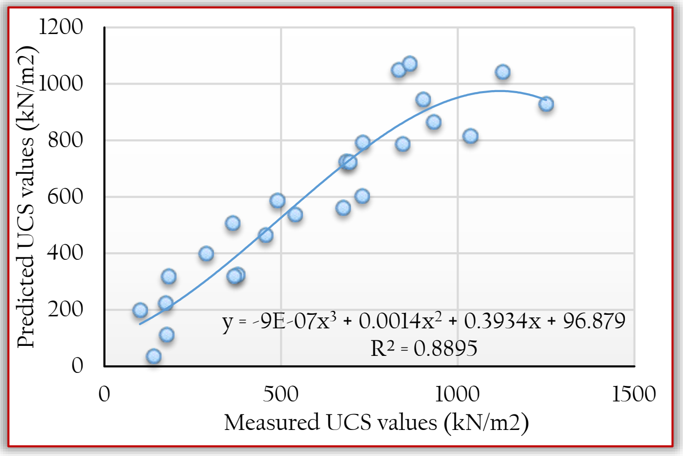

Figure 4: Plot of predicted UCS values against measured UCS values from the regression model

— Reliability assessment on unconfined compressive strength

≡ Influence of unconfined compressive strength on reliability index

The influence of reliability index for UCS of lateritic soil stabilized with cement and treated SF with coefficient of variation in the range of 1–100% is shown in Figure 5–7. Generally, a trend of decrease in the reliability indices was noticed with increase in the coefficient of variation. The reliability index varied linearly with coefficient of variation from 1 to 100%. Reliability index changed significantly which indicate that variation in UCS has major effect on the reliability index for road pavement sub–base materials.

As coefficient of variation changed from 1 to 100%, reliability index for the natural soil computed with 100.57 kN/m² changed from –1.48 to –1.54 (see Figure 5) which indicates that all reliability index obtained were negative indicating failure.

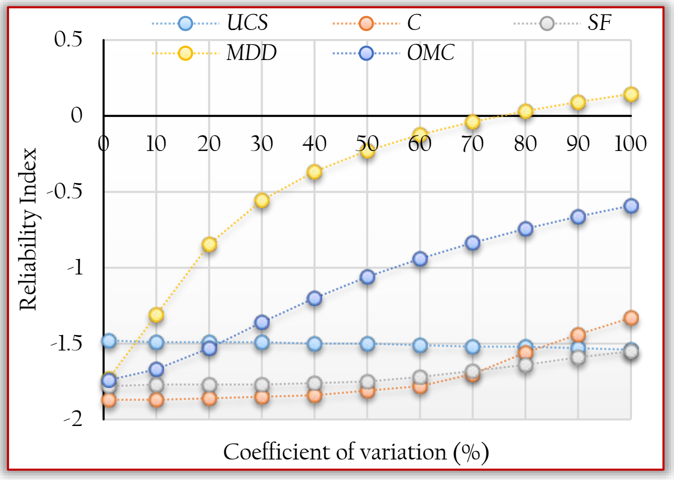

Figure 5: Variation of reliability index with coefficient of variation for unconfined compressive strength for the natural soil

The result was computed using UCS value obtained for the treated but using the standard regulatory minimum requirement of 687–1373 kN/m² for sub–base material of UCS as specified by [20].

The reliability index when computed with 687kN/m² changed from –0.196 to 0.285 (see Figure 6). The reliability index when computed with 1373kN/m² changed from 0.503 to 2.34 (see Figure 7).

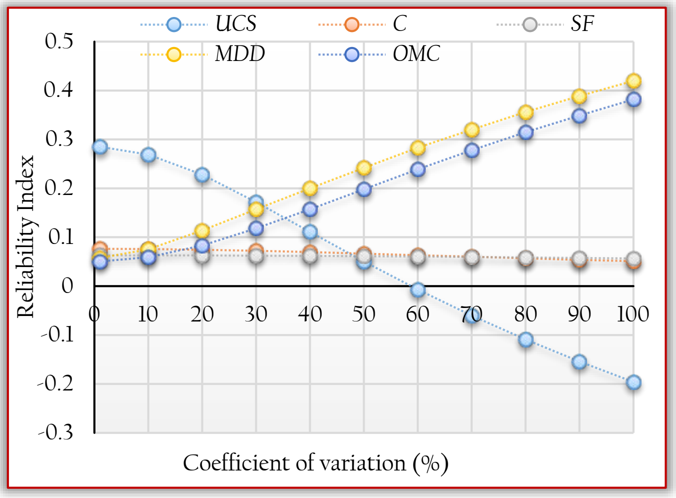

Figure 6: Variation of reliability index with coefficient of variation for unconfined compressive strength of stabilization of lateritic soil with cement and treated sisal fiber computed at 687kN/m²

The significant changes observe in the reliability index values further shows that addition of cement and treated SF has great effect on the UCS value of the treated lateritic soil. The recorded improvement in strength based on laboratory results can be justified with the significant variations in the reliability indices of the treated soil when compared to the untreated soil [13].

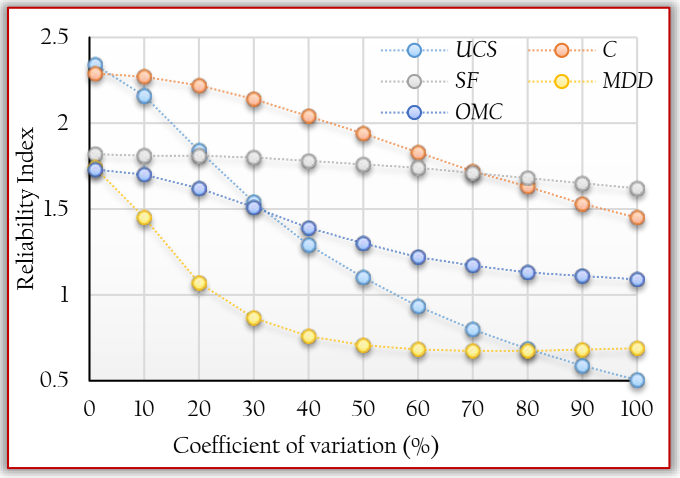

Figure 7: Variation of reliability index with coefficient of variation for unconfined compressive strength of stabilization of lateritic soil with cement and treated sisal fiber computed at 1373kN/m²

Result shows that Cement and SF can greatly improved the geotechnical properties of lateritic soil as indicated by the changes in their reliability index values obtained, also care should be taken in controlling these parameters during filed operation of any geotechnical application.

≡ Influence of cement content on reliability index of unconfined compressive strength

The effect of cement content on reliability index is shown in Figure 5–7. Cement showed a linear decreasing relationship with changes in the coefficient of variation, while the reliability index varied slightly. This result indicates that change in the content of cement has little influence on the reliability index for road sub–base pavement structures. As coefficient of variation increased from 1 to 100%, reliability index values decreased from –1.33 to –1.87 for natural soil computed with 100.57 kN/m² (see Figure 5).

The reliability index when computed with 687kN/m² changed from 0.0509 to 0.0763 (see Figure 6). The reliability index when computed with 1373kN/m² changed from 1.45 to 2.29 (see Figure 7). Similar trend was reported by [2] when he used cement kiln dust which is an indication that the cement is a factor which must be carefully controlled during field compaction for road pavement or any geotechnical studies when lateritic soil – cement –SF mixtures are be used.

≡ Influence of sisal fibre content on reliability index of unconfined compressive strength

The effect of SF content on reliability index is shown in Figure 5 – 7 (with coefficient of variation in the range of 1 – 100%). SF content showed a decreasing correlation with coefficient of variation in the range 1–100%. A slight variation in the reliability index values was noticed with increase in the coefficient of variation, this is also an indication that variation of SF content has little or no influence on the reliability index. As coefficient of variation increased from 1 to 100%, reliability indices varied between –1.55 to –1.78 for natural soil computed with 100.57 kN/m² (see Figure 5).

The reliability index when computed with 687kN/m² changed from 0.0565 to 0.063 (see Figure 6). The reliability index when computed with 1373kN/m² changed from 1.62 to 1.82 (see Figure 7). Result shows that treated soil produced higher reliability indices than the untreated soil (natural soil) which indicates improvement on the UCS of the soil with Cement and SF content.

≡ Influence of maximum dry density on reliability index of unconfined compressive strength

The influence of MDD shows that for natural soil and for reliability index computed with 687kN/m² shows and increase in reliability index with increase in coefficient of variation from 1 to 100% while the reliability index computed with 1373 kN/m² shows a decrease in reliability index with increase in coefficient of variation from 1 to 100% (see Figure 5 – 7).

The increase in reliability index for the MDD indicates that a variation in the MDD value has no drastic effect on the strength value of the soil when used for road pavement sub–base materials. For changes in coefficient of variation from 1 to100 %, Reliability indices increased from –1.73 to 0.145 for the natural soil (see Figure 5).

The reliability index when computed with 687kN/m² changed from 0.0574 to 0.42 (see Figure 6). The reliability index when computed with 1373kN/m² changed from 0.689 to 1.74 (see Figure 7). Treated soil produced higher reliability indices than the natural soil which indicates improvement on the UCS of the soil with Cement and SF content. Similar trend was reported by [2, 21, 19, 13].

≡ Influence of optimum moisture content on reliability index of unconfined compressive strength

The influence of OMC also shows that for natural soil and for reliability index computed with 687kN/m² shows and increase in reliability index with increase in coefficient of variation from 1 to 100% while the reliability index computed with 1373 kN/m² shows a decrease in reliability index with increase in coefficient of variation from 1 to 100% (see Figure 5 – 7).

The reliability index significantly increased with coefficient of variation. It is evident that changes in the OMC influenced UCS significantly as clearly shown in the changes in reliability index.

Similar trend was reported by [2, 21, 19, 13] which is an indication that the OMC is a factor which must be carefully controlled during field compaction for road pavement or any geotechnical studies when lateritic soil – Cement – SF mixtures are used. As coefficient of variation increased from 1 to 100%, reliability indices varied between –0.591 to –1.74 for natural soil computed with 100.57 kN/m² (see Figure 5).

The reliability index when computed with 687kN/m² changed from 0.0503 to 0.382 (see Figure 6).

The reliability index when computed with 1373kN/m² changed from 1.09 to 1.73 (see Figure 7).

— Comparative sensitivity analysis of the reliability indices of the soil variables

A comparative sensitivity analysis of the reliability indices of the laboratory–based model used was compared with the variation in the independent soil parameters considered (C, SF, MDD and OMC) to determine their effect on UCS. Generally, reliability indices varied for all the variables considered with MDD and OMC having more significant effect on the UCS when compared with C and SF. C and SF content have marginal effect on the UCS of the treated soil. From Figure 6 and 7 it could be observed that the increase in reliability indices was more pronounced for MDD and OMC which are also related to the UCS of the soil evaluated. The result of untreated soil (see Figure 5), low and negative reliability indices were recorded for all the soil variables considered. Higher reliability indices recorded for the treated soil depict improvement in the UCS of the soil.

Similar trend was reported by [13]. Based on this results, good quality control of these variables is vital in the field in order to achieve good road pavement.

— Stochastic model assessment of acceptable safety index for unconfined compressive strength

Results of reliability index obtained for UCS of the soil are shown in Table 6–8 for reliability index computed with 100.57 kN/m², 687kN/m² and 1373 kN/m². NKB Report [22] categorically stated that a minimum safety index value of 1.0 and maximum of 2.5 is recommended for serviceability limit state design of structural components. Table 6 shows that the UCS value did not falls within the acceptable range for serviceability limit state.

Table 7 also shows that for a lower value for UCS for sub–base material recommended by [20] (value of 687kN/m²) despite having some positive safety index does not attain the minimum safety index of 1.0 for serviceability limit state.

Table 6. Stochastic model assessment of acceptable safety index for natural soil computed with 100.57 kN/m²

S/N	Variables Factors	Beta Value	Acceptable Range of COV (%)
1	UCS	–1.48 to –1.54	NIL
2	C	–1.33 to –1.87	NIL
3	SF	–1.55 to –1.78	NIL
4	MDD	–1.73 to 0.145	NIL
5	OMC	–0.591 to –1.74	NIL

Table 7. Stochastic model assessment of acceptable safety index for treated soil computed with 687 kN/m²

S/N	Variables Factors	Beta Value	Acceptable Range of COV (%)
1	UCS	–0.196 to 0.285	NIL
2	C	0.0509 to 0.076	NIL
3	SF	0.057 to 0.063	NIL
4	MDD	0.058 to 0.420	NIL
5	OMC	0.050 to 0.382	NIL

The upper limit of UCS value of 1373 kN/m² stipulated by [20] (see Table 8) on the other hand met the requirement of safety index of 1.0 for serviceability limit state but when the coefficient of variation is been varied from 1 to 50 %. This shows that stabilized lateritic soil with Cement and SF can be used to design a geotechnical application when serviceability limit state is been considered.

Table 8. Stochastic model assessment of acceptable safety index for treated soil computed with 1373 kN/m^2

S/N	Variables Factors	Beta Value	Acceptable Range of COV (%)
1	UCS	0.503 to 2.34	1 to 50 %
2	C	1.45 to 2.29	1 to 100 %
3	SF	1.62 to 1.82	1 to 100 %
4	MDD	0.689 to 1.74	1 to 20 %
5	OMC	1.09 to 1.73	1 to 100 %

CONCLUSIONS

The cement stabilization of lateritic soil classified as A–7–6 (10) or CL using treated sisal fibre considered in this study shows that a specimen treated with maximum 0.5% sisal fibre/4% cement content when compacted with the standard Proctor energy yielded 7–day UCS values of 1942kN/m^2. The UCS value met the conventional 1720kN/m^2 criterion for adequate cement stabilization of base courses specified by TRRL [10] for 7 days curing. The regression results shows that there is a strong relationship between the predicted UCS value and the Laboratory UCS value given correlation coefficient (R) value of 0.943.

The reliability analysis carried out indicates that the reliability indices were more pronounced for MDD and OMC which are also related to the UCS of the soil evaluated. Model 1 produced successful result in COV range 1 – 50 % that can be used to predict field UCS of lateritic soil stabilized with Cement and sisal fibre for base and sub–base materials for pavement structures.

Based on the results obtained, the optimum blend of 4% Cement/0.5 % Sisal Fibre treatment on lateritic soil is recommended for used as based material compacted using Standard Proctor energy. Further studies should consider durability analysis and California bearing ratio test on the soil to further assess their strength properties.

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[1.]Ionuţ-Ovidiu MARCOSANU, [2.] Valeriu-Gabriel GHICA,
[3.]Mircea-Ionuţ PETRESCU, [4.]Gheorghe IACOB

PROCESSING OF ALUMINUM CABLES USING THE ELDAN INSTALLATION

[1-4.]Faculty of Materials Science and Engineering, University POLITEHNICA of Bucharest, Bucharest, ROMANIA

Abstract: Even though there are many types of cables that end up in recycling centers, regardless of their nature or shape, they follow approximately the same processing steps: shredding - magnetic / electrostatic / gravimetric separation - granulation. After granulation and separation, the metal fraction obtained in the Eldan installation has a purity of minimum 99.1%. The obtained material was chemically characterized on site by means of X-ray fluorescence spectrometer (Portable XRF Thermo Scientific Niton XL3t). The obtained granules were thermally processed by remelting and refining and subsequently after casting and solidification of the metal followed a drawing process to obtain cables of different sizes (Ø7.6; Ø6.1; Ø5.6; Ø5.1). The samples taken were analyzed compositionally and with an optical microscope. Most of the samples corresponded to the required requirements, but there were also defective samples - oxide films, inclusions and overlapping material.
Keywords: productivity, ELDAN, aluminum wire, recycling

INTRODUCTION

Aluminum is the most abundant metallic element in the earth's crust and the third most abundant chemical element. Bauxite is the ore from which more than 95% of world aluminum production is extracted. According to their aluminum and iron content, bauxites can be white (very rich in Al_2O_3, 60-70%), red (rich in Fe_2O_3, 20-25% and poorer in Al_2O_3, 40-60%) and gray (poorer in Fe_2O_3 and Al_2O_3 than the red ones, but richer in SiO_2).

Currently the most common technology for obtaining alumina is based on the Bayer process.

The Bayer process for extracting alumina from bauxite is carried out in three stages:

- obtaining sodium aluminate by chemical reaction between bauxite aluminum oxide and caustic soda;
- decomposition of the aluminate solution into aluminum hydroxide and sodium hydroxide, under certain conditions of temperature, concentration, reaction time and addition of primer (fresh aluminum hydroxide);
- calcination of filtered aluminate hydroxide at high temperatures to remove the water of crystallization and obtain calcined alumina.

— The principle of obtaining aluminum from alumina

Under industrial conditions, aluminum is obtained by melt electrolysis of alumina dissolved in an electrolyte at about 950°C.

The technological process of manufacturing aluminum has two distinct phases:

- processing of raw materials with aluminum content in order to obtain alumina;
- electrochemical separation of aluminum from alumina by electrolysis.

The electrolyte consists of a mixture of sodium fluoride (NaF) and aluminum fluoride (AlF_3) which is in a proportion similar to that corresponding to cryolite ($AlF_3 \cdot 3NaF$).

The electrolysis process is carried out by passing a high current of direct current - usually up to 700,000 A - and under low voltage of about 4 V. The installation in which the aluminum deposition process takes place is called an electrolysis cell or tank.

— Aluminum recycling

Recycling aluminum means 95% less energy than producing primary Al. Recycling began in the 1900s, expanded during World War II, and exploded with the use of cans for bottling.

Sources of recycled Al include: airplanes, cars, bicycles, boats, cooking utensils, cables, metal joinery, etc. Even though used Al beverage containers make up the bulk of recycled waste, there are many other components that are suitable for this operation, such as electrical cables.

Of course, in the market economy the possibility of recycling is directly related to the recovery of residual values, in the sense that it will be directly proportional to the willingness to make efforts for such a process. From the perspective of recycling, aluminum and its alloys are exceptional materials, as the number of recycling without significant quality deterioration is indefinite.

Almost all the energy absorbed in the first stage of metal production, more precisely 95%, is preserved in the material and ready to be reused at the time of melting. As a result, the production of one kilogram of recycled aluminum has an energy requirement equivalent to 5% of the production of one kilogram of electrolytic metal.

For these reasons, the market exploitation of aluminum waste deserves to be taken into account and is economically viable. We can describe the virtual cycle of light metals, which is frequently described as an energy bank, given that the energy absorbed during production is conserved, which is subject to optimization processes over the years. Energy is saved during manufacturing processes and can be recovered during recycling.

The end result is that the use of secondary aluminum provides not only huge savings in resources, but also an ecological benefit, with reduced emissions compared to the electrolytic process and the guarantee that the material will re-enter a production cycle, therefore without the risk of an ecological impact.

It is estimated that in 2016, in Italy alone, at a production of approximately 600,000 tons, the greenhouse effect was reduced by reducing CO_2 emissions by over 6.5 million tons and saving the energy equivalent of over 2.3 million tons of oil. It should be recalled that in Italy, aluminum producers, especially manufacturers and users of packaging, have complied with national and European provisions and the Consortium of Aluminum Packaging (CiAL), which offers guarantees to companies operating in the process of recovery and recycling and which, by the development of post-consumer recovery of aluminum, contributes to the exploitation of the intrinsic characteristics of the metal in the context of a competitive system.

Also, in the period 2013-2014, the European Union devoted itself very much to the debate on recycling, from which arose the opportunity to complete the existing directives with a new approach, focused on materials rather than flat products at the end of life cycles. In this phase, aluminum has excellent opportunities from the perspective of sustainable development from an economic, social and ecological point of view, given its intrinsic properties that make it advantageous in use, in terms of resource conservation and environmental protection.

Within SC Remat Bucharest South SRL, approximately 1000 tons of aluminum are recovered annually from different types of waste. With the help of the Eldan installation, the cables from different electrical installations are processed, finally obtaining aluminum granules.

In 2021, the aluminum market was growing (the variation of the aluminum stock exchange prices is shown in the figure 1), Remat Bucharest South managing to process 335.22 tons of Aluminum cables on the Eldan installation.

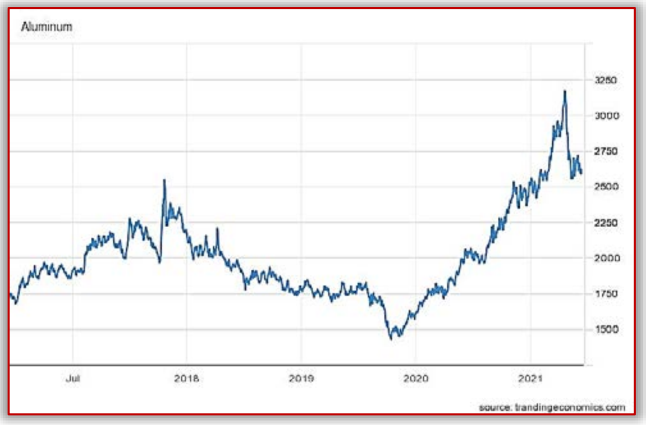

Figure 1. Stock exchange prices for aluminum [4]

Following their processing, 149.19 tons of aluminum granule were obtained. The granule brought revenues amounting to 237,361 euros.

MATERIALS AND METHODS

There are many different types of cables with a variety of different material compounds: flexible wire cables, household cables, power cables, underground cables, copper and aluminum cables, and high-voltage cables with V-PE sheaths. Inherently, the strands in the core are valuable as a secondary raw material due to the high metal content. In most cases, the individual materials in the cable or flexible wire adhere very closely to one another. To expose and process these fractions requires recycling technology that produces small grain sizes for optimum separation.

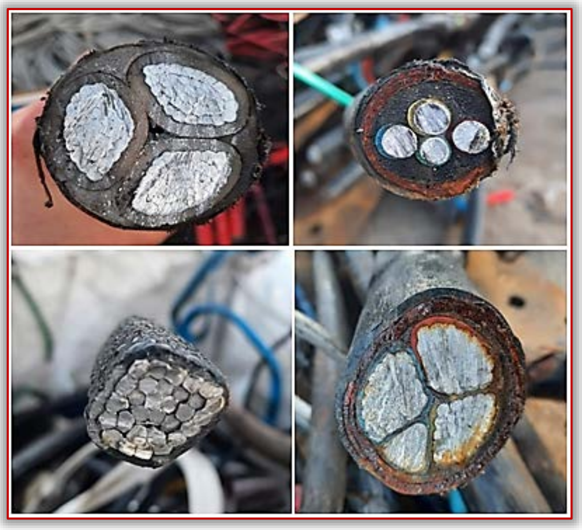

Figure 2. Different types of aluminum cables

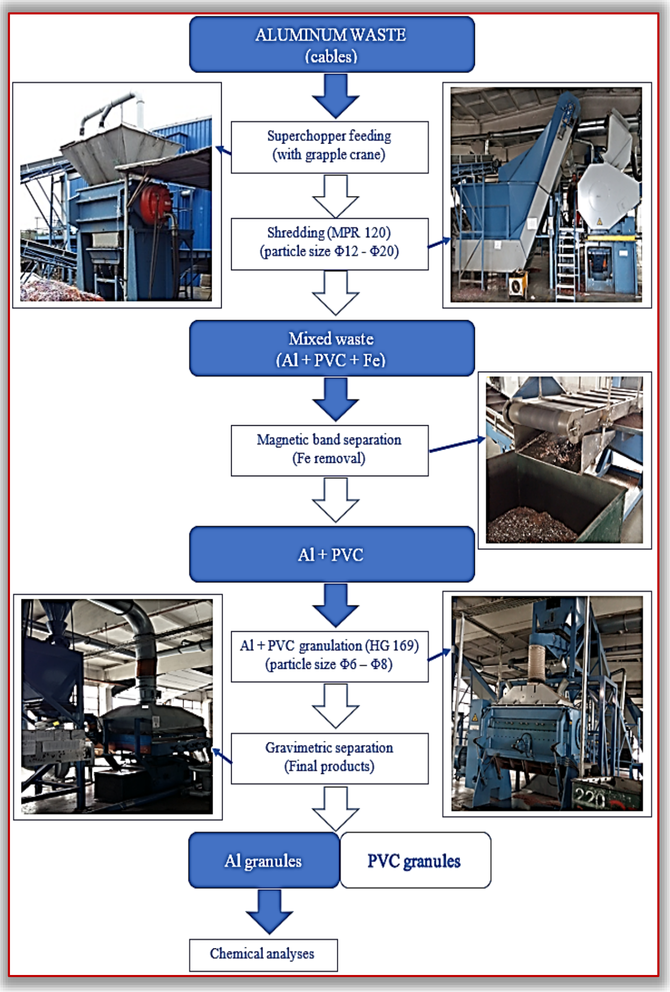

Figure 3. Technological scheme of the process

The Eldan installation has shown greater flexibility than expected in terms of the materials it can process. Today, the system can also successfully process used tires. The waste of Al cables (Figure 2) is loaded with the graft type machine in the Super Chopper tank where they are chopped to dimensions that allow their feeding in the Shredder. A conveyor belt system is used to transport the material. At the exit of the Shredder the ferrous fraction is collected by means of the magnetic belt, and the Al fraction is collected at the end of another conveyor belt.

The cables were processed according to the technological flow shown in Figure 3.

The material introduced on the Eldan installation has the following technological flow: it is chopped, granulated, after which it is electrostatically separated. Electrostatic separation is based on the difference between the conductivity of the materials that make up the mixtures of ground materials in cables: conductive metals and non-conductive plastics.

The principle of operation consists in loading with electric charges for a certain time the surfaces of non-conductive materials, either by ion or electron bombardment, or by friction and thus, the charged particles can be separated from the other uncharged (non-conductive ones).

The particles move in a field generated by an electrode of direct current and high voltage (over 35 kV), being loaded with electric charges. The conductors will be unloaded immediately and will be removed from the drum under the action of centrifugal force. The non-conductive particles will adhere to the drum, being maintained by their own load, and from here they will be directed to another area by brushing.

In 2020, approximately 500 tons of aluminum cables were processed on the Eldan installation, from which: Al granules - 114 tons (Figure 4); Fe - 42 tons; PVC - 344 tons.

Figure 4. Al (Ø8) cable processing sieve and aluminum granules

The obtained material was analyzed to determine the constituent elements by means of X-ray fluorescence spectrometer (Portable XRF Thermo Scientific Niton XL3t).

Al granules processed at Remat Bucharest South were shipped to processing units in order to obtain wire drawn from Al. After processing (melting + correction of the composition, see table), drawn wires of a large dimensional variety were obtained - Ø7.6; Ø6.1; Ø5.6; Ø5.1.

The drawn wire samples were analyzed under an optical microscope, at room temperature, without attack, at magnifications of x25 and x200 and also in terms of chemical composition to determine the purity of Al wires.

Most of the samples corresponded to the required requirements, but there were also defective samples (oxide films, inclusions and overlapping material).

RESULTS AND DISCUSSIONS

The aluminum processed in the Eldan plant, resulting in the form of granules, was analyzed compositionally on the spot using the portable device Niton 3XL3t.

Table 1. Chemical compositions of the recovered material

Element	CC Top	CC2 Middle	CC3 Base	Mean
Al	95.89	96.18	95.96	96.01
Si	2.440	2.420	2.390	2.417
Fe	0.598	0.633	0.622	0.618
Zn	0.056	0.055	0.055	0.055
Zr	0.003	0.003	0.003	0.003
Sb	0.026	0.028	0.032	0.029
Pb	0.006	0.009	0.008	0.008
Total	99.019	99.328	99.070	99.139

Three analyzes were performed from several areas of the material pile (top, middle, base) averaging these values.

The constituent elements by means of X-ray fluorescence spectrometer (Thermo Scientific Niton XL3t) were presented in Table 1.

After reprocessing the Al granules by melting - refining - drawing processes to obtain different types of cables, which will be reused mostly for the same applications, the purity of the material was established by performing standardized chemical analyzes. The chemical composition of recycled aluminum in the form of cables is shown in Table 2.

Table 1. Chemical compositions of Aluminum cables

Elem.	S1	S2	S3	Mean
Cu	0.0033	0.0035	0.0036	0.0035
Fe	0.0853	0.0937	0.0911	0.09
Si	0.0495	0.0522	0.0484	0.05
Mn	0.0010	0.0010	0.0010	0.001
Mg	0.0010	0.0010	0.0010	0.001
Zn	0.00484	0.00526	0.00491	0.005
Ni	0.0028	0.0033	0.0029	0.003
Cr	0.0010	0.0010	0.0010	0.001
Ti	0.0010	0.0010	0.0010	0.001
V	0.00198	0.00207	0.00196	0.002
B	0.00701	0.00703	0.00697	0.007
Pb	0.00197	0.00205	0.00197	0.002
Ga	0.0071	0.00697	0.0070	0.007
Al	99.8322	99.8199	99.8272	99.8264
Total	100	100	100	100

Samples were prepared from the defective areas of the drawn cable samples for microstructural analysis. Various material defects were highlighted: oxide films (Figure 5b), material overlaps (Figure 5c) and non-metallic inclusions (Figure 5d).

Materials with major defects have been returned to the manufacturing cycle.

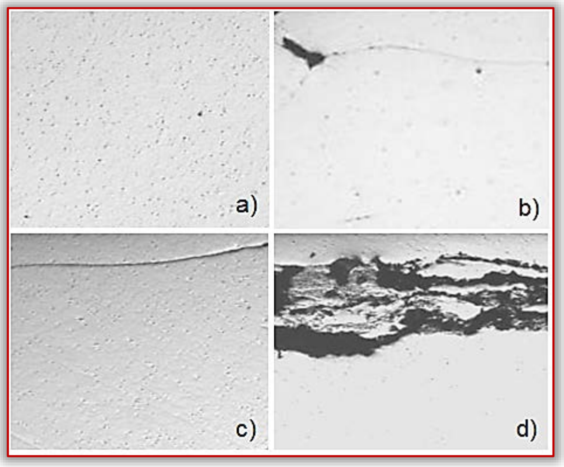

Figure 5. Optical microstructures of analyzed samples:
a) without defects, 25X; b) oxide films, 200X; c) overlaps of material, 25X and d) non-metallic inclusions, 25X

CONCLUSIONS

Recycling aluminum means 95% less energy than producing primary Al. Cable recycling not only preserves and conserves valuable resources; it also significantly reduces energy consumption. Recycling the metals in cables and wire requires only a fraction of the energy that must be expended to initially mine and extract ore. The use of secondary aluminum provides not only huge savings in resources, but also an ecological benefit, with reduced emissions compared to the electrolytic process and the guarantee that the material will re-enter a production cycle.

After reprocessing the Al granules by melting - refining - drawing processes to obtain different types of cables, which will be reused mostly for the same applications, the purity of the aluminum was 99.82%. Most of the products obtained (electrical cables) were made in the required parameters, with some small exceptions, where the defects in the material - oxide films, inclusions and overlapping material - returned it in the manufacturing cycle.

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[1.]Mirko DOBRNJAC, [1.]Nemanja KORUGA, [2.]Nemanja DOBRNJAC

WORKING SUBSTANCE INFLUENCE ANALYSIS ON IRREVERSIBILITY IN HEAT PUMP COMPONENTS

[1.]University of Banja Luka, Faculty of Mechanical Engineering, Bulevar Stepe Stepanovića 71, Banja Luka, BOSNIA & HERZEGOVINA
[2.]University of Belgrade, Faculty of Mechanical Engineering, Kraljice Marije 16, Belgrade, SERBIA

Abstract: The heat pump is a device that raises thermal energy from a lower to a higher temperature level, while consuming energy. Thermodynamic analysis of the heat pump allows us to determine the interdependence of losses in particular parts of the device, as well as the impact of each local irreversibility on the efficiency of the device as a whole. The efficiency of a heat pump is influenced by the thermodynamic parameters of its individual parts: compressor, condenser, throttle valve and evaporator. In this paper, a comparison of different substances which are used as working fluids in heat pumps is analyzed, so as their influence on the irreversibility of heat pump components. The calculation was performed using the EES software package (Engineering Equation Solver) which is used for numerical modelling of thermodynamic systems, process optimization and creating process diagrams.
Keywords: heat pump, efficiency, working fluids, EES software package (Engineering Equation Solver)

INTRODUCTION

World trends in the rational use of renewable energy with the application of new and advanced technologies such as: wind farms, solar systems, heat pumps etc. aim to improve sustainable development and greater environmental protection. The latest works on the development of the heat pump has given significant results. In the past, the ratio of invested electricity and obtained heat energy, using a heat pump, was 1:2, while today these ratios have been brought to 1:6, all thanks to significant investments in the development of this energy resource.

Heat pumps work on the principle of processes in which the heat source is at a lower, and the heat sink at a higher temperature level. The beneficial effect of these devices is the heat taken from the cycle to the heat sink or the heat added into the cycle from the heat source depending on whether they are used for heating or cooling. A heat pump is a device whose basic function is heating with heat that is removed from the cycle. According to the energy balance, the amount of heat dissipated to the heat sink at a higher temperature level, is the sum of the mechanical work added from the environment and the heat added from the heat source at a lower temperature level. [1] [2]

The efficiency of the heat pump is expressed by the COP (*Coefficient of Performance*):

$$COP = \frac{Q_{cond}}{W_{comp}} \quad (1)$$

Q_{cond} – the amount of heat removed from the working substance to the heat sink (beneficial effect)

W_{comp} – work expended to drive the compressor

Changes in states of the working substance in the heat pump circular process according to Figure 1:

1. evaporation 5 – 1,
2. compression 1 – 2,
3. cooling 2 – 3,
4. condensation 3 – 4,
5. expansion 4 – 5

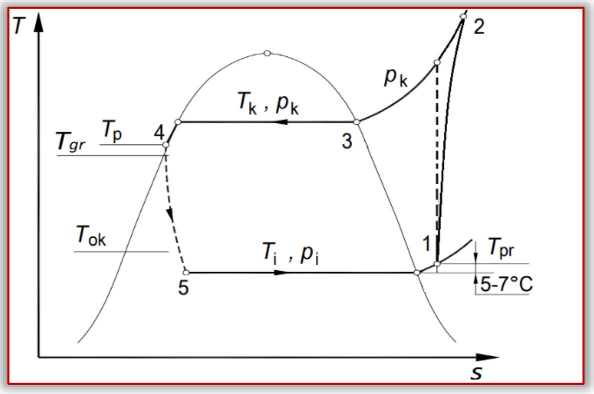

Figure 1. Representation of the real process of the heat pump in the T–s diagram [3]
T_{pr} – temperature of superheated steam before entering the compressor;
T_{gr} – temperature of the space being heated; T_p – subcooled condensate temperature;
T_{ok} – ambient temperature; T_k, p_k – temperature and pressure of condensation;
T_i, p_i – temperature and pressure of evaporation

Heat pumps are systems that transfer heat energy from a lower temperature level (water, earth, air) to a higher temperature level while performing the role of room heating. The heat pump system consists of a heat source circuit, a working substance circuit and a heat sink circuit as shown in Figure 2.

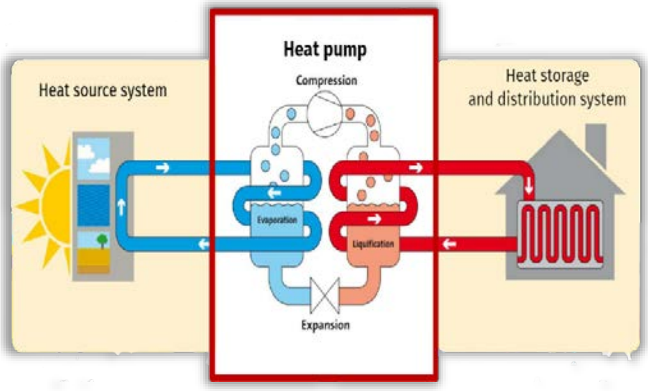

Figure 2. Operation principle of the heat pump

The working substance (working medium) in the heat exchanger (evaporator) takes energy from the heat source, during which it transforms from liquid to vapor. In order to be able to transfer heat to the consumer (in heating mode), we need to increase the pressure and temperature of the working substance, which is achieved by compression. Before entering the compressor, the steam is slightly overheated to temperature T_{pr} in order to avoid the possibility of the liquid phase entering the compressor and to prevent the occurrence of a water hammer.

At a temperature higher than the sink temperature, the working substance is able to transfer heat to the sink in the exchanger (condenser) where it returns to liquid phase (condenses). In order to bring the evaporating pressure back, the working fluid is led from the condenser to the expansion valve, where its pressure is reduced, thus closing the circular process and repeating the procedure.

It is obvious that heat pumps transfer heat energy from a body of lower to a body of higher temperature, so there is a question does this contradict the second law of thermodynamics which says that heat spontaneously passes from a warmer to a cooler body. The answer is no, heat pumps do not contradict the second law of thermodynamics due to the nature of heat pump processes and the energy consumption in the compressor. By compression, in addition to pressure, the working substance also increases the temperature, which must be higher than the temperature of the heated medium, thus enabling the spontaneous transfer of heat from a warmer to a cooler body (the second law of thermodynamics is satisfied when exchanging heat in a condenser). By expansion, the working substance temperature is decreased below the temperature of the heat source, so that the evaporator also enables the spontaneous transfer of heat from a warmer body (source) to a cooler body (working substance). We can say that heat pumps transfer heat from a cooler to a warmer body at a macro–level, but at a micro–level they still transfer heat from a warmer to a cooler body, all in accordance with the second law of thermodynamics.

The real process differs significantly from the ideal, and this irreversibility of the real process can be shown by exergetic analysis.

The goal of exergy analysis is to determine which components of the cycle have the greatest irreversibility and to discover which components need to be improved, aiming towards an improvement to the whole system. The term of irreversibility of the system represents the loss of energy in the cycle, i.e. many unnecessary but inevitable losses due to friction, etc. in the operation of the system. The smaller the value of irreversibility, the closer the system is to the ideal cycle. [4]

The paper analyzes the behavior of the system with modifications of important parameters: dynamic viscosity η, thermal conductivity λ, density ρ, specific heat capacity c_p, velocity w, etc. Energy losses during the flow and the value of the heat transfer coefficient depend on a number of these parameters.

By choosing a refrigerant and changing the temperature of condensation, we influence the heat transfer coefficient and the flow losses, and thus the irreversibility or efficiency of the heat pump as a whole. [5]

GOAL

It is necessary to analyze the influence of different working substances that are used in heat pumps on the efficiency of the system, i.e. their influence on the magnitude of energy losses in individual components: compressor, condenser, expansion valve and evaporator. A simulation calculation was performed for five working fluids to conclude which working fluid is the most cost–effective, which requires the lowest mass flow with the highest heat/energy transfer.

The calculation was performed during the analysis of the heat pump heating system, a building with dimensions of 11 x 10 x 3 m, asuming adding 75 W/m^3 of heat flow to maintain a room temperature of 20°C, at an outdoor temperature of –5°C. The heat pump uses one of the five fluids as the working fluid (refrigerant) R134a, R123, R600a, R152a i R717. The compressor sucks in dry saturated steam at a temperature of –10°C and compresses it isentropically to the pressure of condensation, assuming the efficiency of the compressor from 0,7 to 1. In the condenser, steam is completely condensed and the condensate is subcooled by 5 °C. The calculation was performed for the temperature of condensation at 40 °C. [6].

EXAMINATION RESULTS AND EXERGY ANALYSIS

One of the indicators of the degree of imperfection of the real cycle is the difference between the maximum possible and the actual work in the cycle and is known as irreversibility.

$$Ir = T_0 \Delta S_{Ir} \tag{2}$$

This is often known as the Gouy–Stodola rule.

The rule can also be applied to individual (non–cyclic) processes that take place in individual parts of a complex plant (heat pump). Thus, the thermodynamic analysis is enriched with a new idea, which enables the evaluation of energy transformations. [7]

Irreversibility in the compressor:

$$Ir_{comp} = q_m \cdot T_{amb} \cdot (s_2 - s_1) \ [\mathrm{W}] \tag{3}$$

Irreversibility in the condenser:

$$Ir_{cond} = q_m \cdot T_{amb} \cdot (s_3 - s_2) + \frac{T_{amb} \cdot \phi_{23}}{T_{room}} \ [\mathrm{W}] \tag{4}$$

Irreversibility in the expansion valve:

$$Ir_{exp.valve} = q_m \cdot T_{amb} \cdot (s_4 - s_3) \ [\mathrm{W}] \tag{5}$$

Irreversibility in the evaporator:

$$Ir_{evp} = q_m \cdot T_{amb} \cdot (s_1 - s_4) - (\phi_{23} - P_{12}) \ [\mathrm{W}] \tag{6}$$

≡ q_m – mass flow of working substance
≡ T_{amb} – ambient temperature
≡ T_{room} – room temperature
≡ ϕ_{23} – heat flow for room heating
≡ P_{12} – compressor drive power
≡ s – entropy of numbered states

The overall results for the different working fluids are shown in the diagrams and calculated using EES (Engineering Equation Solver) software package. [8]

The following diagrams show a comparison of the change in irreversibility of the heat pump components: compressor, condenser, evaporator and expansion valve for five selected working substances and for the temperature of condensation T_{cond} = 40 °C. These diagrams help to select the most optimal working fluid for the heat pump system and the given task parameters, and also give information about quality of the working fluids.

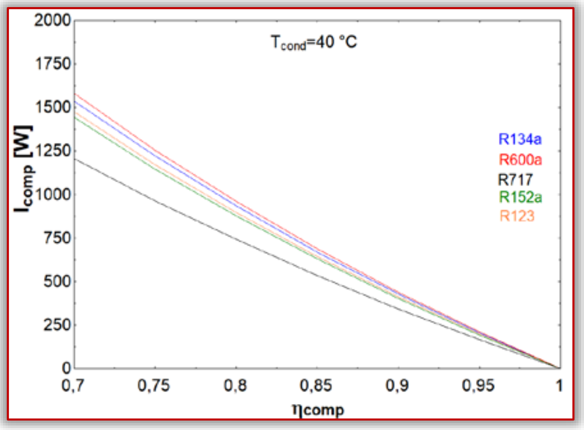

Figure 7. Comparison of compressor irreversibility lines for different working fluids
I_{comp} – irreversibility of the compressor; η_{comp} – compressor efficiency

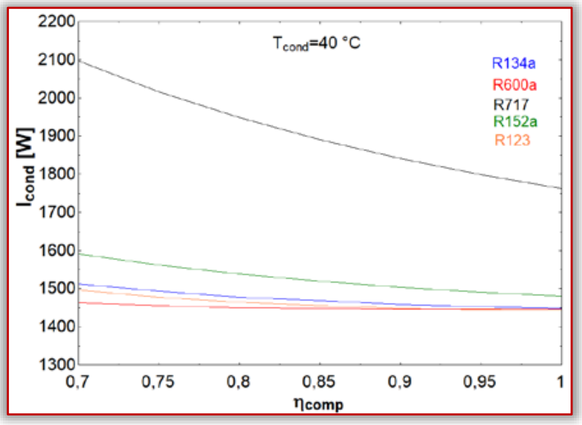

Figure 8. Comparison of condenser irreversibility lines for different working fluids
I_{cond} – irreversibility in the condenser; η_{comp} – compressor efficiency

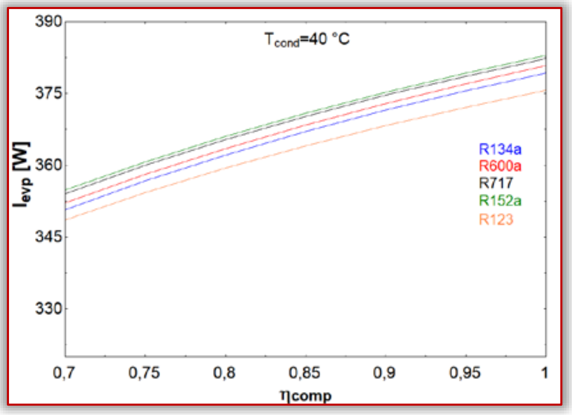

Figure 9. Comparison of evaporator irreversibility lines for different working fluids
I_{evp} – irreversibility in the evaporator; η_{comp} – compressor efficiency

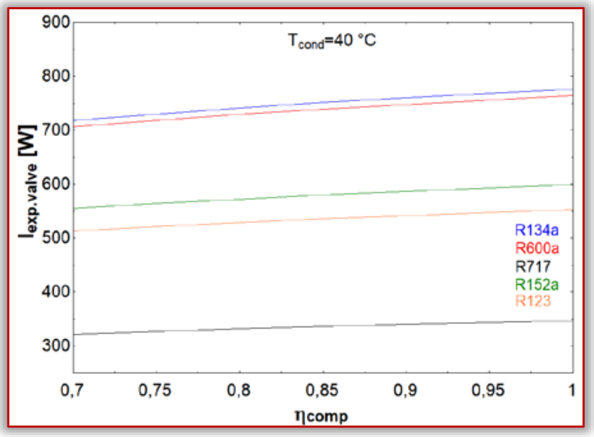

Figure 10. Comparison of expansion valve irreversibility lines for different working fluids
$I_{exp.valve}$ – irreversibility in the expansion valve; η_{comp} – compressor efficiency

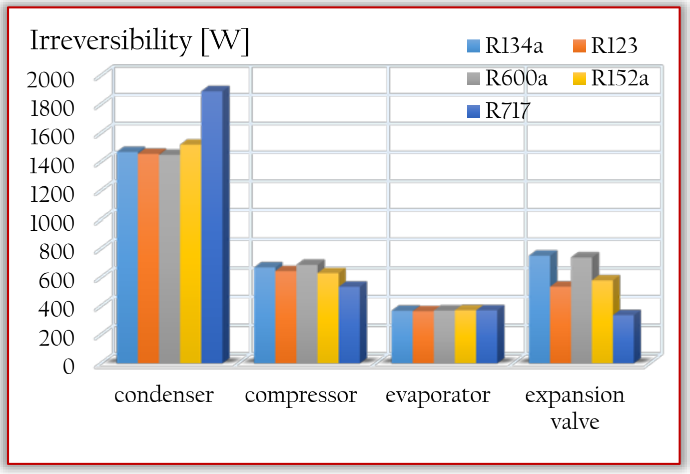

Figure 11. Comparison of the amount of irreversibility in heat pump components for different working fluids

CONCLUSIONS

The exergetic analysis of individual components of the heat pump has shown that most of the energy is lost in the condenser and that this energy loss increases with an increment of the temperature of condensation. From the diagram, it is easy to see that the irreversibilities in the condenser, compressor and expansion valve increase with the increment of the temperature of condesnsation, while the irreversibility in the evaporator decreases with the same increment. When it comes to the influence of compressor efficiency on the irreversibility in heat pump components, it has been shown that with the increment of compressor efficiency (which depends on the type and manufacturer) the irreversibility in condensers and compressors decreases, and the irreversibility in evaporators and expansion valves increases.

In the compressor irreversibility comparison diagram (Figure 7) for all five working fluids, R600a proved to be the worst, because the irreversibility or energy loss, was the highest, and working fluid R717 proved to be the best.

When it comes to the irreversibility in the condenser, the situation is different, the refrigerant R717 proved to be the worst, because the irreversibility is the greatest, whereas

R600a proved to be the best. In the evaporator, refrigerant R152a proved to be the worst because with use of that refrigerant, the irreversibility would be the greatest, while R123 proved to be the best. In the working fluid comparison diagram in terms of irreversibility in the expansion valve (Figure 10), refrigerant R134a proved to be the worst, and R717 proved to be the best.

Finally, the total irreversibility diagram (Figure 11) for the given parameters and selected working fluids shows that refrigerant R134a is the worst due to the highest value of the total irreversibility, and R123 the best. Due to different physical properties, densities and viscosities, the analyzed working substances have different effects on energy loss, so based on the given analyzes, in terms of irreversibility, the choice of a refrigerant has been facilitated.

The analysis was performed for a virtual building, whereas the data for the dimensions of the building, the temperature in the object, the outside temperature and the heat flux given by the heat pump are based on real values.

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[1.]Alaeddine KAOUKA, [1.]A. BENSALEM

DUAL PHASE α + β FORMED IN Ti–6Al–4V TITANIUM ALLOY AND ITS MECHANICAL CHARACTERIZATION

[1.] Laboratoire de Sciences Appliquées et Didactiques, Ecole Normale Supérieure of Laghouat, Laghouat, ALGERIA

Abstract: In this study, the formation of dual phase α + β in Ti–6Al–4V titanium alloy has been described. The microstructure of α + β dual phase was achieved via a heat treatment. Scanning electron microscopy and X–ray diffraction amounts were achieved to reveal the microstructural evolution and to confirm the phase constitution during the decomposition. The detailed microstructure of α + β phase was observed using transmission electron microscopy. The microstructural features included irregular shaped variants, dense and fine twinning with width about 25 µm. The microstructure of α + β dual phase inbred the characteristics of the microstructure of α phase. Moreover, only a specific variant combination of the decomposed α and β phases was observed. Crystallographic orientation of the decomposed α + β phase was similar to that of the initial β phase. These results indicated the existence of a strict variant selection rule between α and β phases.
Keywords: Microstructure, Ti–6Al–4V titanium alloy, mechanical characterization, X–ray diffraction

INTRODUCTION

The formation of microstructures from the high temperature β domain is studied for various titanium alloys. Phase transformation diagrams have been established for various titanium alloys (α + β or metastable β) by electrical resistivity and by synchrotron XRD. For titanium alloys of the α + β or metastable β, depending on the transformation temperatures and the driving force of transformation, various germination and growth mechanisms are involved. At low driving forces of transformation, the germination of the phase is heterogeneous and occurs at grain boundaries followed by wetting along the joint. Lateral growth occurs followed by the formation of α lamella colonies with the same crystallographic orientation as the grain boundary from which they originated. The growth kinetics are strongly controlled by the partition of the solutes between parent phases. The change in the mean composition of the parent phase is also illustrated by the changes in chemical composition characterized by synchrotron XRD during studies under isothermal transformation condition. When the driving force increases, the germination of α grains, with spatial arrangements evolving from a few parallel platelets to individual platelets characteristic of the different α variants in the same β grain. The characteristic sizes of colonies such as intra granular platelets are a function of the transformation temperature; their thickness decreases when the driving force of transformation increases and their number increases [1–2]. For lower temperatures (<500 °C) metastable phases are formed α ' and α ''.

The characterization by XRD synchrotron radiation leading to the lattice parameters phases shows the low partition of the alloying elements. At the lowest temperatures studied, α'' phase has the same lattice parameters as a martensitic phase formed under stress (β metastable alloys). The XRD characterizations confirmed that the transformation sequence is the formation of α'' (then when the temperature increases (as the diffusion of the solutes is more favourable) the α '' phase evolves towards α. The microstructures of these alloys can also be formed during tempering, from the metastable β phase. It is clearly the influence of the heating rate on the microstructures after aging. In fact, the precipitation sequence is a function of this heating rate, with very slow heating rates forming the α '' then α, or α '' then α '. These metastable phases do not precipitate for very fast speeds [3–5]. The α″ martensitic phase is formed via either the cooling of the parent β phase below the martensitic transformation start temperature (Ms) or the application of stress greater than that required for the production of martensitic.

In other hand, titanium (Ti) alloys are considered as the next generation biomedical alloys due to their good biocompatibility. However, these alloys need to improve some their mechanical properties. At for example, high yield strength to safeguard the load–bearing orthopaedic implants against sudden impact. The transformation from the β to α″ phase via heat treatment is accompanied by atomic diffusion, arises via two mechanisms. The first mechanism, hereafter mentioned to as mechanism 1, includes the aging induced decomposition of the β phase [6–7]. This results in the formation of the α″ phase via either the martensitic transformation during aging or the subsequent cooling after aging. The formation of the α″ phase via this mechanism is accompanied by the formation of the β phase with a high content of β stabilizers. The second mechanism, hereafter referred to as mechanism 2, involves the disappearance of the local barriers for α″ formation. The disappearance of the barriers is induced by the short–range atomic rearrangement during aging.

The microstructural formed α″ phase has attracted significant attention. In the literature, it is reported that the crystal structure of isothermally formed α″ continuously changes from β (bcc) to α (hcp) during heating [8] as shown if Fig. 1. The allotropic transformation β ⟶ α (cc ↔ hc) is a martensitic type transformation. In titanium alloys, this transformation occurs by a shear mechanism with athermal germination, possibly followed, in the case of slow cooling (around 2°C/min), thermally activated growth. From the crystallographic point of view, the transformation of the β phase to the α phase can be described by the displacement of atoms in a plane followed by a rearrangement of them perpendicular to the plane: this mechanism is characteristic of reactions without diffusion say displacives. The concentration of beta genic elements is sufficient for the β phase, or metastable at room temperature. This alloy class offers the advantage of power generate a large number of microstructures on condition of mastering the mechanisms fundamentals related to the decomposition of the β–metastable phase.

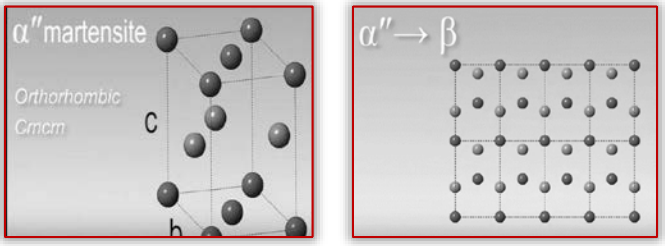

Figure 1. Allotropic transformation β ⟶ α (cc ⟷ hc)

The microstructure and morphology of the α + β dual phases are strongly dependent on the mechanism of formation and the crystallographic conditions between the α and β phases. The microstructure of the α + β dual phases that are formed via the precipitation of the α phase from the supersaturated β phase has been observed in various studies [9, 10]. However, there are limited reports on the microstructure of the α + β phases that are formed via the decomposition of the α″ phase, the α″ phase is formed via martensitic transformation or isothermal aging.

In this study, we try to confirm that good mechanical properties could be achieved by formation of equiaxed fine–grained a phase embedded in þ–matrix. A good combination of high strength and low Young's modulus is necessary for the design and fabrication of biomedical titanium alloys. The response of the mechanical behavior to the microstructural evolution in the alloy was investigated.

The objective of the present study was to explicate the microstructure of the α + β phases that were formed via decomposition (i.e., β ⟶ α″ ⟶ α + β). The crystal structure of the Ti–6Al–4V alloy was investigated using Scaning Electron Microscopy (SEM) and X–ray diffraction (XRD). The microstructures were observing using scanning electron microscopy (SEM). The α + β phases exhibited a unique microstructure comprising fine lamellae, and the existence of a strict variant selection rule between the decomposed α and β phases was observed. The microstructure of the α + β phases that were formed via the decomposition was subjected to crystallographic analysis and discussed based on the results of the systematic microstructural observations.

MATERIALS AND METHODS

This study mainly focused on Ti–6Al–4V titanium alloy. In this alloy, the β phase is metastable at room temperature, and heat treatments suitable make it possible to generate a large number of microstructures on condition to master the fundamental mechanisms linked to the decomposition of the β phase. In order to study the micro–mechanisms responsible for the mechanical properties of this alloy as well as their microstructure. We used different techniques. The titanium Ti–6Al–4V alloy has the theoretical nominal mass composition of 5% aluminum, 4% vanadium, 0.35% Iron, 0.16 oxygen, 0.03 nitrogen and 90.46 % titanium. However, there is a slight dispersion in the composition of the alloy due to the presence of traces of impurities and the exact composition of the alloy is presented in the Table 1.

Table 1. Chemical composition of titanium alloy Ti–6Al–4V

Element	aluminum	vanadium	iron	oxygen	nitrogen	titanium
Weight w.t.%	5	4	0.35	0.16	0.03	90.46

The specimens are deformed post mortem, during in situ tests under SEM. The samples used during the in situ deformation were taken from the head of the deformation. The samples that were used in the manufacture of thin sections observable under a microscope. An electrochemical polishing is then carried out using an electrolytic thinner.

The phase constitution was determined using XRD at room temperature using Cu Kα radiation with Si powder as the reference material. The step size and scanning speed of XRD measurement in this study were 0.0084° and 30 s/step, respectively. The microstructure was observed at room temperature using SEM (TUSCAN) in conjunction with energy–dispersive X–ray spectroscopy (EDS).

The microstructure of the alloy is composed of a centered cubic β matrix, in which both precipitate α nodules or platelets but also the thin α phase lamellae. Solution treatments in α / β domain lead to bimodal structures made up of primary α grain in a β– matrix transformed. The temperature is kept at a lower temperature from 1200 °C, the pre–existing α platelets or nodules grow larger. On the other hand, the very fine ones as coverslips are put back into solution. It is during the subsequent quenching that precipitate new thin lamellae of αs phases, the nodules or platelets of α phase remaining unchanged during this cooling. Income raising the temperature and keeping it at a much lower temperature β then make it possible to grow the lamellae of phase that precipitated during the quenching after dissolving.

RESULTS AND DISCUSSION

The phase constitution of the sample treated Ti–6Al–4V titanium alloy was investigated and presented in Figure 2. The α and β phases were detected via the XRD in the sample that was aged. The XRD measurements detected the presence of a low–intensity peak of the α phase.

The α phase remained because the resolution treatment time was not enough to obtain the single β phase. However, most of the α phase was resolved, and the resolution treatment induced a reverse transformation to the β phase.

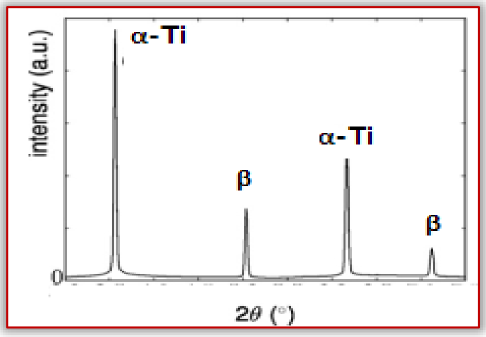

Figure 2. XRD profiles obtained at room temperature

The β phase in the sample directly transformed to the α″ phase via aging at 600°C. Furthermore, the α″ single phase was obtained before the decomposition. Thus indicating that macroscopic phase separation was not necessary for the formation of the α″ phase in the titanium alloy. This result was similar to that in the previous studies in the literature [11–13]. Each peak of the α″ phase shifted with the increase in the aging time. The crystal structure of the α″ phase approached that of the α phase, and the peak shift corresponded to the changes in the crystal structure of the α″ phase. A heating obtain the α + β dual phase via the decomposition of the α phase was determined.

Titanium alloy has a relatively heterogeneous microstructure made up of colonies of α phase, this phase has precipitated in the centred cubic β matrix. Thus, in the microstructure of this alloy, the α phase precipitates in colonies. The α phase precipitates in the form of platelets and the α phase in the form of fine lamellae as shown in Figure 3. The microstructure of the decomposed α + β phases was observed. The sample for SEM is shown in Figure 3. Thus, the sample comprising the decomposed α + β phases was resolution treated.

The micrograph presented shows the presence around the α nodules an area measuring between 20 and 25 μm thick, made up of β matrix and in which no αs lamella phase precipitates. The existence of this zone can be attributed to the difference in stoichiometry between the α and β phases of the alloy. During the precipitation of nodule, the alphagenic elements are absorbed by the hexagonal phase nodule, and therefore pumped from the β matrix.

The precipitation of the α lamellae in this depletion zone during the heat treatment of income becomes difficult, even because of the greater scarcity of alphagenic elements in the immediate vicinity of the nodule. However, it could not be demonstrated directly with the experimental means. In particular, the EDX was not conclusive because it presented measurement uncertainty well beyond the expected local variations in composition. Relationships of orientation observed are equivalent to those determined above for the titanium alloy.

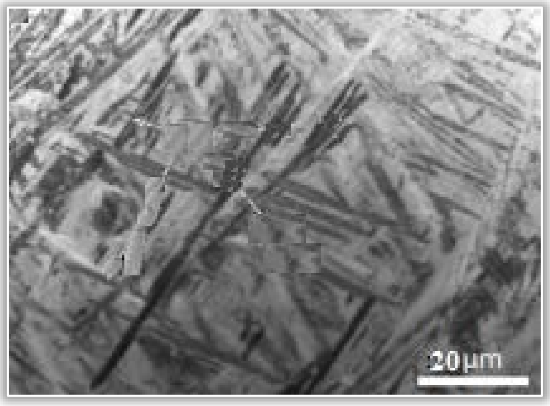

Figure 3. Lamellar microstructure of sample x 1000

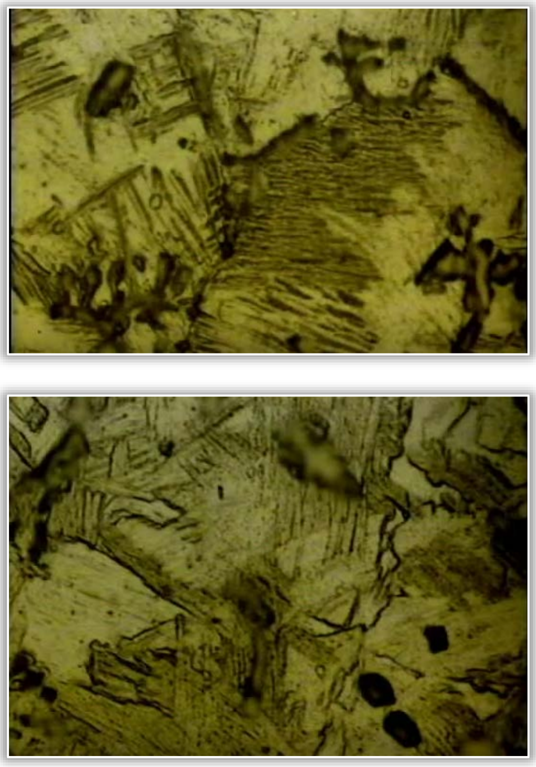

Figure 4. Results of the SEM that were obtained from the same sample and region

CONCLUSIONS

The microstructure of the α + β phases was evaluated in this study. The obtained results were summarized as follows.

- The microstructure of the + β phases inherited the characteristics of the microstructure, it was achieved via a heat treatment.
- Scanning electron microscopy and X–ray diffraction amounts were achieved to reveal the microstructural evolution and to confirm the phase constitution during the decomposition.
- The detailed microstructure of α + β phase was observed using transmission electron microscopy and he microstructural features included irregular shaped variants, dense and fine twinning with width about 25 μm.
- Only a specific variant combination of the decomposed α

and β phases. The crystallographic orientation of the decomposed β phase was similar to that of the initial β phase. These results confirmed the existence of a strict variant selection rule between the α and β phases, and this rule originated from the α″ variant that was formed before the decomposition. The α″ variant determined the parallel plane and parallel direction between the α and β phases.

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[1.]Una MARCETA, [1.]Bogdana VUJIC, [2.]Jelena VUKOVIC

ATMOSPHERIC DISPERSION OF RESUSPENDED DUST FROM LANDFILL A MODELING APPROACH

[1.]University of Novi Sad, Technical Faculty "Mihajlo Pupin" Zrenjanin, SERBIA
[2.]Faculty of Technology Zvornik, University of East Sarajevo, BOSNIA & HERZEGOVINA

Abstract: Data on dust resuspension from solid waste landfills are unavailable in transition countries. Due the complex dust composition, its resuspension could cause serious health effect on surrounding inhabitants. In this paper, influence of resuspended dust from solid waste landfill in medium side city in Serbia on surrounding were modeled. Emission factor for dust resuspension were calculated according to the resent research and dispersion in air were simulated using ADMS Urban modeling software. According to the obtained results, modeled concentration in selected receptors were below limit values for dust defined by EU Directives. Even though simulation could be starting point for indication of pollution levels, systematic measurement around landfill is imperative in Serbia.
Keywords: air pollution, dust, air dispersion, modelling

INTRODUCTION

Air pollution is one of the main factors that have negative influence on quality of life and health of population in urban areas. Exposure to the air pollution could have fatal consequences and according to the World Health Organisation (WHO) it causes premature death for a 4,2 million people every year all over the world (WHO 2021). Air pollution causes cardiovascular, various respiratory disease and lung cancer, and it is the main issue in solid waste management, especially in developing countries where landfilling on uncontrolled dumps is dominant waste treatment. This waste management practice implies negative environment impacts like odours, dust, noise, groundwater pollution and greenhouse gas emission. Although the dust emission from landfills intensively occupies attention of the scientific community and the decision makers because of its complexity and potential strong influence on human health, this pollution phenomenon is not explored enough (Di Felice P, 2014; Han et al., 2014).

Information on chemical composition of resuspended particles, especially qualitative and quantitative heavy metal content is crucial because of it's negative health effects. Research provided in Malesia analysed connection between respiratory symptoms at children's with the dust resuspended from solid waste landfill (Esphylin et al., 2018). In resent studies, provided in Indonesian city of Semarang, total suspended particles as well as heavy metal content (Pb i Zn) originated from landfill were investigated . Samples analysis revealed concentration of Pb below limit value (0,84–1,78 μg/m^3). Detected Zn concentration were from 7,87 do 8,76 μg/m^3 but limit value is not defined by Indonesian low (Budihardjo et al., 2018). Also, the influence of heavy metal were analysed at different distances from two landfills in Egypt. Concentration of some metals (Cd, Cu, Ni, Cr i Zn) in ambient air samples were the highest at the sampling sites near the landfills reducing with the distance from the landfills (Rashad M and Shalaby E A, 2007). Study provided at the landfill located at the Crete had a goal to determinate the exposure of landfill workers to the fugitive dust emission and consequently to the heavy metals like Cr, Mn, Zn, Ti i Pb. Results indicated that presence of heavy metals in human tissue is related to the high heavy metals concentration in landfill dust (Chalvatzaki et al., 2015). High concentration of heavy metals causes respiratory i cardiovascular issues at male landfill employee (Chalvatzaki et al., 2014). High influence of landfill on environment is also confirmed in research provided in United Kingdom, where the heavy metal content in particulates (PM10 and PM2.5) from landfill were analysed. Comparing heavy metals content in samples from landfill with samples from urban areas showed higher concentration of Fe and Pb in landfill samples (Koshy et al., 2009).

In transition countries, like in Republic of Serbia, there are no reliable data on any emission from landfill. Since fugitive dust emission or dust resuspension from landfill were not investigated at all, a comprehensive data gathering could be useful for modelling methods like one of the approved methods that could give an indicative pollution level. Regarding the fact that there are no data on concertation of particles originating from the landfills due to the wind resuspension, in this paper emission rate as well as dust dispersion in ambient air will be modelled.

METHODOLOGY – MODELLING METHODS

When there are no measuring data, modelling methods could be useful tool for reaching indicative levels of pollution concentrations. In this paper the simulation was carried out using Gaussian dispersion model: The Atmospheric Dispersion Modelling System software (ADMS) which is developed by the consulting company "Cambridge Environmental Experts Consultants" (CERC). ADMS is one of the widely used dispersion models which simulate a wide range of pollution from various sources. However, ADMS Urban is data demanding software that requires data of emission source (physical characteristics and emission rate) and surrounding environment (meteorological condition and terrain configuration) as well (CERC, 2001).

RESULTS AND DISCUSSION

— Source of emission

The landfill site of city of Zrenjanin covers an area of 6,71 ha. Waste from the city and surrounding settlements (123 362 people are covered) are disposed at this landfill. The dump contains cca. 268.400m^3 of mostly of communal waste, waste from construction sites and non–hazardous medical waste (RPWM, 2011). The average waste height is 4m and the modelled annual weight of the disposed is 42 116 tons per year (Vujic et al., 2009). Landfill is partly fenced. Waste is mixed with the soil and periodically is covered with inert material. The source is defined as the area type like it is defined in *Air Quality Modelling Guidelines* (Air Permits Division Texas, 2014). Landfill is graphically represented with the help of the ADMS Mapper program. The graphical segment of the landfill presents a real environment of the simulation (Figure 1). In general, landfill is situated south–west of the city, on the 5km distance from the city centre and 1,7km from the nearest houses (Figure 1).

Figure 1. Research area, landfill in Zrenjanin

— Meteorological conditions

Data for air dispersion modelling include two sets of meteorological data:

1. Required parameters: Wind speed (m/s) and wind direction (°) and parameters related to the sensitive surface flux: year/day/time/cloud cover or urface flux (W/m^2)
2. Additional meteorological data: Boundary layer height (m), Surface temperature (°C), lateral spread (°), relative humidity (%)

The meteorological parameters used in this paper included summer period (June and July of 2021), period with the low precipitation. Dominant wind direction in the selected period were north–west (NW) and south–east (SE) (Figure 2). Average temperature during this period were 26ºC (maximum 38 ºC, and minimum 12 ºC). Average cloud cover were 3 octas.

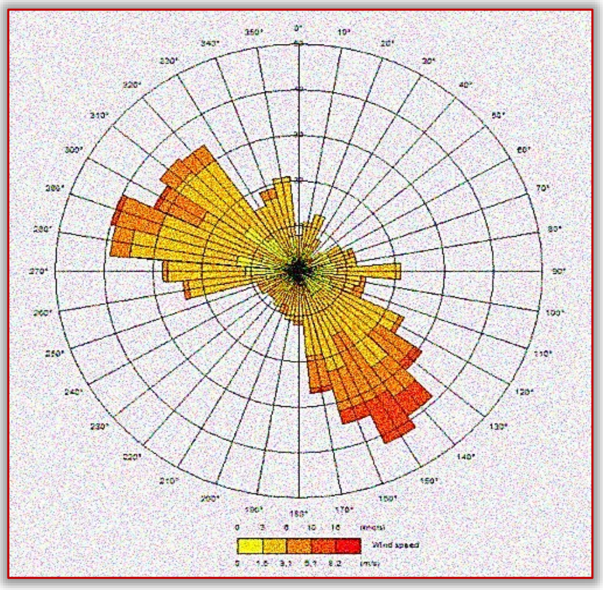

Figure 2. Wind rose for the period of June and July of 2021

— Emission rate

Dust resuspension depends on landfill area covered with soil, type of the roads (paved or no paved), number and weight of the truck that operates on daily basis, meteorological data: prevailing wind speed and relative air humidity. For this research, to define the landfill dust resuspension an emission factor was calculated according to the methodology described in Yu–Jin (2008). For fraction emission flux (F in g cm^{-2} s,) reduction factor (R) for barren land of 0.1, average wind speed (u_z) at reference height *of 10m of 277cm/s,* von Kármán constant (k) of 0,4 and surface roughness length (z_0) for barren land of 1cm were used.

— Terrain configuration

For the modelling of propagation of methane from landfills, surface roughness of 1m which is typical for cities and woodlands is used in this paper.

— Sensitive receptors

To specify landfill influence on surrounding area, a few sensitive receptors were selected (Table 1). The receptors were selected according to its vulnerability, location, and distance from the landfill and regarding the dominants wind direction as well. Hence, the nearest houses (Houses 1, Houses 2 and Ranch), as well as City beach that is very crowded during the summer period.

Table 1– Senzitive receptors caracteristics

Receptor name	Coordinates		Receptor height (m)	Distance from landfill (m)
Houses1	449231.88	5024825.50	1.50	2700
Ranch	448696.50	5024005.00	1.50	2250
City beach	451682.16	5022156.50	1.50	1500
Houses2	450917.62	5024044.00	1.50	1700

— Dust dispersion and concentration levels

According to the results obtained using the meteorological data for the whole period of June–July 2021 (Scenario S1), particulate concentration was the highest at the landfill itself, reaching concentration of 377 μg/m^3. Since the World Health

Organization defines daily limit values for total suspended particles of 120 μg/m^3 (WHO 2005), while EU defines 150 μg/m^3 (EU Council Directive 80/779/EEC) modelled concentration in surrounding area (sensitive points) were lower and the intensity of landfill influence is very low (Table 2).

Figure 3. Modelled concentration in surrounding area (sensitive points)

Table 2–Modeled dust concentrations in different scenarios

Receptor name	Dust concentration in different scenarios (μg/m3)		
	S1	S2	S3
Houses1	2	0	1
Ranc	3	0	4
Landfill	377	148	92
City beach	8	6	0
Houses2	1	0	0

Furthermore, to identify most unfavourable condition, detailed analysis of meteorological data was provided. Hence, two scenarios for modelling were selected:

- S2–hot days (32ºC) days with SE wind direction reaching the speed of maximum 7m/s, with very high could cover (Cl=7 octas).
- S3–days with lower air temperature (24ºC) with dominant NW wind direction reaching maximum wind speed of 5m/s, with moderate cloud cover (Cl=5octas).

The two scenarios were processed and modeled concentration of particles in ambient air for the sensitive receptors were obtained (Table 2). These concentrations indicate that particles from landfill were highest at the landfill itself, and the sensitive receptors remained with no significant influence of landfill.

Although, the results indicated minor influence of landfill on surrounding area, it should be investigated furthermore by considering more reliable emission factors for dust resuspension, data on landfill infrastructure and maintaining and operating practice on landfill. However, monitoring data should be most desirable for this kind of research.

CONCLUSION

Even the huge number of landfills in Serbia are in the vicinity of settlements jeopardizing environment and population health, in general there no practice of air quality monitoring near these emission sources. In these situations, modelling of emission rate and atmosphere dispersion could be useful to indicate potential pollution concentration and most endangered areas.

However, by Serbian low, the recommended method for air pollution modeling is not defined, but deviation between modeled and measured concentration is allowed to be 50%. Hence, in this paper the emission rate of particulates was calculated and modelling of dust resuspension from landfill and its dispersion in the atmosphere were performed. Results indicated that modeled concentration were very high at landfill itself reaching concentrations higher than limit value, but very low at the selected sensitive receptor that are close to the landfill. This could be starting point for establishing continual monitoring of air quality in area surrounding the landfill.

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[1.]Paul YOHANNA, [2.]Kazeem ISHOLA, [1.]Chen Manasseh AONDOVER,
[1.]Jiges Kamji FORTUNATUS, [1.]Fwangshak Gayus MIJE, [1.]Badamasi ABDULRAHMAN

A COMPARATIVE STUDY ON PROPERTIES OF LATERITIC SOIL TREATED WITH RICE HUSK ASH AND METAKAOLIN GEOPOLYMER

[1.] Department of Civil Engineering, University of Jos, Plateau State, NIGERIA
[2.] Department of Civil Engineering, Osun State University, Osogbo, Osun State, NIGERIA

Abstract: The impact of rice husk ash (RHA) and Metakaolin (MTK) geopolymer in improving lateritic soil for pavement application was investigated. RHA and MTK geopolymer each was applied to a soil sample in concentrations of 0, 5, 10, 15, and 20% by dry weight of soil. Particle size distribution, Atterberg limits and compaction test are among the tests performed. Using Microsoft Office Excel software, a one-way analysis of variance (ANOVA) was performed. Results obtained, noted that with an increase in geopolymers content, a decline in the proportion of fines in the soil was recorded. The liquid limit for both treated soil declined from its natural value of 50% to a minimum of 46 and 35% at 20% geopolymer, for RHA and MTK geopolymer in that order. The plastic limit of natural soil increased somewhat from 24.37% to highest values of 31.8 and 25.7% at 20% geopolymer for both RHA and MTK geopolymer treated soil respectively. In the case of plasticity index, values generally decreased with increasing geopolymer content for both treatments. Maximum dry density (MDD) increased at first, then later declined. MDD values of 1.64, 1.76, 1.75, 1.69, 1.62 Mg/m^3 and 1.62, 1.76, 1.7, 1.69, 1.71 Mg/m^3 were obtained at 0, 5, 10, 15, and 20% RHA and MTK geopolymer content, respectively. Optimum moisture content (OMC) initially declined and then increased with higher geopolymer content. Analysis of variance (ANOVA) demonstrates that RHA and MTK geopolymer has a substantial influence on the treated soil. According to the findings, a 20% RHA and MTK geopolymer blend improved the soil's geotechnical qualities and is recommended for geotechnical engineering applications such as sub-base material for rural roads.

Keywords: pavement application, geopolymer, rice husk ash (RHA), Metakaolin (MTK), ANOVA

INTRODUCTION

Lateritic soils that meet specific standards for usage as road construction materials are in high demand in emerging countries around the world, especially Nigeria and other Africa countries, due to the rising need for road infrastructure and massive population growth (Mir, 2015). There is pressure on geotechnical engineers to use weak soils like lateritic soil for the development of various infrastructures, but some lateritic soils are not readily appropriate for use as road construction material in their natural state (Francis and Vernantus 2013). As a result, there is a pressing need to increase efforts to improve locally available soils for use in road construction.

Lateritic soils are the product of tropical or subtropical weathering. They're also the most prevalent reddish, tropically pedogenic surface build-ups in Nigeria and other parts of the world, including Australia, Asia, and South America (Gidigasu 1976). Due to the poor state of this soil, technical soil stabilization was implemented to change its characteristics, such as shear strength and compressibility, and thus meet engineering standards for project sites (Venda Oliveira et al., 2011; Kalkan, 2013; Osinubi et al., 2015).

Soft soils, on the other hand, have traditionally been stabilized by adding lime, ordinary Portland cement (OPC), and/or specific additions like pozzolanic materials to the mix. Studies on the ability of lime, cement as preferable binder constituents to bind soil particles, result in a better material (Farouk and Shahien, 2013; Modarres and Nosoudy, 2015). However, there are chemical technology introduced in soil stabilization to reinforced soils with inadequate engineering features such as Enzymes, liquid polymers, resins, and acids. These are the most frequent chemical substances employed in numerous geotechnical applications. The actual chemical makeup of these brands has not been disclosed owing to the profit-making nature of these products (Rauch et al., 2002, Tingle et al 2007). It's also been noted that the chemistry of OPC produces a lot of carbon dioxide (CO_2) per ton of finished product (Osinubi *et al.,* 2015) and these contributed to the environmental hazard.

The waste materials generated by industrial and agriculture units have also become an environmental hazard that researchers have discovered to be effective for soil development. As a result, substituting OPC in soil stabilization with a geopolymer (i.e material such MTK and RHA admixed with alkaline activators) will lessen the stabilization process and total ecological impact. The applicability of RHA and other agricultural wastes for soil improvement has been reported in several literatures (Yohanna *et al.,* 2016; Sani *et al.,* 2018; Ishola *et al.,* 2019). Furthermore, large-scale garbage burning pollutes the environment and may contribute to ozone layer depletion, necessitating the use of geopolymer. Geopolymer is a mineral composition rich in silica and alumina that is made from basic raw ingredients.

According to (Sarka and Piecha, 2016), geopolymer materials have been employed in the creation of Formula 1 vehicles solely for their remarkable fire resistance, as well as in the production of concrete roads, which are used all over the world in the construction of airport runways. There is a scarcity of information about geopolymer's application as a soil improver.

The impact of RHA and MTK geopolymers on lateritic soil as a road pavement material application is investigated in this study.

MATERIALS AND METHODS

— Soil Sample

Lateritic soil in its disturbed form was taken at Abattoir in Jos, Plateau State, Nigeria (between 9°52′50"N and 8°53′20"E). To avoid organic matter inclusion, the soil was dug to a depth of roughly 0.5 to 1.0 m prior to collection. Soil samples were neatly packaged in plastic stacks and conveyed to the lab for a moisture content test.

— Rice Husk Ash

Rice husk was gathered from Dadin-kowa village in Plateau State, Nigeria's Langtang South local government region. Rice husks were collected in sacks, air dried, and then thoroughly burned in ovens at 1200°C for about an hour. The pulverized ash was sieved by means of BS sieve No 200 and put in storage in a watertight polythene bag. Using a NitonTM XL3t XRF analyser, the oxide composition of the specimens was studied using X-ray fluorescence.

— Metakaolin

The metakaolin for soil enhancement was obtained from Katsina state's processed kaolin clay. After that, the metakaolin was sieved using a 0.75mm sieve.

— Alkaline Activators

The Sodium Hydroxide (NaOH) and Sodium Silicate (Na_2SiO_3) were sourced from a chemical shop in Jos, Plateau State Nigeria. The NaOH and Na_2SiO_3 were added to prepared lateritic soil mixtures by the dry weight of the soil in the ratio of 1:1 as recommended by Gabriel (2018).

— Index Tests

Particle size distribution was done with the use of hydrometer analyses (wet sieving) and mechanical sieve as described in Head (1992). The Atterberg limits(i.e comprising of liquid limit, plastic limit and plasticity index) test was done on soil passing 0.425 mm opening in accordance with British Standards 1377 and 1924 (BSI 1990).

Soil samples prior both particle size distribution and Atterberg limits test were mixed with RHA and alkaline activators (i.e NaOH and Na_2SiO_3) to produce lateritic soil- RHA geopolymer. RHA geopolymer was added to the soil sample in concentrations of 0, 5, 10, 15, and 20% by dry weight of soil. Similar processes were applied in mixing lateritic soil- MTK geopolymer.

— Compaction

Compaction tests were conducted following the procedure outlined in BS 1377 (BSI 1990) to determine the compaction characteristics of the natural and the RHA and MTK geopolymer-treated soil. Standard Proctor (BSL), compaction energy was used. Soil samples prior to compaction test were mixed with RHA and alkaline activators (i.e NaOH and Na_2SiO_3) to produce lateritic soil- RHA geopolymer. RHA geopolymer was added to the soil sample in concentrations of 0, 5, 10, 15, and 20% by dry weight of soil. Similar processes were applied in mixing lateritic soil- MTK geopolymer.

— Statistical Analysis

Statistical evaluation of test results by mean of One-way analysis of variance (ANOVA) was achieved using Microsoft office excel package.

RESULTS AND DISCUSSION

— Index properties

Initial study on the soil properties in its untreated state is presented in Table 1. Proportion of soil passing aperture size 0.075mm was noted to be 44.74%. Liquid limit and plastic limit were 40 and 24.4% while plasticity index of 25.6 was recorded. Comprehensive report of the soil properties are presented in Table 1. Grain size curve of the untreated soil is shown in Figure 1.

Table 1: Geotechnical properties of natural soil

Properties	Quantity
Natural moisture content (%)	12.30
Percentage passing BS No. 200 (%)	44.47
Liquid limit (%)	50
Plastic limit (%)	24.4
Plasticity index (%)	25.6
AASHTO classification	A-7-6
USCS	CL
Specific gravity	2.50
Maximum dry density (Mg/m^3)	1.64
Optimum moisture content (%)	17.80
Color	Reddish brown

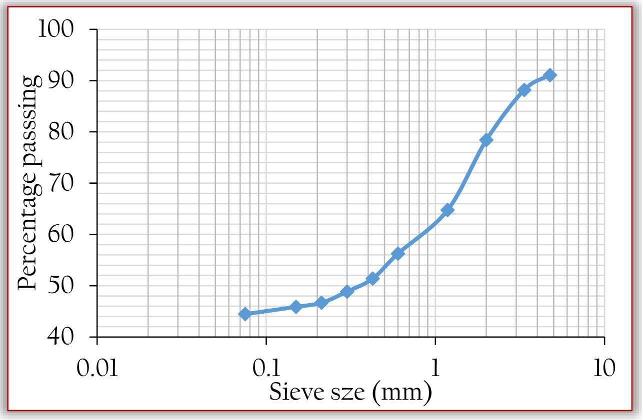

Figure 1: Grain size curve of the untreated soil

— Grain size distribution

The variations of grain size curves of the lateritic soil with RHA and MTK geopolymer are displayed in Figures 2 and 3. The particle size distribution curves for RHA geopolymer initially shifted to the left at 5%, then to the right at 0, 10, 15, and 20%, with respective fines content values of 44.47, 44.59, 38.77, 27.23, and 35.74%, respectively. In the case of MTK geopolymer, a similar tendency with the curve shifting from left to right from 44% (0% M TK) in natural soil to 32% (15% MTK). The right-shifted grain size curves for the two stabilizers show a decrease in the percentage of fines. The decrease in fines fraction with increase in RHA and MTK geopolymer content may possibly be accredited to flocculation and clustering of the lateritic soil with geopolymer mixtures which facilitated the clay fraction to form bigger soil sizes (Akinmade, 2008; Amadi, 2010; Al karagooly, 2012; Portelinha et al., 2012; Etim et al.,2019).

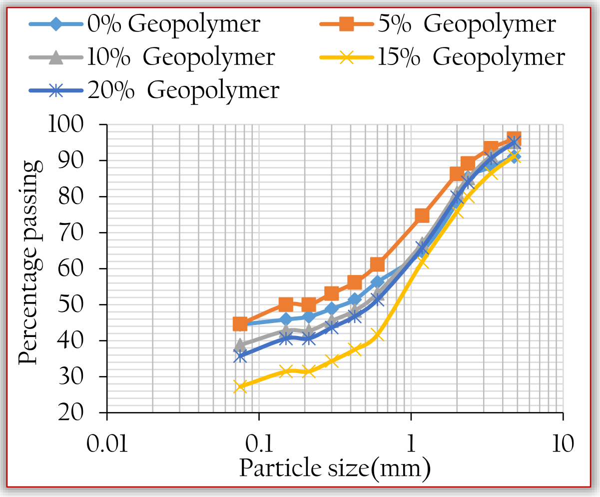

Figure 2: Grain size curve of RHA geopolymer treated lateritic soil

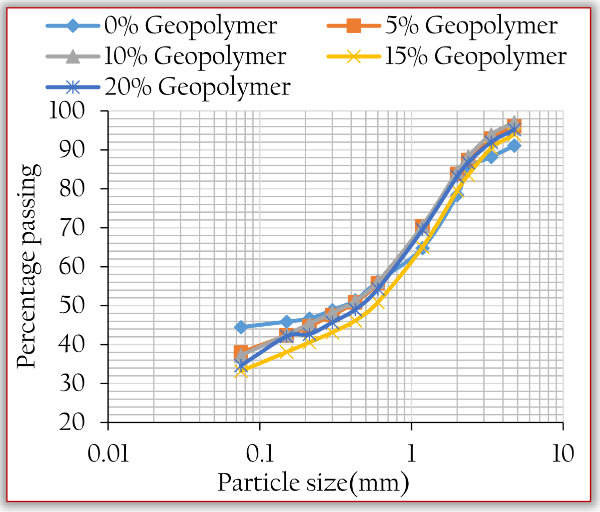

Figure 3: Grain size curve of metakaolin geopolymer treated lateritic soil

— Liquid Limit

The changes in liquid limits with RHA and MTK geopolymer contents for the treated lateritic soil is shown in Figure 4. According to the graph, The liquid limit for both treated soil generally declined from its natural value of 50% to a minimum of 46 and 35% at 20% geopolymer, for RHA and MTK treated soil in that order. Liquid limit values of 50, 47, 50, 54 and 46% were recorded at 0, 5, 10, 15 and 20% RHA geopolymer content in that order. In the case of MTK geopolymer treated soil, limit limits values of 50, 46.9, 40.5, 45 and 35 were recorded at 0, 5, 10, 15 and 20% MTK geopolymer in that order. A comparative study shows that MTK geopolymer recorded lower liquid limit values when compared to RHA geopolymer treated soil. This could be linked to the potency of MTK geopolymer to stiffen the soil more than that RHA geopolymer. A general statement for the decline in the liquid limit for both treatments could be attributed to cation exchange processes in which Ca^{2+} in the mix reacted with ions of lower valence in the clay structure, resulting in flocculation and agglomeration. (Osinubi and Umar 2003; Ramesh et al. (2013) and Oluremi et al. (2017). An analysis of variance (ANOVA) on the liquid limit results (see Table 3) shows that both RHA and MTK geopolymer were statistically significant. For RHA (F_{cal} = 83.597 > F_{crit} = 5.318) and MTK (F_{cal} = 60.251 > F_{crit} = 5.318). However, the effect of RHA was more pronounced when compared to that of MTK.

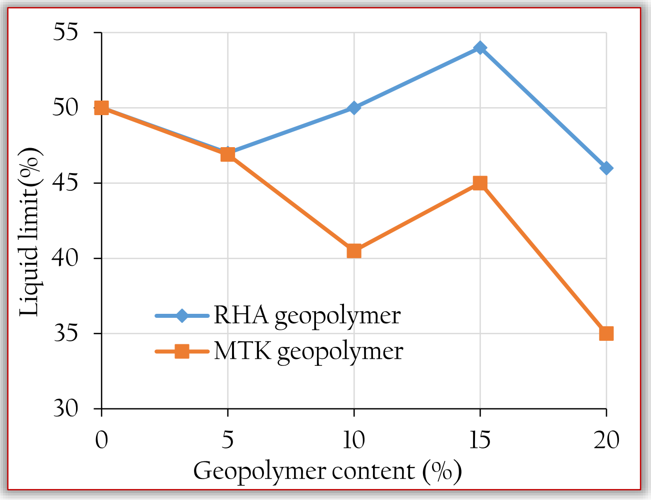

Figure 4. Plot of Liquid limit of RHA and MTK geopolymer treated lateritic soil

Table 2: ANOVA Analysis for Plasticity Properties of Lateritic Soil with RHA and MTK Geopolymer Mixtures

Property	Source of Variation	Degree of freedom	F_{cal}	P-Value	F_{crit}	Remark
Liquid Limit	RHA Geopolymer	1	83.597	1.65E-05	5.318	SS
	MTK Geopolymer	1	60.251	5.42E-05	5.318	SS
Plastic Limit	RHA Geopolymer	1	35.876	0.000327	5.318	SS
	MTK Geopolymer	1	14.298	0.005379	5.318	SS
Plasticity Index	RHA Geopolymer	1	0.593	0.46355	5.318	NS
	MTK Geopolymer	1	0.350	0.570519	5.318	NS

SS=Statistically Significant, NS=Not Significant

— Plastic Limit

The result of the plastic limit test on lateritic soil treated with RHA and MTK geopolymer is shown in the Figure 5. The plastic limit of RHA geopolymer treated soil increased from 50% to 54% at 15% geoplymer content, then decreased to 46% at 20% geoplymer content, whereas the plastic limit of MTK geopolymer increased marginally from 24.37% at 0% metakaolin geopolymer content to 25.7% at 20% geoplymer content. Zaman et al. (1992), Phanikumar et al. (2004), Brooks et al. (2011), and Alkaragooly et al. (2012) have all shown similar decreasing patterns. The decline may perhaps be associated with flocculation and clustering together of the soil rising from cation exchange reactions whereby Ca^{2+} additives reacted with ions of lower valence in the soil structure. ANOVA analysis on the Plastic limit results (see Table 2) shows that RHA and MTK geopolymer were statistically significant. For RHA (F_{cal} = 35.876 > F_{crit} = 5.318) and MTK (F_{cal} = 14.298 > F_{crit} = 5.318). However, the effect of RHA was more evident when compared to that of MTK.

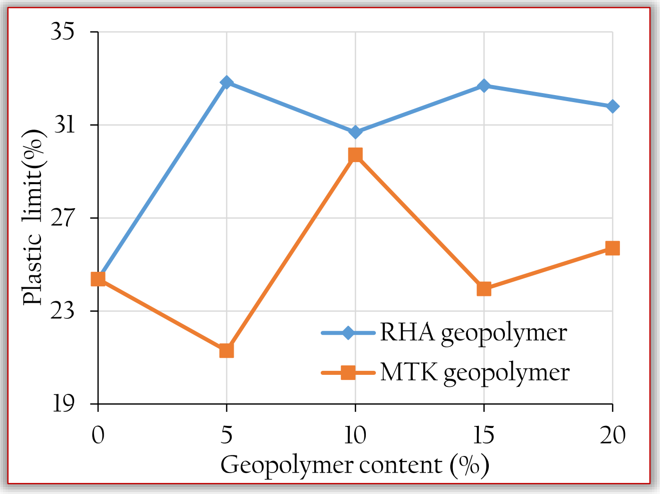

Figure 5. Plot of Plastic limit of RHA and MTK geopolymer treated lateritic soil

— Plasticity index

The result of the plasticity index test on lateritic soil treated with RHA and MTK geopolymer is shown in the Figure 6. The plasticity index of treated lateritic soil in general decreased with increasing RHA geopolymer concentration. At 0, 5, 10, 15, and 20% geoplymer concentration, values of 25.63, 14.18, 19.31, 21.31, and 14.21 were obtained. On the other hand, for MTK geopolymer treated with 0, 5, 10, 15, and 20% content by dry weight of soil caused a decrease in plasticity index with the values 25.63, 24.98, 10.79, 23.95, and 11% respectively. In general, the decline could be linked to formation of cementitious compound and exchange of cations between the soil and the additives (Annafi et al., 2020; Yohanna et al.,2020). ANOVA test on the plasticity index results (see Table 2) shows that RHA and MTK geopolymer were not statistically significant for RHA (F_{cal}= 0.593< F_{crit} = 5.318) and MTK (F_{cal} = 0.350< F_{crit} = 5.318).

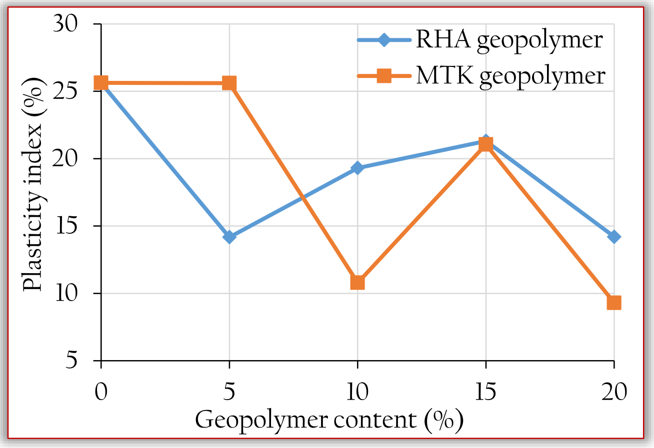

Figure 6. Plot of Plasticity index of RHA and MTK geopolymer treated lateritic soil

— Maximum dry density

The effect of RHA and MTK geopolymer on the MDD of lateritic soil is revealed in Figure 7. It was noted that for treated soil with RHA geopolymer, MDD increased at first and then declined as the geopolymer percentage increased. At RHA geopolymer concentrations of 0, 5, 10, 15, and 20%, MDD values of 1.64, 1.76, 1.75, 1.69 and 1.62 Mg/m^3 respectively were recorded. MDD for MTK geopolymer increased from 1.64 mg/m^3 at 0% to 1.75 mg/m^3 at 5%, then declined to 1.69 mg/m^3 20% MTK content. Although both RHA and MTK geopolymer reported similar trend, MTK geopolymer recorded lower MDD values. Similar trend of increase in MDD values were reported by Phanikumar et al. (2004), Jadhao and Nagarnaik (2008) as well as Kumar and Puri (2013). The observed increase in MDD could be due to RHA and MTK geopolymer that filled the micro pores within the compacted soil fractions and moreover, The recorded trend may possible be associated with the flocculation and clustering of the clayed fractions of the soil linked to interchange of cations of soil and the additives(Yohanna et al,2020). This is in conformity with the discoveries reported by Osinubi (2000), Oriola and Moses (2010; 2011), Amadi (2010), Osinubi and Oyelakin (2012) as well as Ishola et al., (2020). ANOVA analysi on the plasticity index results (see Table 2) shows that both RHA and MTK geopolymer were statistically significant. For RHA (F_{cal}= 5.526> F_{crit} = 5.318) and MTK (F_{cal} = 5.450> F_{crit} = 5.318). However, the effect of RHA was more evident when compared to that of MTK.

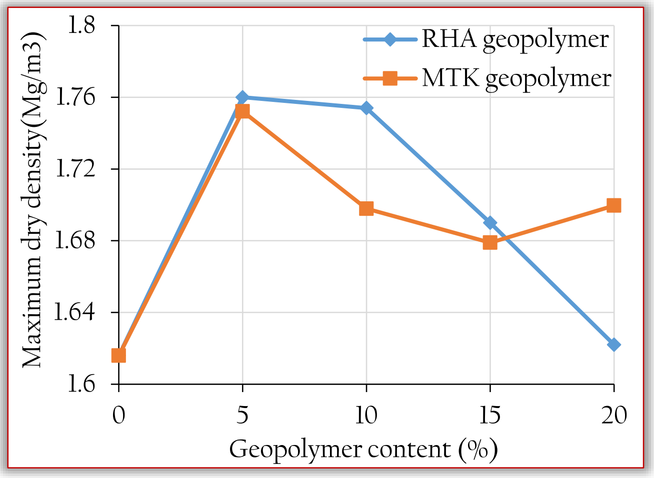

Figure 7. Plot of MDD of RHA and MTK geopolymer treated lateritic soil

Table 3: ANOVA Analysis for Compaction Characteristics of Lateritic Soil with RHA and MTK Geopolymer Mixtures

Property	Source of Variation	Degree of freedom	Fcal	P-Value	Fcrit	Remark
MDD	RHA Geopolymer	1	5.526	0.046624	5.318	SS
	MTK Geopolymer	1	5.450	0.048	5.318	SS
OMC	RHA Geopolymer	1	6.167	0.037911	5.318	SS
	MTK Geopolymer	1	216.225	0.038	5.318	SS

— Optimum moisture content

The changes in OMC of lateritic soil mixtures with RHA and MTK geopolymer content is shown in Figure 8. Initial decrease in OMC values was first recorded for RHA geopolymer content, thereafter increased with higher geopolymer content. OMC values of 17.8, 15.7, 15.5, 22.5, and 23% were recorded at 0, 5, 10, 15 and 20% geopolymer content respectively. In the case of MTK geopolymer treated soil, OMC values of 17.5, 18, 19, 22 and 15.5% were recorded at 0, 5, 10, 15 and 20% MTK geopolymer in that order. Although both RHA and MTK geopolymer reported similar trend, RHA geopolymer treated soil recorded higher OMC values in most cases when compared with that of MTK geopolymer treated soil. The initial decrease could be due to self - desiccation of the mixtures during which all the water was used up, resulting in low hydration. When no water movement to or from soil- Geopolymer matrix is permitted, the water is used up in the hydration until too little is left to saturate the solid surfaces and hence the relative humidity within the paste decreases (Osinubi, 2001; Moses *et.al.,* 2012; Osinubi *et al.,* 2015). An analysis of variance (ANOVA) test on the plasticity index results (see Table 2) shows that the effects of both RHA and MTK geopolymer on lateritic soil were statistically significant. For RHA (F_{cal}= 6.167> F_{crit} = 5.318) and MTK (F_{cal} = 216.225> F_{crit} = 5.318). However, the effect of MTK was more evident when compared to that of RHA.

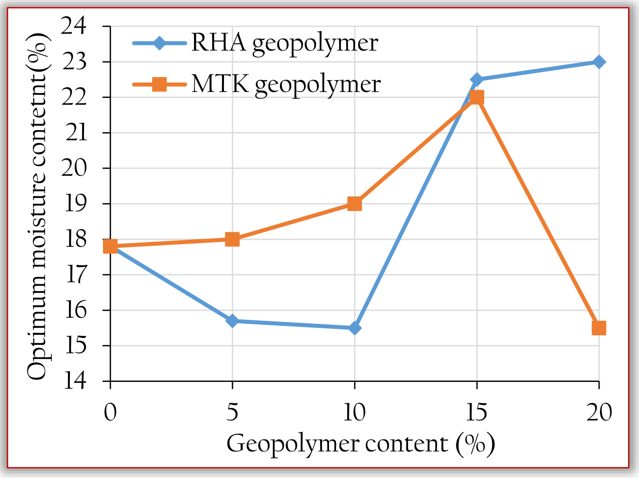

Figure 8. Plot of OMC of RHA and MTK geopolymer treated lateritic soil

CONCLUSIONS

The research work investigated the effect of RHA and MTK geopolymer on the geotechnical properties of lateritic soil. Based on the study, the following conclusions were drawn:

- The proportion of fines decreased with increase in both RHA and MTK geopolymer contents. The liquid limit for both treated soil declined from its natural value of 50% to a minimum of 46 and 35% at 20% geopolymer, for RHA and MTK geopolymer in that order. The plastic limit generally increased while plasticity index decreased for both RHA and MTK geopolymer treated soil.
- Maximum dry density (MDD) increased at first, then later declined. MDD values of 1.64, 1.76, 1.75, 1.69, 1.62 Mg/m^3 and 1.62, 1.76, 1.7, 1.69, 1.71 Mg/m^3 were obtained at 0, 5, 10, 15, and 20% RHA and MTK geopolymer content, respectively. Optimum moisture content (OMC) initially declined and then increased with higher geopolymer content.
- Analysis of variance (ANOVA) reveals that RHA and MTK geopolymer has a substantial influence on the treated soil.
- Based on the result obtained, an optimal blend of 20% RHA and MTK geopolymer blend improved the soil's geotechnical qualities and is recommended for geotechnical engineering applications such as sub-base material for rural roads.

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[1.]Chinglung CHANG

AN ONLINE TOOL DIE MONITORING SYSTEM FOR THE STAMPING PROCESS: AN APPLICATION OF DEEP METRIC LEARNING

[1]Fu Jen Catholic University, Graduate Institute of Business Administration, Taipei City, TAIWAN

Abstract: Effectively monitoring the conditions of the tool die in the production line's stamping process is essential, as operators can only inspect the conditions when the product is produced. Convolutional neural networks (CNNs) have demonstrated promising results for classifying complex signals including accelerometer signals, but their practicality have been restricted due to a lack of flexibility in adding new classes and a low accuracy when faced with low sample numbers per class. This study applies deep metric learning (DML) methods to enhance the CNN method. It develops a tool die monitoring system to apply when monitoring the stamping process. It applies signal extraction from sensors and signal classification using DML methods. The system provides information by which operators can monitor tool tie conditions and thus avoid unexpected tool die damage, machine downtime, and unplanned repairs. It further results in a reduction of tool and scrap costs through early failure detection. Manufacturing quality can thus be guaranteed, and productivity can be improved.
Keywords: stamping, monitoring, deep metric learning, Siamese network, triplet network

INTRODUCTION

The stamping process is essential in the manufacturing industry, where a breakdown or unplanned maintenance could lead to a severe disruption of productivity. The need for a highly efficient stamping process has led to an increase in stamping force. However, this has come at the expense of the lifespan and durability of the tool die. One way to combat this is by creating a new design or using new materials in the design of the tool die to make it more robust. Another method is to improve the monitoring of tool conditions. The current common method for assessing the stamping tool die conditions still relies heavily on workers' manual and visual inspection for wear and tear on the tool. However, by the time such conditions are noticed, it is already too late as the product has already started to be affected. It is therefore necessary to develop a system that can eliminate the dependency on human workers and rather provide continuous monitoring of tool wear.

Incorporating sensors such as accelerometers into the milling process is a robust and effective way to achieve real-time process monitoring (Kulis, 2013). However, extracting useful information from sensors is still challenging. Differentiating only one wear condition compared with a standard is not difficult, but when many wear conditions need to be classified, it becomes difficult to investigate the signal and identify the information source.

Signal processing is widely applied to better understand what information lies inside those signals. Signal processing can extract time-based or frequency-based features such as maximum peak, average value, root mean square, standard deviation, crest factor, variance, kurtosis, and skewness (Wu, Hoi, Xia, Zhao, and Wang, 2013). However, there are specific drawbacks to this method. For example, because all features are extracted manually, it can require a lot of man-hours (Workman, Souvenir, and Jacobs, 2015). Furthermore, these manually extracted features tend to not adapt well to evolving conditions and scenarios. More recently, deep learning has been applied to address these issues (Lin, Cui, Belongie, and Hays, 2015). Convolution neural network (CNN) employs nodes as a type of filter that allows this architecture to extract features from complex and non-linear data. Deep metric learning (DML) is developed by mimicking the ability of humans. When learning, humans can differentiate visual objects by looking at similar features. Humans are good at extracting and generalizing visual features. DML tries to do the same thing by training the CNN as a feature extraction (encoder) that can respectively extract similar and dissimilar features from objects into embedded features. The ability to learn from such similarities gives DML the advantage of flexibly adding new classes without requiring model retraining.

The purpose of this study is to develop a system (tool die monitoring system, TDMS) to monitor the conditions of tool dies in a stamping process through signal extraction from sensors and signal classification applying DML methods. The information provided by the TDMS would help production operators know of potential issues before the tool dies wear out or break down and thus improve production quality and efficiency.

RELATED WORK

There are several studies related to the monitoring of stamping tool conditions using signal processing and conventional machine learning methods. Ge, Du, and Xu (2004) apply an auto regressive model to determine discrete time series stamping signals and conduct feature selection by applying a hidden Markov model for classification. Bassiuny, Li, and Du (2007) extract features from strain signals by applying empirical mode decomposition, where the extracted features are tracked using the Hilbert marginal spectrum. They apply linear vector quantization to identify faulty processes. Some studies also use audio signals to monitor stamping processes. Ubhayaratne, Pereira, Xiang, and Rolfe (2017) develop a low-cost monitoring system using sound. They develop a method of semi-blind signal extraction to eliminate noise from surrounding machines. They find the frequency band 2-6 kHz contains the most important wear-related information. Shanbhag, Rolfe, and Pereira (2020) investigate galling wear using acoustic emission generated by tool wear fractures. They find that the acoustic emission mean-frequency can be used for condition monitoring to identify galling and non-galling conditions. Ge, Du, Zhang, and Xu (2004) further use a support vector machine combined with a kernel function to monitor the stamping process. Zhang, Li, Zhou, and Wagner (2018) use a 4-level wavelet decomposition method to extract strain signal features. A semi-supervised clustering algorithm is then applied to the features to detect punching failures. The method is effective for failure detection in punching processes.

The use of CNN based on 1-dimensional (1D) data signals has also gained popularity for the monitoring of other processes. Zhang, Sun, Guo, Gao, Hong, and Song (2020) diagnose bearing faults. They apply 2D-CNN to transformed 1D vibratory bearing data to automatically extract features and classify bearing conditions. Eren, Ince, and Kiranyaz (2019) directly apply 1D-CNN to vibratory bearing data which allows for a much more compact architecture than the 2D-CNN and requires less data preprocessing.

Recent development of few-shot learning based on the DML method with all its advantages over traditional CNN have shown to provide successful applications in fault diagnosis. Zhang, Li, Cui, Yang, Dong, and Hu (2019) develop a deep neural network based on the Siamese neural network to classify rolling bearing conditions. It shows good results while being more flexible, providing more robust signals, and requiring a lower number of samples than the traditional CNN method. Wang, Wang, Kong, Wang, Li, and Zhou (2020) develop a metric-based meta-learning method called *reinforce relation network* to transfer scenarios from experimental situations to actual working situations as related to bearing fault diagnosis.

DML is also known as similarity-based learning and is a branch of machine learning. It can also be applied to image recognition (Weinberger and Saul, 2009), visual search (Wang, Song, Leung et al., 2014), and image-based geo-localization (Vo and Hays, 2017). The distance between samples is used to determine the similarity of samples (Davis, Kulis, Jain, Sra, and Dhillon, 2007). More similar samples have a closer distance. Before the popularity of deep learning, one of the popular algorithms from similarity-based learning was the nearest neighbor rule. The Euclidian distance or Mahala Nobis distance are widely applied in the rule. However, the Mahala Nobis metric faces a linear transformation issue; it is incapable of transforming non-linear data (Bellet, Habrard, and Sebban, 2014). Supervised DML, which is one of DML's two categories, the other being unsupervised DML (Kulis, 2013), has the capability of non-linear transformation by activating the non-linear structure function.

Based on artificial neural networks, a Siamese network (Bromley, Guyon, LeCun, Säckinger, and Shah, 1993) describes a network that has two identical sub-networks joined together at output. During the training phase, these two sub-networks extract features from samples and provide signatures. The joining network then measures the distance between these two samples. A Siamese network is similar to a supervised DML in that the identical sub-networks can be applied to feature mapping (Chopra, Hadsell, and LeCun, 2005). Schultz and Joachims (2003) propose a method for learning distance metrics from relative comparisons. Hoffer and Ailon (2018) take a similar concept from Chechik, Sharma, Shalit, and Bengio (2009) and Wang et al. (2014) and propose a triplet network to learn metric embedding and corresponding similarity functions. However, it is inefficient and sometime computationally impossible to compute all the triplet types across the whole training set. Moreover, it might result in poor training as mislabeled and poor samples could dominate the hard negatives and easy negatives. Schroff, Kalenichenko, and Philbin (2015) propose triplet selections to constrain an embedding space to be within a dimensional hyperspace and propose triplet selection for a faster convergence in the training process.

METHODOLOGY

Signal acquisition and signal classification are two parts of the methodology applied to develop this study's TDMS. Signal acquisition covers data preprocessing and signal extraction. Data preprocessing transforms raw information into data that the system can understand. The signal from the sensors in this study only occur when the stamping machine is in activity. The vibration signal data does not match the signal length, and thus it cannot be used for CNN input. Standardizing the data is therefore required. A root mean squared algorithm is thus applied to extract only certain signal data, as determined through a template matching technique. First, both the template signals and incoming signals are transformed into their root mean squared form with the same resolution. Second, the template signal is then selected. The selection process is manual and comprised of several templates for every class. Third, the template signal slides along the incoming signal, where in each sliding window the similarity is measured using distance d between the template and incoming signal. If the distance d is below the threshold θ, this study starts to search for the local minima until $d>\theta$. Several distance metrics are investigated to determine which is the most suitable. Finally, if the above conditions match, the incoming signal is extracted. An auto threshold is used to automatically calculate the threshold θ needed for the signal extraction to determine the local minima for the distance metric. Two distance metrics, standard deviation, and variance, are used to determine the auto threshold, respectively.

Signal classification covers the model architecture through DML (Kaya and Bilge, 2019). Siamese and triplet networks are the main models applied in this study. A sequential 1D CNN is used as the feature extractor for each main model. The

Siamese network has two types of loss: contrastive and cross-entropy. A contrastive loss requires the distance between two embeddings to calculate the loss function. A cross-entropy loss applies a probability calculation, where after the distance metric is calculated, a sigmoid activation function is used to produce the probability of similarity. The triplet network has three types of triplet selections: Hard-soft-margin, hard, and semi-hard negatives. Online triplet mining is used since it provides an efficient method of training the triplet network.

RESULTS AND DISCUSSION

Figure 1 presents the setup of the TDMS. An acoustic emission sensor is installed on the back plate of the machine to detect frequency, speed, and vibration, with frequency from 20Hz to 20MHz, sensitivity from 0.087v/ με to 0.092V/ με, and range from 1000mm to 1500mm. An industrial server with the specifications of Intel® Core™ i7/ 16GB, DDR4, 2933MHz, and 1 TB 7200 rpm 3.5" hard drive collects the data from the sensors and sends it to TDMS.

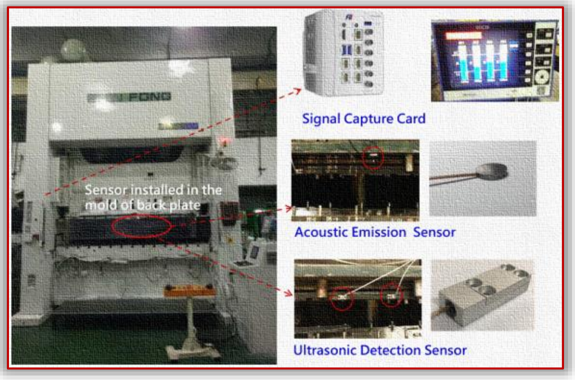

Figure 1. Setup of the TDMS

This study applies TensorFlow 2.4 on top of Python 3.8 to develop the TDMS. The TDMS runs in an Anaconda environment and Nvidia GPU is utilized to train the model. Signal extraction and classification are the main functions that the TDMS executes.

Signal extraction: During signal extraction, distance metrics that measure the similarity between the template and incoming signals are used for signal comparison and analyzation. Metric performance is measured using the following steps: First, the presence and/or absence of stamping signals and noise signals are determined. Second, the time required by each metrics to do the same signal extraction process is computed. All metrics can detect the presence of a stamping signal to some degree. Kurtosis, root-mean-square deviation, skewness, and mean show distinguished values whenever a signal is present. Third, the auto-thresholding performance is examined and analyzed to determine how effective the auto-thresholding values are regarding locating the start of the local minima in the root-mean-square deviation and mean values, respectively. The parameters included in this test are sensitivity, miss rate, and positive predicted value.

Signal classification: The models are evaluated using different numbers of training samples to simulate the lack of training data observed in real world stamping process scenarios. Each class is evaluated according to individual sample sets. These sets are then respectively divided into training and test sets containing 60% and 40% of the samples. Each sample set is randomly sampled five times, and each random sample is trained and tested four times. In total, every sample set undergoes 20 training processes to generate new models. To determine the efficacy of each loss function to enable each feature extractor to distinguish between different classes, embedding projections are produced for every feature extractor as shown in Figure 2. This is the comparison of principal component analysis from embedding projections for all trained and untrained feature extractors.

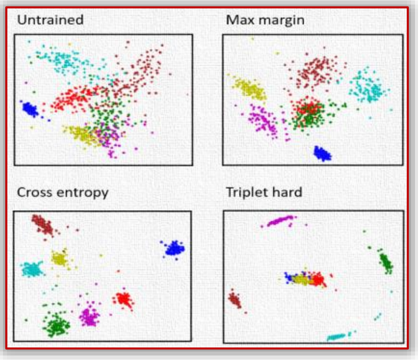

Figure 2. Comparison of feature extractors

Through signals from the sensors, the TDMS monitors the abnormalities such as material jumping and crashing into the machine. The TDMS sends out data to timely trigger an alarm and the machine shuts down. The operators can solve abnormal issues directly based on the information from the TDMS. The TDMS applies ultrasonic sensors to monitor machine tonnage, improve product yield, and reduce machine adjustment time. Real-time acquisition of stamping pressure data enables the detection of abnormal stamping motions. Anomaly issues trigger the stamping machine to be stopped in time to avoid continuing making defect products as shown in Figure 3.

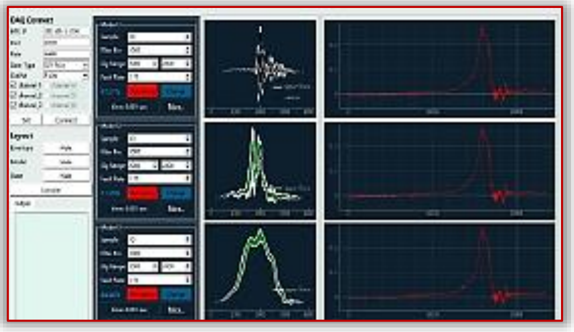

Figure 3. Tool die monitoring system

When an operator solves the anomaly issue, both production output and machine utilization rate can be increased. The TDMS supports stamping production in achieving the highest productivity and manufacturing quality. Information provided by the TDMS is essential for ensuring efficient machines, tools, and quality monitoring whenever millions of parts are produced monthly.

This system is suitable for common situations in the processes that are likely to cause product defects. In stamping processes, foreign objects in the mold (wrenches, screwdrivers, and other tools left by the mold repair team), burrs generated during the stamping process (metal square sheets), metal skips, metal wool, and raw materials with foreign objects can all be detected accurately. The system can automatically collect, build, and optimize the model, and the stamping process can be detected without affecting production. Through this system, production efficiency and utilization rate can be improved, product quality can be ensured, mold repair and time costs can be reduced, production yield can be greatly improved, and the dependence on inspectors can be reduced.

CONCLUSION

This study develops a tool die monitoring system for the stamping process. Signals from sensors, as raw data, first go to data preprocessing for data extraction either in the same class or cross-class signal. The DML method is then applied for signal classification and recognition. The results then go into the TDMS to visualize the die status for production operators. Auto-thresholding can be used as an effective base thresholding value for signal extraction. The TDMS provides information by which operators can monitor tool tie conditions and thus unexpected tool die damage, machine downtime, and unplanned repairs can be avoided. It furthermore facilitates a reduction of tool and scrap costs through early failure detection, leading to the guarantee of manufacturing quality and the improvement of productivity.

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[1.]Solomon SUDI, [2.]Richard Balthi MSHELIA, [3.]Sagir Lawan WAZIRI

ASSESSMENT OF THE IMPACT OF HYDROCHLORIC ACID ON METAL IMPURITIES AND SILICA CONTENT OF RICE HUSK ASH

[1.]Department of metallurgical and Materials Engineering, Airforce Institute of Technology, Kaduna, NIGERIA
[2.]Department of Mechanical Engineering, Faculty of Engineering, Nigerian Army University, Biu, NIGERIA
[3.]Department of Mechanical Engineering, Kano State Polytechnic, Kano, NIGERIA

Abstract: Rice is the main staple food of Nigeria, recent government policy on local content in agriculture has led to a boom in the cultivation of rice in the country. Rice husk which is a by–product of rice production is being considered for industrial applications as it has very little value in the food value chain. This study investigates the effect of hydrochloric acid in the leaching of rice husk to remove metal impurities and improvement of the percentage of silica content in the composition of rice husk ash. Rice husk was collected from a milling plant and washed to remove sand particles and dust. The cleaned rice husk was then leached with 1M of Hydrochloric acid (HCl) by heating it in an oven at 70°C for 3 hours. Thereafter, it was washed thoroughly with distilled water and air dry. The sample was calcined in a furnace at about 700°C for six hours and thereafter analysed using X–ray fluorescence technique. It was found that the leaching process with HCl had increased the Silica content of the rice husk ash from about 79.3% to about 92.8%. Likewise, the metal impurities in the rice husk ash had significantly reduced. It can be concluded that leaching rice husk ash with HCl makes it more suitable for industrial application.
Keywords: biosilica, rice husk, rice husk ash, XRF

INTRODUCTION

Rice is the number one staple food in Nigeria, the Federal Government's policy that banned the importation of rice has spurred an astronomical rise in the local production of rice in the country so much that Nigeria has now overtaken Egypt as the highest producer of rice on the continent – Nigeria now produces about 8 million tonnes of out of the Africa average of 14.6 million tonnes of rice annually [1]. The boom in the cultivation of rice in the country has resulted in a commensurate rise in the number of rice mills in the country and consequently the production of large quantities of agricultural waste – rice husk to be specific.

Rice husks (RH) are the hard protective coverings of rice grains that are separated from the grains during the milling process. RH which is the major by–product of rice milling and agro–based biomass industry is a cellulose–based fibre that contains approximately 20% silica in amorphous form and is usually produced in large quantities [2].

Rice husk is not edible as such it cannot be used as animal feed like other agricultural wastes/residues, thus, in most places in Nigeria, it is burnt or used for landfilling. The low economic value of RH and the problems associated with its disposal has prompted researchers and environmentalist to seek alternative usage for it.

One of such is the usage of rice husk ash (RHA) to partially replace cement in the preparation of cement concrete as an additive, it equally enhances the corrosion resistance and durability of concrete [3], [4].

RHA is produced from the burning of rice husk, upon burning, RH yields 14–20% ash, which is rich in Silica (about 60%) with trace amounts of metallic impurities and can be an economically valuable raw material for the production of biosilica [5].

Biosilica from RHA are used in various industrial applications such as; Chemical Industry, Electronic Industry, Glass industry and Building. Bansal, Ahmad, & Sastry [6] reported that nanocrystalline silica obtained from RH is used in commercial applications such as catalyst support, resins, fillers in polymers as well in biomedical applications.

Zamani, Mohajerani, & Ataie [7] also reported that silica gotten from RH is being considered as a possible raw material for the production of semiconductors due to its unique property of being highly reactive due to fine particles having large porosity and surface area. Biosilica is also used as pozzolone in cement when Portland cement is partially replaced by rice husk.

Despite the aforementioned industrial applications of biosilica and its huge prospects for wider industrial applications, its usefulness is limited by the level of metal impurities present in it. The higher the silica content of RHA and the fewer metal impurities it contains, the more desirable it becomes.

Therefore, for RHA to be suitable for industrial usage, there is a need for it to undergo a purification process to reduce its impurities and improve its silica content. This research explores the role hydrochloric acid (HCl) plays in the improvement of silica content and reduction in mineral impurities content of RHA.

MATERIALS AND METHODS

— Materials and Equipment Used

The materials used for this experiment include rice husk which was sourced from a local mill in Kura, Kura Local Government Area of Kano State, Nigeria. Tap water, 1M dilutes hydrochloric (HCl) acid and distilled water. The equipment used includes a digital weighing balance, a 2000 cm^3 aluminium pan, a muffle furnace (Carbolite Technology with model number CWF and capacity of 1100°C), an electric oven with a capacity of reaching 900°C, a measuring cylinder of 2000 ml capacity, X–Ray Fluorescence and a spectrometer (Epsilon panalytical Model DY1055).

— Sample Preparation and Calcination

Rice husk weighing 500 grammes without rice grains and sand particles was washed thoroughly with tap water to remove dust and other possible impurities.

The washed sample was then air–dried. This was done because impurities could influence the properties and composition of the rice husk ash.

The cleaned RH was leached with 1M HCl, the leaching process was carried out by heating the mixture of rice husk and HCl in the ratio of 1:10 in an oven at 70°C for 3 hours. Thereafter, the mixture of rice husk and HCl was washed with distilled water and air–dried.

The leached rice husk was calcined by putting the RH sample in a crucible and placed inside the furnace. The furnace was switched on and set at a temperature of 700°C and allowed for six hours. White RHA was obtained as shown in Figure 1.

Figure 1: White RHA obtained from Calcination

— Sample Characterization

An X–ray Fluorescence (XRF) analysis of the RHA sample was undertaken by first weighing 5 gramme of the sample using a macular balance. A binder (cellulose powder) was added to it and a pellet was produced using a manual compression machine.

The pellet produced was loaded into the sample chamber of the spectrometer, the machine was then set to a voltage of 30 kV and current of 1mA, these are required to produce the x–ray to excite the sample for 10 minutes.

Five gramme of unleached RHA was mixed with the binder and pellet of similar size as the previous was produced using the manual compression machine. This pellet was equally loaded into the sample chamber of the spectrometer and the machine was set at the same voltage and current as in the first case. This sample is meant to serve as a control for the experiment.

RESULTS AND DISCUSSIONS

It was observed that the ash produce after the calcination of RH is white, indicating the complete combustion of carbon. The result of the chemical analysis of rice husk ash which was carried out using X–Ray Fluorescence (XRF) is shown in Table 1.

Table 1: Chemical Analysis of Rice Husk Ash

Components (Oxide Element)	Composition by Weight (%)	
	Control	Leached Sample
SiO_2	79.30	92.80
P_2O_5	6.98	0.001
K_2O	5.64	1.43
CaO	3.06	1.40
Al_2O_3	2.54	0.002
MgO	0.06	0.001
Fe_2O_3	1.00	0.8
TiO_2	0.44	0.12
MnO	0.33	0.21
SO_3	0.24	2.40
BaO	0.20	0.0098
ZnO	0.15	0.055
Cr_2O_3	0.024	0.23
CuO	0.02	0.058
V_2O_5	0.01	0.008

It can be seen from the table that the result of the chemical analysis showed that RHA contains a high percentage of silica (SiO_2) along with thirteen (13) oxides components as impurities. The oxides of Phosphorus (P), Potassium (K) and Calcium (Ca) and Aluminium exist in a considerably higher percentage than other elements which are less than one percent, this could be because these elements are essential nutrient uptake by the plants as such exist in larger quantities than other metals [8].

It can also be seen from the table that the Silica content of the unleached rice content was 79.3%. However, on treatment with HCl acid, the content increased to 92.8%. Though this is not the purest form of silica in RHA as others researchers have found higher values using other methods, for example, Ma et al., [9] used NH_4F to extract silica from RHA and was able to obtain Silica with purity levels of 94.6%.

Likewise, Bakar, Yahya, & Gan [10] who used hydrochloric acid and sulphuric acid to pre–treat RHA before heating in an oven found out that the Silica content of the RHA had increased to up to 99.6%. In the same vein, Liou & Yang [11] found out that the silica content of RHA could be enhanced to up to 99.48% by extracting the silica from a leached RHA using NaOH. Reports on the varying composition of rice husk ash and silica content is largely dependent on many factors such as the type of fertilisers employed, variety of rice paddy and climatic or geographical factors [12]. These findings notwithstanding, it can be said that the silicate content of RHA in this study has been found to increase by up to 13.5% by leaching with HCl acid.

Leaching RHA with HCl acid has also been found to affect the percentage of metal impurities, as can be seen in Table 1, the content of phosphate (P_2O_5) which have been found to reduce the strength of Portland cement (when RHA is used as cement additive) [13], [14] has reduced from 6.98% to 0.001%. This reduction is quite significant, it shows that the potentials for use of RHA as cement additive can be greatly improved by leaching with HCl acid.

The Potassium Oxide (K_2O) content of the RHA was found to have dropped from 5.64% to 1.43% upon leaching with HCl acid. This enhances the viability for the industrial application of RHA especially as cement additive as potassium oxide is undesirable in cement as it causes damage to kiln and attacks reinforced concrete [15].

It was also found that the leaching process with HCl acid reduced the Calcium Oxide (CaO) content of the RHA from 3.06% to 1.40%, this makes the usage of the RHA for the production of glass more suitable as higher CaO content in glass makes it more prone to devitrification thus making it less desirable for usage especially at elevated temperatures [16]. The brittleness of components produced using RHA can equally be significantly reduced when the Al_2O_3 content of the RHA additive is leached with HCl acid thus reducing its presence from about 2.54% to about 0.002% as seen in Table 1. The percentage content of all metal impurities in the RHA was found to have been reduced except for Cr_2O_3 and CuO which were found to have increased from 0.024 to 0.23 and 0.02 to 0.058 respectively.

Without a doubt, the leaching of RHA with HCl acid greatly improves its usability and desirability for industrial application as the silica content is enhanced and the content of undesirable metal oxides present in the ash is largely diminished.

CONCLUSIONS

This study reveals that biosilica with a high percent purity of 92.8% with minimal impurities can be produced from RHA by simple leaching with HCl acid. This suggests that HCl acid has proved to be effective in removing mineral contaminants, thereby improving the purity of silica content in RHA composition and making it more suitable for industrial applications.

Other researchers can vary the concentration of the HCl acid to see if it has any effect on the purity level of the biosilica produced and the mineral oxide impurities.

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[1.]Iuliana GĂGEANU, [1.]Ana–Maria TABARASU, [1.]Catalin PERSU,
[1.]Dan Iulian CUJBESCU, [1.]Gabriel GHEORGHE, [2.]Catalin DUMITRESCU

EXPERIMENTAL RESEARCH ON OBTAINING BIOMASS TABLETS

[1.]National Institute of Research – Development for Machines and Installations Designed to Agriculture and Food Industry – INMA Bucharest, ROMANIA
[2.]INOE 2000 – Subsidiary Hydraulics & Pneumatics Research Institute, ROMANIA

Abstract: Renewable energy technologies have the great advantage of using inexhaustible, low–polluting resources with an insignificant contribution to climate change. In addition, their use reduces dependence on conventional resources that will be depleted in the not–too–distant future. Solid biofuels are produced from biomass materials, especially wood, and are new fuels that meet the new requirements of using "clean" and regenerative energy. The paper presents a series of experimental research for obtaining biomass tablets using specially designed equipment, which are a viable solution for the recovery of lignocellulosic waste from vineyards and orchards and beyond.
Keywords: biomass, lignocellulosic waste, agricultural waste, tableting, solid biofuels

INTRODUCTION

Agricultural activity is a source of greenhouse gases (GHGs), but also an absorber, especially by storing carbon dioxide in soil organic matter and biomass (INMA Bucharest, 2008; Golub et al., 2020; Kukharets et al., 2020).

In terms of emissions absorption, agriculture and forestry, unlike other economic sectors, have the ability to fix carbon in the atmosphere through the process of photosynthesis and sequester it in soil and biomass. In particular, pastures, wetlands and forests have the ability to fix carbon in large quantities. On the other hand, carbon stocks may be lost, for example as a result of land use change (deforestation, pasture ploughing, wetland drainage, etc.) or as a result of extreme weather events (storms, fires, etc.), which leads to the rapid release of carbon stored in the atmosphere in the form of CO_2 (Matache et al., 2011, Capareda S.C., 2014).

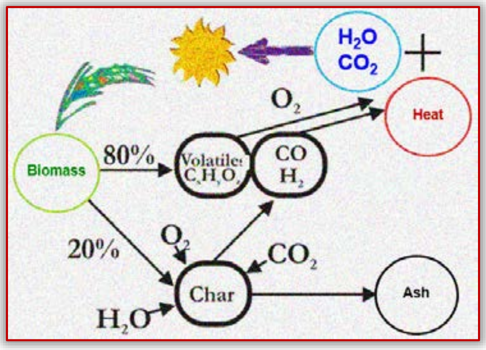

Figure 1 – Biomass combustion diagram and closed carbon circuit (Gurau L., 2016)

Biomass produced in agriculture and forestry and used for energy (energy from renewable sources) or as a raw material (biomaterials, plant chemistry) is another way to increase carbon sequestration (INMA Bucharest, 2008; Tumuluru et al., 2010, Voicea et al., 2014; Vladut et al., 2010).

The most efficient mechanism for capturing solar energy on a large scale is biomass growth. The total amount of carbon in biomass can produce 110 times more energy than human energy needs (Milko et al., 2020).

During the period of cheap oil, which ended in the 1970s, biomass as an energy resource was secondary. Currently, biomass is considered one of the main sources of renewable energy of the future, due to its great potential and the various related positive effects on social and environmental issues (Tabil & Kashanienejad, 2011).

The energy content of biomass can be used by direct combustion or by chemical conversion into fuels, followed by combustion. Biomass has a very important role in fixing carbon dioxide in the atmosphere, the ambient air with an average concentration of 350 ppm (parts per million) carbon dioxide is also an important reserve (Romania's Energy Strategy 2019–2030; Ungureanu et al., 2018; Voicea et al., 2015).

In all European countries, various lignocellulosic biomasses have started to be used to produce renewable energy (European Commission, 2005). Out of these, we can mention agricultural residues (straw, straw containing manure) or fractions of solid municipal waste available in large quantities, but little of this potential is currently used. Not all wastes have an adequate content for their treatment with the help of available techniques for transforming lignocellulosic biomass into renewable energy such as anaerobic digestion, ethanol production or thermal recovery (European Commission, 2005).

Forest waste includes unusable waste, dry trees, trees that do not meet commercial standards, and other trees that cannot be marketed and must be cut down to clear the forest. Some species of energy plants also belong to the category of woody biomass, these being for example fast–growing trees (Vladut et al., 2012).

In order to increase the density of biomass and to allow the automation of the combustion process, it is currently used to transform biomass into pellets, briquettes of tablets.

The paper presents an experimental research on obtaining tablets from biomass residues using a specially designed tableting equipment, this being a solution for the recovery of lignocellulosic waste.

MATERIALS AND METHODS

In the current climate and environmental context, it is desired to obtain energy from green fuels by energy recovery of biomass and biofuels and also increase the quality of the environment, thus meeting the requirements of the European Union, the use of biomass for energy purposes. Among the objectives achievable after conducting research and implementing the results, there are: promoting clean energy technologies; obtaining additional energy resources, different from the traditional ones; adoption of environmental protection measures; management and recovery of ligno–cellulosic residues from horticultural exploitations in biofuels with energy values.

The experimental model of ligno–cellulosic waste tableting equipment – TDL (figure 2), is composed of a compaction die, a compaction assembly with hydraulic compaction cylinder that presses the biomass, forcing it to reduce its volume, a feed hopper with auger that feeds the die biomass material, a die closing plate, a hydraulic cylinder for emptying the die by moving the plate in the closed–open position, a hydraulic group which powers and actuates the 2 cylinders, fitted with hydraulic distributors, 5 proximity sensors that allow to control the movement of the cylinders during the compaction process and an automation box where the control of the whole system is done.

Figure 2 – Experimental model of lignocellulosic waste tableting equipment

The experimental model of ligno–cellulosic waste tableting equipment is designed to obtain compacted solid biofuel – tablets that can be used both as a biofuel for heating and as a material for the production of smoke and heat for protection during late spring frosts / hoars.

The mass of material is introduced into the feed hopper of the equipment, and from here, it is taken up by the transportation auger and reaches the tableting die, where it is compressed by the piston connected to the hydraulic installation, thus forming the tablets. The evacuation of the tablets takes place at the bottom of the equipment, immediately below the die, by pushing it outwards by the evacuation piston.

The material used for obtaining compacted tablets was represented by woody biomass: sawdust (figure 3) and mixture of sawdust and agricultural vegetable residues (figure 4).

The following methodology was used for obtaining tablets with the equipment:

≡ the biomass materials used as raw material were crushed to the desired dimensions;
≡ the initial moisture of the raw material was determined by means of the drying oven and the thermobalance and the material was brought to the desired moisture by drying or spraying with water;
≡ the mass required for each batch was measured using a balance;
≡ the mass of material was homogenized;
≡ the actual process of obtaining the tablets was performed using the tableting equipment (figure 5).

Figure 3 – Sawdust used for obtaining tablets

Figure 4 – Biomass mix used for obtaining tablets

A total amount of 5 kg of material (introduced into the feed hopper) was used for each material batch (sawdust or sawdust and agricultural residues mix).

Figure 5 – Aspects from experiments

RESULTS

After conducting the tableting process, tablet samples were collected (figure 6) to be analysed.

During and after conducting the experiments, a series of very important parameters in the production process were monitored for each sample: tableting time, tablet length and diameter, calorific value, ash content, moisture, tablet density, volatile matters content.

Figure 6 – Pellet samples obtained using the tableting equipment

Table 1. Compaction time per tablet

Sample 1	Sample 2	Sample 3	Average
Time [seconds]			
30	31	27	29.33

To determine the length and diameter of the tablets, tablets were randomly selected and were measured in order to determine their length and diameter, the results being shown in Table 2.

Table 2. Biomass tablet length

Sample		Length [mm]	Diameter [mm]
Sawdust	1.	44	120
	2.	46	120
	3.	43	121
	Average	44.33	120.33
Sawdust and agricultural residues mix	1.	41	124
	2.	40	126
	3.	38	128
	Average	39.66	126

From table 2 it can be seen that tablets obtained using a mix of sawdust and agricultural residues (cereal straws) had a smaller length, meaning that the initial material had more spaces between particles, but they had higher diameter, meaning that they started to expand after existing the compaction die.

The calorific value of tablets was determined using a CAL3K–U Oxygen Bomb Calorimeter System, according to the method described in the standard SR EN 18125: 2017 – Solid biofuels. Determination of calorific value. The ash and volatile matter content were determined using a calcination furnace, according to the method described in standards SR EN ISO 18122:2015 – Solid biofuels – Determination of ash content, respectively SR EN ISO 18123:2015 – Solid biofuels – Determination of the content of volatile matter.

Moisture content was determined by drying tablet samples in a drying oven according to the method described in standard ISO 18134–1:2015 – Solid biofuels – Determination of moisture content – Oven dry method – Part 1: Total moisture – Reference method. The results of the determinations are given in Table 3.

From table 4, it can be seen that tablets obtained from the mixture of sawdust and agricultural residues registered smaller unit densities, due to the fact that they started expanding after they exited the die.

Table 3. Calorific value, ash, volatile matters and moisture content of tablets obtained

Samples		Calorific value [MJ/kg]	Ash content [%]	Volatile matter content [%]	Moisture content [%]
Sawdust	1.	16.41	6.53	71.84	8.25
	2.	16.13	6.78	72.19	8.46
	Average	16.27	6.655	72.59	8.36
Sawdust + agricultural residues mix	1.	14.22	7.41	72.21	9.54
	2.	14.16	7.52	75.21	9.73
	Average	14.19	7.465	75.08	9.64

To determine the tablets' unit density, the formula $\rho = m / v$ was used, where ρ is the unit density, m is the mass of the tablet and v is the volume of the tablet. The results are shown in Table 4.

Table 4. Unit density of the tablets obtained

Sample		Unit density [kg/m^3]
Sawdust	1.	441.21
	2.	434.82
	3.	436.47
	Average	437.50
Sawdust + agricultural residues mix	1.	389.52
	2.	387.15
	3.	391.73
	Average	389.47

CONCLUSIONS

Romania has sufficient biomass resources to obtain solid biofuels at small scale or at an industrial level, the raw material being generally agricultural and forestry residues that are available in all regions and to any category of population. Biomass compaction is one of the easiest and overall affordable ways to convert biomass into biofuels that are also possible to burn in already existing wood burners.

Tablets represent an affordable way to compress biomass, tableting equipment having simpler construction than pelletizers or briquetting machines, translated into easier and less resource consuming maintenance. Biomass tablets obtained from sawdust and sawdust + agricultural residues mix have good quality in terms of moisture, calorific value, volatile matter content. Tablets obtained from the sawdust and agricultural residues mix have lower densities, but they can still be successfully used as solid biofuel and have the advantage that they can also be used as smoke / heat material in burners for orchards / vineyards protection.

Acknowledgement

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Research & Development Institute for Food Bioresources (IBA Bucuresti), University of Agronomic Sciences and Veterinary Medicine of Bucuresti (UASVMB), Research-Development Institute for Plant Protection – (ICDPP Bucuresti), Research and Development Institute for Processing and Marketing of the Horticultural Products (HORTING), Hydraulics and Pneumatics Research Institute (INOE 2000 IHP) and Romanian Agricultural Mechanical Engineers Society (SIMAR), in Bucuresti, ROMANIA, in 29 October, 2021.

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[1.]Nicoleta Alexandra VANGHELE, [1.]Adriana T. MUSCALU, [1.]Andreea MATACHE,
[1.]Ancuţa Alexandra PETRE, [1.]Dumitru Bogdan MIHALACHE, [1.]Mariana Mădălina STANCIU

USE OF BAMBOO BIOMASS FOR THE PRODUCTION OF SOLID BIOFUELS

[1.] National Institute of R&D for Machines and Installations Designed to Agriculture and Food Industry (INMA), Bucharest, ROMANIA

Abstract: Bamboo is a versatile, fast–growing plant that is found in abundance, especially in Asian countries. Bamboo is also a plant that fits perfectly with many of the UN's goals of sustainable development, increasing the use of energy from renewable sources, combating poverty, or even reducing the effects of climate change and soil erosion. Precisely because of this abundance in recent decades, the fields in which bamboo is used have become increasingly diverse. Due to the high values of caloric power, volatile substance content and low ash and moisture content, bamboo is a suitable crop for bioenergy production. As the cultivation of bamboo does not require large investments, it can also be grown by individual producers. Due to its many benefits, this species is an ideal crop, especially for part of the population of some developing countries. This is used in agriculture, furniture, food and pharmaceuticals and cosmetics. The processing of bamboo results in a significant amount of plant residues that can be transformed into biomass. In addition to the use of bamboo biomass for energy production after obtaining and using pellets, briquettes or even coal, it can also be used as mulch to increase the yield of agricultural crops. Globally, the consumption of natural resources in addition to depleting the planet's reserves, generating numerous pollutant emissions, should be monitored to detect especially the causes that cause its increase, in order to reduce the danger of extinction of life on the planet. This paper presents a brief summary of some uses of bamboo biomass for the production of solid biofuels such as stains, briquettes and coal.
Keywords: bamboo, biomass, pellets, briquettes, charcoal

INTRODUCTION

Bamboo is part of a large family of herbaceous plants, the family Poaceae, characterized by a fast pace, which can be grown sustainably in various parts of the world. Thus, plants in this family are found in various geographical areas, located in Africa, Asia, Australia, India and America (Newell, J (2004).

Bamboo is a sustainable resource, which can grow in different climatic conditions, preferring especially tropical areas. This species contributes substantially to the improvement of air quality, as it releases approx. 35% more oxygen and absorbs approx. 40% more carbon dioxide than trees. Planting bamboo is also beneficial for fixing carbon, against soil erosion and purifying the environment. (Bamboos Market Size, 2019).

Bamboo forests cover an estimated area of 37 million hectares (ha), equivalent to almost 4% of the total forest area in the world (FAO 2014) (Food and Agriculture Organization of the United Nations. Improving the socio–economic benefits of forests. The state of the world forests 2014. Rome Italy 2014). There are also some varieties of this species that grow successfully in mild temperate areas in Europe and North America (INBAR 2015a).

As the cultivation of bamboo does not require large investments, it can also be grown by individual producers. Due to its many benefits, this species is an ideal crop, especially for part of the population of some developing countries.

Bamboo is also a plant that fits perfectly with many of the UN's goals of sustainable development, increasing the use of energy from renewable sources, combating poverty, or even reducing the effects of climate change and soil erosion.

Compared to the chemical composition of wood, the cellulose content of bamboo is lower, being similar to that of softwood. Also, the lignin content is between that of softwood and that of hardwood. The ash content of bamboo is 3 to 4 times higher than that of wood. (Ye CY, et al. 1989).

Due to the high values of caloric power, volatile substance content and low ash and moisture content, bamboo is a suitable crop for bioenergy production. (Kumar R. and Chandrashekar N., 2014).

Biomass, by definition, consists of the biodegradable part of plant material, which is the most abundant renewable resource on the planet. (T.C. Maria, et. Al.2011). It can be said that biomass is the first form of energy used by man, with the discovery of fire.

Globally, the consumption of natural resources in addition to depleting the planet's reserves, generating numerous pollutant emissions, should be monitored to detect especially the causes that cause its increase, in order to reduce the danger of extinction of life on the planet (Darie, Silviu 2020).

Out of the desire to find an alternative source of energy to replace fossil fuels, which are depletable sources, the possibility of using bamboo residues (plant residues) as biomass for biofuel production was studied (Pongthornpruek S. and Sasitharanuwat A., 2019).

Thus, in addition to the use of bamboo biomass for energy production after obtaining and using pellets, briquettes or even coal, it can also be used as mulch to increase the yield of agricultural crops. (Usio, N., et. Al. 2021).

MATERIALS AND METHODS

— Bamboo pellets

Biomass pellets are one of the products developed as an alternative to new energy sources used as fuel. So pellets are a biofuel produced from wood waste, agricultural residues, energy crops, which come in the form of cylindrical granules, characterized by certain standard sizes. Thus the diameter is between 5 ... 8 mm, and the length has variable dimensions, reaching up to approx. 50 mm. (Gageanu I., et. al. 2016).

The technology of obtaining the pellets (Figure 1) consists in introducing the ground biomass from a feed hopper in a compaction chamber, from where it is directed and forced to pass through a cylindrical hole, at very high pressures, in certain suitable conditions (possibly of high temperature and a certain humidity), so that the raw material can be transformed into a compact solid mass of cylindrical shape. (Gageanu I., et. al. 2016, Vlăduț V. et.al. 2012).

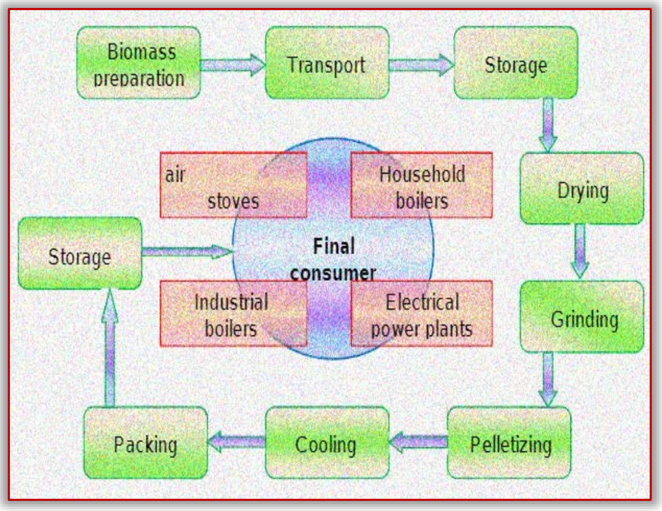


Figure 1. The stages of the technological process of pellet manufacturing (Vlăduț V. et.al. 2012)

Biomass raw materials that can be transformed into pellets are numerous, the most commonly used being: wood, branches, sawdust, wood chips, peanut shell, sunflower peel, sugar residue, yeast, coconut shell, coffee grounds, corrugated cardboard, straw, cotton swab, tobacco waste, mustard stalk, jute waste, rice husk, bamboo chips, bamboo dust, tea waste, wheat stalk, palm fruit husk, soybean bran or other forest or agricultural waste (Figure 2).

Figure 2. Biomass raw materials (Source: www.bestbriquettepress.com)

The manufacturing process of bamboo pellets is the same as for pellets obtained from other types of biomass. The raw materials are ground into powder before being pressed, obtaining pellets with diameters between 6 and 12 mm. Bamboo pellets can be made from stems, leaves or even powders that come from making various objects (www.bestbriquettepress.com). Bamboo pellets have satisfactory burning characteristics and high mechanical strength (Jacky Michael Pah, et.al., 2019).

— Stages of the process of obtaining bamboo pellets

- Grinding and drying bamboo is done to turn the raw material into powder, usually using a hammer mill. Before starting the grinding process, dust and any foreign matter must be removed from the raw material. After crushing, the raw material is dried using a rotary dryer, so that the humidity of the resulting pellets is reduced, below 10%.
- Manufacture of pellets, consists in compressing the dry powder into pellets, at high pressure and speed using a press, also known as a bamboo pellet machine.
- Cooling and storage of pellets is done immediately after the pelletizing process by lowering the temperature, to improve quality and durability. Then the pellets are stored in places free of moisture. (http://www.gcmec.com).

— Bamboo biomass briquettes

The materials from which the briquettes can be obtained are the same as in the case of pellets. Lighters are considered to be the best way to replace firewood. Since the late 90s, the demand for lighters used for heating the house, either for fireplaces or stoves, has increased, being still on an upward slope (Martha Andreia Brand et. 2019).

The process of obtaining bamboo briquettes is similar to that of obtaining pellets, namely: first the raw material is crushed using a hammer or roller crusher. After chopping, the raw material is dried, then placed in a press to obtain the actual briquettes, which are then dried to be stored at the end.

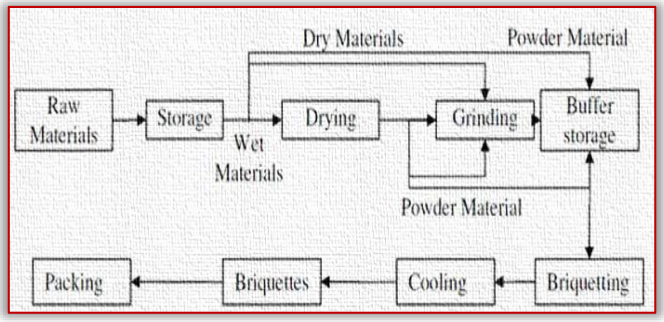


Figure 3. Scheme of the biomass briquetting process (Source: www.bestbriquettepress.com)

— Bamboo charcoal

By definition, bamboo charcoal is the product obtained by subjecting bamboo to the process of pyrolysis. Bamboo charcoal can be classified into raw bamboo charcoal and bamboo lighter charcoal, depending on the raw material used (https://en.wikipedia.org/wiki/Bamboo_charcoal).

Bamboo charcoal (Figure 4) has a micro–porous structure with countless small cavities. Compared to charcoal, bamboo charcoal has about four times more cavities and a larger specific surface area.

Depending on the end use, the quality of the coal can be measured and specified in various ways. Normally, the amount of heat obtained by burning coal and the yield of the object to be heated to which the appropriate combustion equipment is added are the main criteria for assessing the maximum coal yield. (James G. Speight, 2020).

Two processes are used for carbonization: one of combustion that takes place directly in an oven, the other being a mechanical process (Pei–Hsing Huang et. Al. 2014).


(a)


(b)


(c)

Figure 4. Bamboo charcoal (a) www.pinimg.com; (b) https://yo–holding.com/bamboo–coal; (c) https://yo–holding.com/bamboo–coal

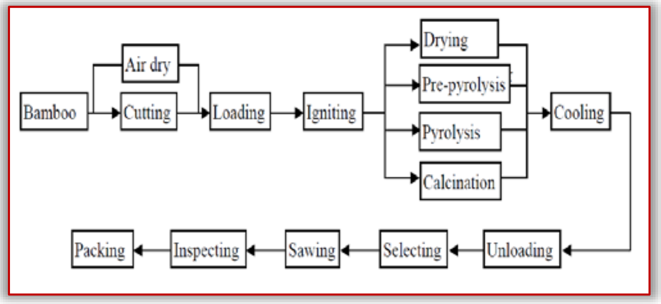


Figure 5. The process of bamboo charcoal production (J. Shenxue 2004)

In the 1990s, a carbonization chamber built in the ground was used to produce bamboo charcoal. However, this method does not ensure the obtaining of quality coal, in addition, not being at all in accordance with the rules of environmental protection. Therefore, after more than ten years of experiments and improvements in bamboo charcoal manufacturing technology, the use of pear (brick) kilns has been used. A mechanical kiln is used to produce bamboo charcoal briquettes. The bamboo charcoal production process is shown in Figure 5.

RESULTS

— Equipment used for processing bamboo biomass

Figure 6 shows a pellet manufacturing plant produced in China by Zhengzhou Leabon Machinery Equipment Co., Ltd. It consists of machinery that performs the steps of the manufacturing process presented above. This plant is designed to turn bamboo biomass into pellets. Depending on the chosen model, the working capacity can be between 400 – 1000 Kg / h, and the drive can be provided by an electric motor, a diesel engine or a tractor (https://www.zzleabon.com).

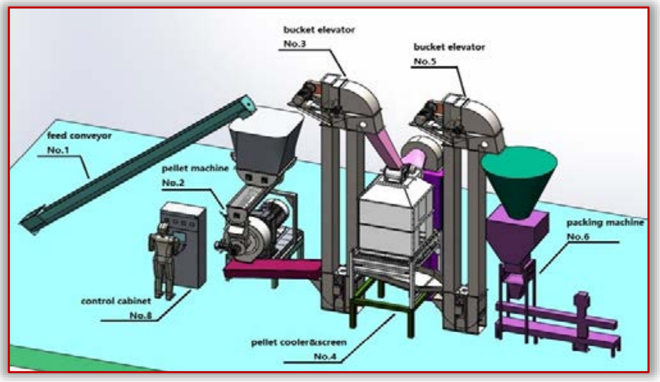


Figure 6. Agro Waste Pellet Mill Installation (Source: https://www.zzleabon.com)

Gemco (China) produces several types of equipment for the manufacture of pellets (Figure7). The operation of the equipment can be ensured by: electric motor, diesel engine, gasoline engine or a tractor, the equipment being classified according to this criterion. Equipment can also be classified according to the field of use of the pellets: for burning (energy production) or for animal feed (http://www.gemco–energy.com)

The main element of this machine is the granulation chamber, where the material loaded by the feeding system is compressed between the roller press and the mold. With the help of the knife, the pellets coming out of the holes of the flat mold are cut, being then collected in a container of dimensions and subsequently, stored.

Figure 7. ZLSP 420 Wood Pellet Mill Machine (Source: http://www.gemco–energy.com)

HENAN RICHI MACHINERY CO., LTD (China) produces the MZLH pelletizer, this being a new type of machine for the production of biomass pellets, with high efficiency.

The raw material consists mainly of various wastes and bamboo chips. The feeding system ensures a uniform supply with the crushed raw material, centrifuged by the rotation of the mold ring. The material is then subjected to an extrusion process, being pressed and molded into the mold. The process is continuous, and the product discharged from the mold, having a columnar shape is dimensioned to a certain length, by a cutting system.

Figure 8. MZLH pelletizer (Source: https://www.pellet–richi.com)

The equipment for the manufacture of bamboo biomass briquettes is very varied, being represented by the models of manual presses (Figure9) up to the fully automated ones.

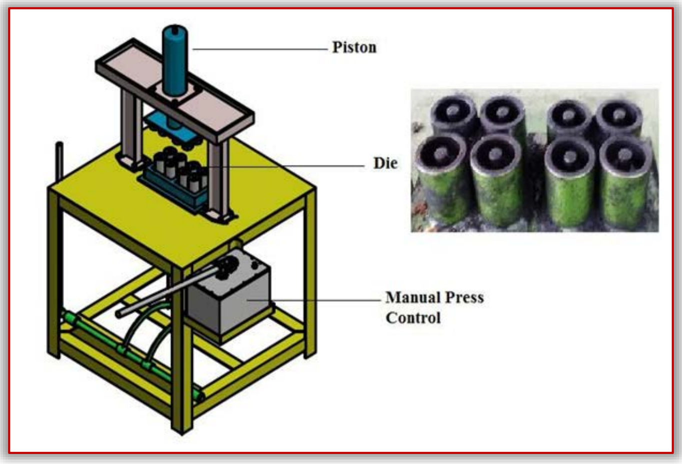
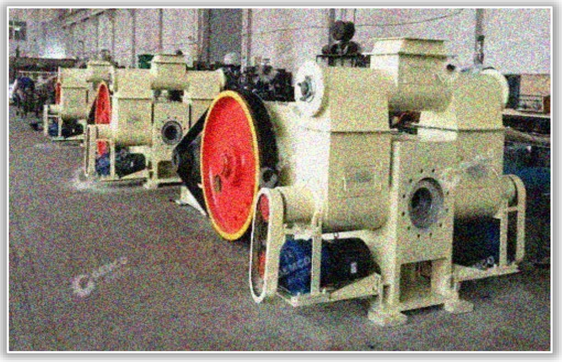


Figure 9. Isometric view of the manual briquetting hydraulic press machine. (Mallika Thabuot et al. 2015)

Gemco Enery manufactures several types of machines for obtaining bamboo briquettes, classified according to the method of pressing: Biomass briquetting machine by stamping, Screw briquetting machine, as well as a complete biomass production line.



(a)

(b)

(c)

Figure 10. Types of equipment for the manufacture of briquettes (Source: http://www.gemco–energy.com)
(a) Biomass briquetting machine with stamping; (b) Screw briquetting machine; (c) Complete biomass processing line

Beston (China) has developed a machine model for the manufacture of bamboo charcoal using One Step Two Fire technology (Figure11). This technology is applied to obtain coal and bamboo by–products (tar and wood vinegar). Four models of this machine are available, classified according to the supply capacity between 0.5 and 5 t / h and the engine power between 45kw / h and 125kw / h.

Figure 11. Beston bamboo charcoal machine
(Source: https://bestonmachinery.com)

ABC Machinery Co., Ltd. (China) builds a production line of bamboo charcoal making machines, with a production capacity of 2 t / day. The raw materials used to make bamboo charcoal are bamboo chips, bamboo powder, to which wood chips and sawdust are added.

The manufacturing process consists in crushing the raw material, drying, briquetting, carbonizing it, resulting in the final product – coal. Figure 12 shows the main components of the production line:

1. Crushing system;
2. Drying oven and main pipes;
3. Drying system and evacuation of materials;
4. Screw feeding system;
5. Briquetting system (biomass chopsticks production capacity 500 kg h–1);
6. Carbonization system (with a manufacturing capacity of coal briquettes of 2 tons / day);
7. Cooling system;
8. Air circulation system.

The main advantage of this production line is energy efficiency, because the carbonization process uses the gas recirculation system. Once the carbonization system is turned on, the waste generated can be recycled without adding new fuel to continue production.

Figure 12. Bamboo Charcoal Making Machine Production Line
(Source http://www.bestbiomassmachine.com/)

CONCLUSIONS

Both pellets and bamboo briquettes are a source of renewable energy and thus an alternative to traditional fuel sources, achieving a cost reduction of up to 50%.

They have multiple advantages such as:

≡ are environmentally friendly, as less than 1% of their contents become ash. They also have very low gas emissions as they burn;
≡ has calorific value compared to coal (approximately 4800 kcal) being much more compact;
≡ they have a small table, their transport and storage, being done easily.
≡ can serve as fuel for heating, cooking or steam generators.

In addition to being used as a fuel, bamboo charcoal has multiple uses in the pharmaceutical and cosmetics industries. Due to its ability to regulate humidity, bamboo charcoal is used in deodorants, soaps or various types of cosmetic creams. In addition, the microporous structure makes it a unique and natural absorption system, like a hard sponge that can catch impurities, harmful materials and gases. This property is recommended for deodorization, purification, moisture control and even for the treatment and treatment of wastewater.

Solid bamboo biofuels are a renewable and energy efficient resource, important for the current context.

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[1.]Marina Cristinela ŢUCUREANU, [1.]Carmen Otilia RUSĂNESCU, [1.]Larisa PURDEA,
[1.]Mihaela BEGEA, [1.]George IPATE, [1.]Alexandru CÎRÎC

ASPECTS REGARDING THE STABILIZATION OF RESIDUES RESULTING FROM WASTE INCINERATION

[1.] University POLITECHNICA Bucharest, Faculty of Biotechnical Systems Engineering, ROMANIA

Abstract: In this paper are presented the methods of stabilizing the residues resulting from waste incineration. The main components which pollute the environment and human health that are found in this type of waste are: heavy metals: Cd, Cr, Cu, Ni, Pb and Zn, dioxins. Residue treatments are needed to reduce the impact on the environment. The methods of separating the contaminants from the waste incineration residues presented in the paper are: separation by water use, separation by acid use, separation by the use of microorganisms, separation by electrodialysis. The methods of heat treatment of residues from waste incineration are: vitrification, smelting, sintering, pyrolysis, physical and chemical separation. Methods of chemical stabilization of contaminants from waste incineration are performed with: iron oxides, carbon dioxide and phosphoric acid, using phosphate as a stabilizing agent, which binds heavy metals in the form of phosphate minerals, stabilization using sulfur that binds heavy metals into insoluble compounds. Heat treatments reduce the volume of waste by 60% or more to almost 95%.
Keywords: stabilization, solidification, vitrification, incineration, sintering, pyrolysis

INTRODUCTION

The development of the economy and urbanization have led to an increase in the quantities of solid waste generated, opting for their heat treatment processes through incineration units. This method of waste treatment has also grown due to the filling up to maximum capacity of existing landfills, requiring the creation of new landfills that negatively influence the quality of air, water and public health (Gong, B., et al, 2017).

The composition of industrial waste varies, including in this category hazardous waste that is usually loaded with heavy metals toxic to environmental factors, such as Cd, Cu, Cr, As, Pb (Nicolae, A., et al, 2020). Heavy metals are not biodegradable and tend to accumulate in living organisms and affect environmental factors, requiring the application of treatments to eliminate and capture them.

Waste incineration is an alternative method of waste management (Ioana, A., et al, 2016; Ţucureanu, M., et al, 2019). Due to the capacity of the waste reduction process, waste incineration has advanced in the face of waste disposal. However, the waste incineration process generates residues that are mainly divided into fly ash and bottom ash (Gong, B. et al, 2017).

An integrated part of waste management systems is the management of waste from their heat treatment. The main purpose of the management of waste incineration is to prevent any impact on human health or the environment which is characterized by emissions of particulate matter or emissions of substances (Sabbas, T., et al, 2003).

Fly ash resulting from the waste incineration process is a dangerous by–product because it contains heavy metals such as Cd, Zn, Pb, Hg, Cu, Cr, etc., and the readability of these heavy metals is outside the regulations in most cases (Gong, B. et al, 2017).

Due to these harmful compounds found in the resulting residues, their stabilization treatments are used such as thermal processes, stabilization / solidification processes and separation processes.

The washing process can separate a large proportion of heavy metals and soluble salts contained in the residues resulting from the waste incineration process. In this treatment a liquid base such as water or an aqueous acid solution is used, reducing the concentrations of chloride and heavy metals. The reduction of the concentrations of heavy metals and chlorides is not significant, hardly complying with the regulations of the legislation in force, being necessary the application of other treatments (Gong, B. et al, 2017).

Washing with acid–based solutions is more efficient for removing heavy metals from bottom residues compared to washing them with plain water. Regardless of the liquid used for washing, the wastewater used in this process captures heavy metals and soluble salts, thus creating a secondary source of pollution (Gong, B., et al, 2017).

Stabilization / solidification treatments are the most common techniques in waste treatment, in the treatment of residues from waste incineration, this treatment manages to limit the leakage capacity of heavy metals by forming constant blocks or inert compounds by adding additives or binders (Gong, B. et al, 2017).

This type of treatment comprises the following steps: solidification, stabilization, hydration and precipitation reactions. The solidification step is a process for mixing the residues with liquid following the solidification of the suspension.

Heat treatment of stabilization of residues is a promising method for fixing heavy metals by heating the residues to very high temperatures between 700–1600°C. This type of treatment is characterized by vitrification, sintering and melting of solidified residues (Gong, B., et al, 2017). As hazardous waste, the residues from the control of air pollution are most often stored in special landfills without taking into account their recovery (Lam Charles, et al, 2010; Bacinschi, Z. et al, 2010; Purdea, L., et al, 2019; Rusănescu, CO, et al, 2019).

All treatments for waste incineration developed in recent years are based on principles such as changing their character from hazardous to non–hazardous and even inert, (Lam Charles, et al, 2010). Residues of solid, liquid or gaseous nature result from the waste incineration process. The volume of these residues represents about one tenth of the initial volume of waste (Sabbas, T., et al, 2003). The residues resulting from incineration are: bottom ash, ash resulting from the boiler and economizer, residues from the control of air pollution, fly ash, residues from the sieving area of the grate.

MATERIALS AND METHODS

Figure 1 shows the methods for treating waste from incineration of waste.

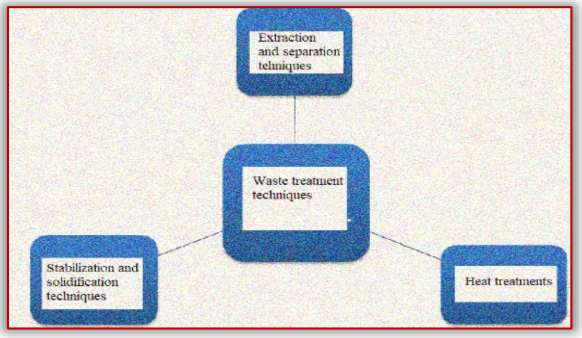

Figure 1 – Waste incineration techniques

The methods for separating contaminants from waste incineration waste are:

Separation by the use of water, the mixing of water with the residues resulting from the incineration of waste results in the formation of an alkaline suspension characterized by a pH with a value close to 11–13 but also with high concentrations of salts such as Cl, Na. The suspension also contains heavy metals such as Pb, Zn, Cr and As.

Separation using acid, acidic solutions extract the salts present in the residue. Due to the solubility of heavy metals at lower pH values, the use of acid is more efficient for heavy metals in the residue, so the acid is more efficient than water. About 30–60% of the cationic heavy metal content can be removed from the residues using acid.

Separation by the use of microorganisms The processes known as bio–hydrometallurgical processes are based on the bio–absorption process, a process of physico–chemical interaction between groups of surfaces charged by microorganisms and ions in solution, in which both living organisms and the dead. In this regard, a multitude of microorganisms are known, including those such as algae, bacteria, yeasts and fungi, which can accumulate active gold, (Schaeffer, N., et al, 2018). Bio–hydrometallurgy is a process used to recover metals from solid materials such as low–grade ores.

Separation by electrodialysis Metals can be extracted by applying a stream, thus facilitating the migration of ions in a residue suspension to an anode or cathode. Ion exchange membranes can be subsequently used to separate metal ions from the suspension of treated residues, (Astrup, T., et al, 2009).

The technique requires that the metals be in the aqueous phase and the release from the solid can be optimized by resorting to complexing agents (Astrup, T., et al, 2009).

This process involves two stages and it is necessary to extract the metals in the first stage through the use of water and then apply the second stage of the separation process by electrodialysis (Astrup, T., et al, 2009).

The removal rate of metals is about 20–70% for metals such as Zn at a ratio of 5 liters of water per kilogram of residue, (Astrup, T., et al, 2009). The efficiency of metal extraction from the mixture is also due to the intensity of homogenization.

The methods of heat treatment of residues from waste incineration are: (Astrup, T., et al, 2009).

- Vitrification involves melting a mixture of glass residues and precursors such as silicon at temperatures between 1000–1500°C. In this process, the components of the residues are bonded into the glass materials, thus encapsulating the residues. The materials used to form the glass could be other types of mineral waste, the properties of the final product depending to a large extent on the additives used (Sabbasa, T., et al, 2003).
- Melting the resulting material consists of several metal phases. Process temperatures are similar to the temperatures used during vitrification, vitrification processes as well as melting processes are most often applied to residues such as bottom ash. The melting processes are similar to those of vitrification, in which case no additives are added to form the glass.
- Sintering involves heating to a stage at which the individual particles are attached to each other. The sintering of the residues was mainly used for the bottom ash, the process often involving the reintroduction of the residues in the incinerator. The temperatures at which the sintering process is performed are around 900–1300˚C producing a denser and less porous material.
- Pyrolysis is most often used for organic waste in combination with incineration residues. The residue components are then heated to high temperatures and mixed with the other products introduced into the pyrolysis process. The characteristics of the products resulting from the process of pyrolysis depend to a large extent on the waste with which the residues were mixed.

RESULTS

The main components harmful to the environment and human health found in waste are:

- Slightly soluble salts, such as Cl and Na salts;
- Heavy metals: Cd, Cr, Cu, Ni, Pb and Zn.
- Dioxins (Ahamed, A. et al, 2021).

Residue treatments are needed to reduce the impact on the environment due to the release of contaminants. The elimination of these risks can be done by binding them in the residue matrix and by removing them (Țucureanu, M., et al, 2019).

Bottom ash is a slag–like residue collected from the combustion chamber (Hyks Jiri, et al, 2011). Table 1 shows the concentrations of the elements found in bottom ash, fly ash and in semi–dry residues from an industrial waste unit (Hyks Jiri, et al, 2011).

Table 1. Chemical composition of residues from high capacity incineration plants

Element		Bottom ash	Semi–dry residues	Flying ash
Dry substance	[%]	84.9 – 97.9	95.3	98.8
Ca	[g/kg]	96.5 – 108	331	181
S	[g/kg]	3.5 – 5.6	35	57
Al	[g/kg]	39.1 – 65.6	18.3	35.7
Si	[g/kg]	198 – 248	63	90
Na	[g/kg]	23.2 – 29.4	16	42.3
K	[g/kg]	8.8 – 11.6	17.1	50
Cl	[g/kg]	3.0 – 9.0	17	122
Mg	[g/kg]	10.0 – 13.1	7.8	14.1
Fe	[g/kg]	79.9 – 100	9.7	13.8
As	[g/kg]	25.0 – 45.2	80	380
Ba	[g/kg]	1360 – 1750	620	1120
Cd	[g/kg]	2.6 – 3.7	100	240
Co	[g/kg]	20.4 – 26.2	8.9	20.9
Cr	[g/kg]	434 – 914	200	700
Cu	[g/kg]	2060 – 14300	500	1170
Mo	[g/kg]	7.62 – 20.1	9	28
Ni	[g/kg]	242 – 526	37.5	67.4
Pb	[g/kg]	1080 – 3530	2100	6800
Sr	[g/kg]	311 – 634	500	400
V	[g/kg]	40.7 – 59.3	19,8	39.7
Zn	[g/kg]	2660 – 4230	9100	31700
Sb	[g/kg]	51.4 – 105	340	1170
P	[g/kg]	3779 – 5237	3400	10000
Toc	[g/kg]	14.0 – 19.0	2,7	0.7

TOC – total organic carbon

Table 2. Treatments applicable to residues from the incineration of waste

Types of treatments applicable to residues	
Basic principle of treatment	Process
Physical and chemical separation	Dimensional separation
	Mechanical separation
	Eddy–Current separation
	Wash
	Chemical extraction
	Chemical precipitation
	Ion exchange
	Adsorption
	Crystallization / evaporation
Solidification and / or stabilization	Solidification / stabilization with hydraulic binders
	Chemical stabilization
	Aging / precipitation
Thermal treatment	Sintering
	Vitrification
	Melting

Bottom ash untreated is a heterogeneous material, consisting of calcium–rich minerals and silicate. In large incineration plants most of the bottom ash consists of molten products such as glass, iron, bones and all kinds of minerals, heavy metal contamination is low (Hyks Jiri, et al, 2011). The treatment of waste from incineration of waste must be considered an integral part of any management, use and neutralization option. A variety of treatment options for waste incineration residues have been developed for application before reuse or final disposal depending on the purpose of the waste use (Sabbasa T, et al, 2003). Table 2 shows the treatments applied to the incineration residues.

— Physical and chemical separation

The purpose of the separation methods is to improve the quality of the waste from the incineration of waste and to optimize its capacity. These techniques include processes such as: washing, leaching, electrochemical process and heat treatment, (Lam Charles, et al, 2010). The main action of these processes is based on the removal of heavy metals and salts from residues, mainly using water or acidic solutions (Astrup, T., et al, 2009).

— Solidification and stabilization

The solidification / stabilization process uses an additive or binder to chemically and / or physically fix the hazardous content in the residues. Stabilization aims to minimize the solubility and toxicity of contaminants. In the case of solidification, binders used such as cement aim to encapsulate residual materials, to immobilize contaminants and reduce readability (Lam Charles, et al, 2010).

The methods of chemical stabilization of residue contaminants from waste incineration are:

≡ The addition of iron oxides ($FeSO_4$) to a residue suspension can increase the absorption capacity of heavy metals (Astrup, T. et al, 2009). This technique involves several steps: the first step involves the extraction of water, slightly soluble salts and mixing with iron sulphate. The second stage comprises the oxidation of iron to form the precipitation of iron oxides, the adjustment of the pH to a value of about 10–11 and the dehydration of the residue.

≡ Stabilization with carbon dioxide and phosphoric acid binds metals such as carbonates or relatively insoluble phosphates. Phosphate stabilization as a stabilizing agent binds heavy metals in the form of phosphate minerals.

≡ Sulfur stabilization binds heavy metals into insoluble compounds. This technique is regularly used to treat process wastewater and residues. This process using sulfur is recommended in the case of flue gas cleaning installations. The residual sludge contains inactivated sulfur compounds that mixed with the residues can improve the leakage properties of the final product.

The latest integrated stabilization process comprises four stages, (Lam Charles, et al, 2010): removal of alkaline chlorides by dissolution; phosphoric acid additions; calcination; solidification with cement. This combined process destroys toxic organic compounds, reduces the reactivity of heavy metals and solidifies hazardous compounds without exceeding the leaching limit, (Lam Charles, et al, 2010).

Applying a combined wash–immobilization treatment to treat fly ash could remove significant amounts of chloride and sulfate and turn heavy metals into less reactive forms. At the end of the washing process, the wastewater used in this process can be treated by reducing the pH to 6.5–7.5 (Lam Charles, et al, 2010).

Solidification processes are based on processes whose purpose is to physically and hydraulically encapsulate residues and their harmful compounds.

A process of chemical stabilization involves the precipitation of insoluble compounds that incorporate metals into their composition. The use of treatments based on hydraulic or chemical binders positively influences the mechanical properties of the material (Sabbasa, T. et al, 2003).

The aging and precipitation processes are used in order to alter the physico–chemical properties of the minerals, thus reducing the trace elements such as Cd, Cu, Pb, Zn and Mo. These processes can influence the decrease of pH and contamination but also the formation of more stable mineral species. These types of processes can be applied especially to the bottom ash. After completion of the material resulting from the treatment of bottom ash, it is necessary to store it before use for periods of weeks or months. Aging and precipitation treatments can be artificially improved to accelerate the chemical reactions responsible for filtering contaminants from the waste matrix, thus using accelerated carbonation to reduce the flow of soluble salts, lead and zinc, (Sabbasa, T., et al, 2003).

— Heat treatments

The heat treatment process can reduce the volume of waste by 60% or more to almost 95%. The resulting residue is more resistant to leaching and is more environmentally stable, becoming an optimal material for applications such as use as a raw material in the construction industry. A temperature of about 1,400°C or higher will destroy dioxins, furans and other toxic organic compounds that can be found in the residue. Due to the high temperatures used in the process, the cost is usually high, and the release of contaminants during melting is possible requiring additional control of air pollution, (Lam Charles, et al, 2003). Combined treatment methods aim at the following (Sabbasa, T. et al, 2003):

- decontamination of ferrous metal residue;
- decontamination of non–ferrous metal residue;
- decontamination of the salt residue;
- optimization of the physical properties of the residue;
- optimization of the chemical properties of the residue;
- optimization of the mechanical properties of the residue;
- decontamination of the residue in order to recover it in different applications.

CONCLUSIONS

Progress has been made in recent years on integrated waste management systems. Waste treatment technology, the reduction of landfills and the recovery of waste from incineration of waste have become integrated methods of these systems. With the development of incineration lines and the appearance of more waste, the problem of pollution caused by them began to appear. These pollutants are characterized by heavy metals, salts from washing waters, or other forms of emissions. Residue treatments have been developed to reduce the risks to the environment and human health. The overall strategy that any country must take into account must be to reduce environmental pollution.

Many of the applications for waste incineration waste are still being researched and environmental and technical issues have discouraged their reuse. Even if waste treatment increases the total cost of the waste neutralization process, the benefits of recovering it are beginning to be widely observed. For residues containing significant amounts of contamination, treatment is recommended in order to reduce the rate of contamination into soil or water.

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[1.]Carmen BRĂCĂCESCU, [1.]Ancuta NEDELCU, [1.]Oana–Diana CRISTEA, [1.]Ana ZAICA

CONSIDERATIONS ON THE IMPORTANCE OF THE CONDITIONING OF INDUSTRIAL HEMP SEEDS

[1.] National Institute of R&D for Machines and Installations Designed to Agriculture and Food Industry (INMA), Bucharest, ROMANIA

Abstract: Hemp (Cannabis sativa L) is a plant whose use is expanding in countless industries. Given that there are many facilities to purchase hemp now, it is important for growers to produce the best quality product for processing. In this article, different conditioning solutions (cleaning, sorting and storage) and technical equipment are analysed in order to obtain high quality seed material or raw materials for industrial hemp processing. The quality of a crop, as well as of the products obtained after processing, crucially depends on maintaining a favourable climate during the storage period, maintaining the physical and chemical properties of the seeds resulting from the harvest. Non–compliance with the rules cancel the good practices applied by farmers during each stage prior to this time. Seed damage is associated with genotype, history and physical and chemical compositions. Hemp seed can be dried to a low moisture content and stored at low temperature for several years. In order to process, store and capitalize the seeds for sowing, immediately after harvest, must be maintained the properties of biological value, of improvement and maintenance of those of cultural value, of carrying out appropriate treatments against diseases and pests, of packaging and labelling the seeds according to destination and the provisions of the regulations in force, to periodically analyse the seeds in accredited laboratories and to deliver or use them only on the basis of quality certificates or analysis bulletins.
Keywords: hemp seed, conditioning, dryer, separator

INTRODUCTION

In order to process, store and capitalize the seeds for sowing, immediately after harvest, must be maintained the properties of biological value, of improvement and maintenance of those of cultural value, of carrying out appropriate treatments against diseases and pests, of packaging and labelling the seeds according to destination and the provisions of the regulations in force, to periodically analyse the seeds in accredited laboratories and to deliver or use them only on the basis of quality certificates or analysis bulletins (Duda M., et al., 2007).

Also, the seeds of each cultivated species can reach a maximum quality level in a complex of conditions that ensure the most favourable interactions between their genetic nature and the large number of variables during their formation on the plant and during harvesting, primary processing, conditioning and preservation (Tenu I e al., 1988; Mogârzan A. et al., 2003).

During formation and maturation there are a number of factors that can prevent this maximum level from being reached, either by all the seeds produced by the respective crop, or only by some plants or some seeds on a plant. It is generally considered that the seeds reach their maximum quality at the beginning of full maturity, and from this moment, either on the plant or in the period from harvesting to sowing, except for physiological maturation in some species, only deteriorating processes take place (Mureşan T. et.al., 1986; Jovičić D. et.al, 2019).

On the other hand, the quality of a crop, as well as of the products obtained after processing, crucially depends on maintaining a favorable climate during the storage period, maintaining the physical and chemical properties of the seeds resulting from the harvest. Non–compliance with the rules cancel the good practices applied by farmers during each stage prior to this time.

Hemp (Cannabis sativa L) is a plant whose use is expanding in countless industries. Given that there are now many facilities to purchase hemp now, it is important for growers to produce the best quality product for processing.

This article analyses different solutions for cleaning, sorting and storage in order to obtain high quality seed material or raw materials for processing industrial hemp.

MATERIALS AND METHODS

Seed damage is associated with genotype, history and physical and chemical compositions. Hemp seed can be dried to a low moisture content and stored at low temperature for several years. According to the literature, hemp seeds contain 20 ÷ 25% protein, 20 ÷ 30% carbohydrates, 10 ÷ 15% insoluble fiber and especially 25 ÷ 35% oil which was considered to be the main contributor to seed damage (Garavand et al., 2013; Mahapatra N., 2020).

The steps prior to the introduction of the seeds in the conservation depot are shown schematically in figure 1.

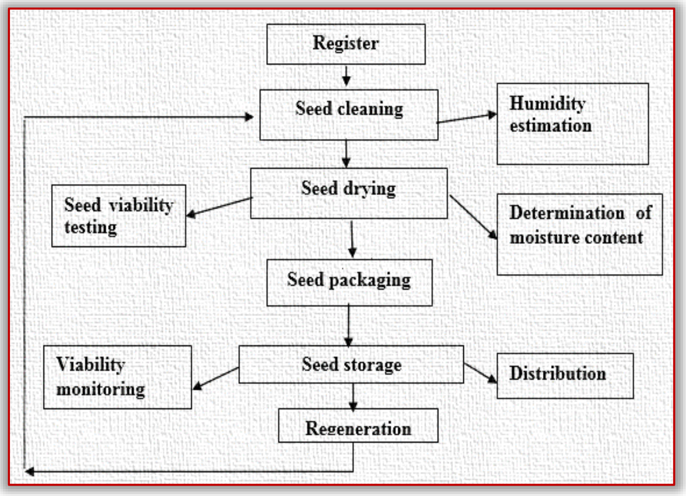

Figure 1 – The seed processing stages in order to preserve them and use as sowing material

Processors require industrial hemp seeds which are of good quality and which generally comply with the following standards and their explanations as shown in table no.1 (Kaliniewicz Z., 2021; Suriyong S. Et al., 2015).

Table 1. Requirements regarding the physico–chemical properties of industrial hemp seeds for processing

No.	Properties	Requirements	Remarks
1	Variety	From the approved list of hemp varieties	
2	Color and appearance	Brown–gray seeds	Good quality ripe hemp seeds will have dark marks on them. Degraded, immature or frozen seeds have a light brown, colorless seed layer.
3	Aroma and smell	light aroma and smell of walnut	
4	Purity	99,9% of cleaned seeds the maximum mixture of impurities is 0.1% by weight	All poor quality seeds must be removed through the cleaning process. Contamination with other crops, especially wheat, weeds and foreign materials, can lead to a repeated cleaning process and reduced or rejected raw materials
5	Toxins	acceptable levels of coliform and e–coli	–
6	Moisture	< 8÷9%.	–

To maintain optimum quality, harvested hemp seeds require immediate aeration within 3÷4 hours of harvest. Harvesting capacity should be appropriate to aeration capacity and seed drying.

Growers can improve the quality of hemp seed crops by minimizing their damage during harvesting, cleaning and handling.

Samples are taken throughout the conditioning process to ensure that the seeds are of the highest quality. After completion of the conditioning process, a sample must be sent (taken) for testing. This will ensure that the seeds meet official standards, while providing all the information needed for certification.

With the help of the technical equipment manufacturing industry, high–performance equipment has been developed to meet the processing and conditioning needs of hemp.

Drying technique is typically the single greatest determinant of end–product quality. Over–dried product will have low yield and under–dried product will mold.

Hemp seed is large, similar to wheat, and air moves through it easily (Păun A. et.al, 2018; Dudarev I. et al., 2020). One to three weeks of aeration is required to dry grain, depending on ambient conditions, grain moisture, fan and bin capacity.

Fluid beds use evenly distributed airflow to suspend and fluidize product, like ping–pongs ball over airstreams. Heat is used to improve performance, but because it is not the primary driver of evaporation, does not burn the oils like other popular methods. Because fluid beds perform best with shredded material, they are ideal for pre–rolls and extraction biomass.

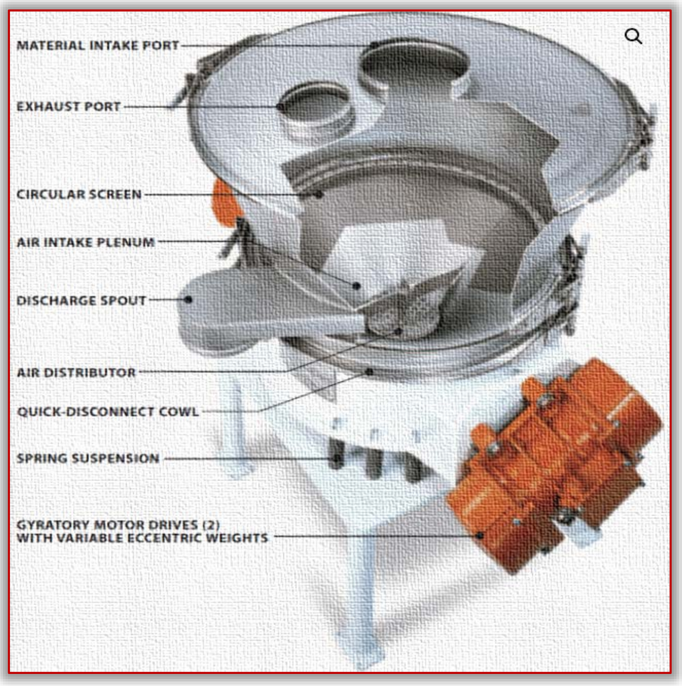

Figure 2 – Fluid bed dryer– constructive scheme
(https://abmequipment.com/hemp–processing/drying/hemp–drying–systems)

Fluid bed dryers (Figure 2) use air traveling at a rate just higher than the product's terminal velocity, suspending the product above the grate. The large amount of dry air passing through the product achieves the same dry–rate as rotary (tumble) dryers without the use of high temperatures. Because they require homogenized product and can degrade product by up to 2 points, they're most popular for extraction biomass and pre–rolls.

Drying methodology is arguably the most important factor in differentiating processors and provide a competitive edge. Until recently, tumble and belt dryers have been the standard for the industry, however, both have inherent flaws and drawbacks. Tumble dryers use heat as an accelerant.

Belt dryers draw air from above, which creates concentrated air streams which inevitably causes wet spots which are prone to mold or over–drying.

Technological processes of separation and cleaning seeds are extremely important, since seed quality and cost depend on these processes. The seed separation and cleaning processes are carried out on separators of various types (Mureşan T et al., 1986; Duda M et al., 2007).

Hemp separators are placed after the dryer to separate the stalks and stems from the bud. Because bucking is too tedious for large–scale operation, it's much more efficient to grind everything together and separate it once dry. These separators are incredibly resilient, easy to use, and come with hardware to accommodate changing biomass properties.

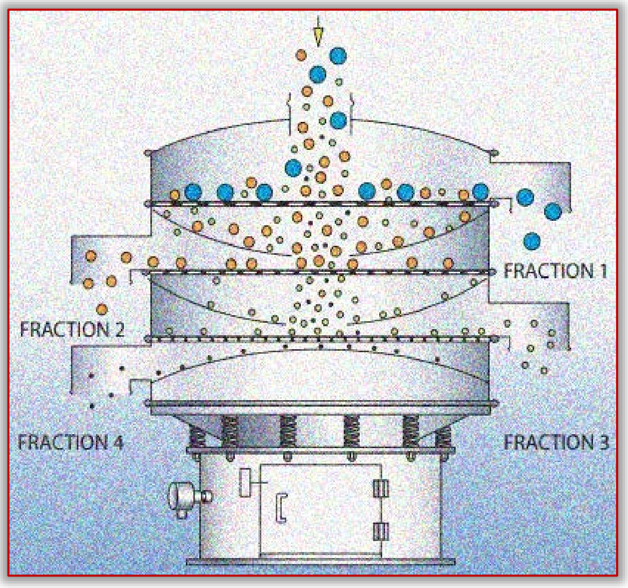

Figure 3 – Circular vibratory screeners – Principle of operation
(https://www.kason.com/assets/files/Kason_Vibroscreen_Brochure)

The main screening assembly of a screener (Figure 3) is suspended on rugged springs that allow it to vibrate freely while minimizing power consumption and preventing vibration transmission to the floor. The assembly is equipped with one imbalanced–weight gyratory motor that creates multi–plane inertial vibration for the purpose of controlling the flow path of material on screen surfaces, and maximizing the rate at which material passes through the screen.

Material is fed onto the centre of the screen, causing particles larger than screen apertures to travel across the screen surface in controlled pathways, and exit through a discharge spout located at the screen's periphery, while particles smaller than screen apertures pass through the screen onto a lower screen or exit through a lower discharge spout.

Seed cleaning equipment will also need to be thoroughly cleaned to ensure cross contamination with other grains, especially wheat, does not occur. Most seed cleaning equipment, including air and screen, indent and gravity tables, are suitable. Colour sorters are becoming more common for ensuring the seed meets the strict quality specifications of 99.9 % purity because purity is a key issue with hemp seed. A representative sample of the cleaned hemp seed should be collected after cleaning and submitted to the processor according to their requirements.

RESULTS

Storage of seed is an important process of plant production to avoid unfavourable environmental conditions and the acceleration of the deteriorations, which is started after harvest. Storage conditions play an important role to maintain high seed quality, which directly related to environmental conditions (mainly temperature and relative humidity). However, the sensitivity of seed to high temperature is depended on the water content that the higher moisture content, the looser viability. Seed deterioration is associated with the genotype, seed history and their physiological and chemical compositions. As in hemp, seed is determined as an orthodox seed that can be dried to low moisture content (mc) and stored at low temperature for several years (Suriyong S. et al., 2015).

When selecting storage systems for hemp, priority should be given to cleanliness, handling, conditioning and aeration capabilities.

Hopper bins with aeration are the best choice. Flat metal bins with aeration flooring are also a good choice. Mini–bulk bags have been used to store hemp seed as long as the moisture content is eight per cent or less.

To plan and perform seed processing operations a thorough knowledge of the physical and mechanical properties of seeds is required. The structure and operating parameters of processing machines are largely determined by the seed properties.

Based on the evaluated properties, seeds are classified by those that are the most suitable for industrial processing and the production of propagating material, food, or feed. Only certified seeds that have been graded based on their size should be planted to guarantee uniform field emergence and uniform stands, which are easier to cultivate and harvest Because sorting processes based on seed mass are difficult to implement in industrial practice due to considerable variations in seed size and mass, other physical parameters that are significantly correlated with the seed mass are used in sorting and cleaning operations (Kaliniewicz Z. et al., 2021). Therefore, the specific attributes of the processed seeds, the variations in the physical properties of seeds, and the correlations between these properties should be thoroughly examined before planning industrial operations.

CONCLUSIONS

Growers can improve the quality of hemp seed crops by minimizing their damage during harvesting, cleaning and handling. This can be achieved by harvesting a higher percentage of acceptable moisture content from seeds and by slowing down the speed of harvesting devices, harvesting and cleaning equipment.

To preserve grain quality, hemp seed must be properly dried, stored and monitored. Regardless of the storage method, the stored products must be periodically supervised and controlled, so that unfavourable phenomena can be prevented and combated.

The adequacy of artificial aeration or drying of hemp seeds depends on the moisture content of the seeds at harvest and the temperature / humidity conditions of the ambient air. It is essential to correlate the drying and conditioning capacity of the hemp seeds with the harvesting speed, being recommended to have an excessive drying capacity of the seeds, thus avoiding the risk of losing the quality of the seeds.

Acknowledgement

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[1.]Iulian DUMITRU, [1.]Florin NENCIU, [1.]Valentin VLADUŢ,
[1.]Iulian VOICEA, [1.]Remus Marius OPRESCU, [1.]Cristinel DUMITRU

CONSIDERATIONS REGARDING THE HARVESTING AND PROCESSING OF WALNUTS

[1.] National Institute of R&D for Machines and Installations Designed to Agriculture and Food Industry (INMA), Bucharest, ROMANIA

Abstract: Establishment of walnut plantations can be a successful business in the medium and long period of time. In terms of planting technology, maintenance, harvesting and recovery of the walnut kernel, it is not needed for a considerable effort from both the financial and the labor force. Harvesting and peeling walnuts from the green cover can become one of the easiest stages in the exploitation of walnut plantations. In this context, existing walnut harvesting machines and equipment on the market can ensure and meet the farmer's requirements. Self–propelled, or towed walnut harvesters can also be used on sloping land. The existence of nut shakers makes it possible to shorten the harvesting period and increase the harvesting efficiency for large plantation areas. The harvesting period of walnuts differs from one variety to another and even from one tree to another. It can be considered that even at the level of a tree the nuts have different harvesting phases (nuts usually have a massive crown), depending on their position. Depending on the variety that has been planted, and the geographical position of the walnut culture, distinguishes three categories of walnut ripening periods – early, semi–early and late. If the harvesting and preservation of walnuts is done in strict compliance with the harvesting technologies and their preservation, can last for years without losing the taste qualities. Due to the very high demand on the market, the development of a walnut plantation business on large areas can become very attractive. Considering that young walnuts have the crown formed without the intervention of the human factor, we have new evidence that walnut plantations are easy to maintain compared to other types of plantations.

Keywords: walnut harvesting, walnut peeling machine, walnut processing

INTRODUCTION

Walnut cultivation was first certified in temperate areas of the Balkans, this being an optimum area for growing and developing. Walnut plantations have been developed in countries such as Iran (Hassani D., et al, 2020), Greece, China (Liu, et al, 2020), Serbia, Hungary (Bujdosoa and Csekeb, 2021), France, Bulgaria and Romania. In 2017, Romania have been ranked on first place in the production of walnuts within the European Union, after France and Italy, with a production of 45,800 tons (https://agrointel.ro). From a genetic point of view, in recent years the walnut has experienced a great development. Many producing countries such as France and the USA have studied the morphological characteristics of walnuts intensively (Bernard A. et al, 2018). The walnut is reaching a height of up to 30 meters, for certain varieties. Walnut fruit (core) is used in both the food and pharmaceutical industries (Pahlavani et al, 2020). Walnut flowers, walnut bark and green coating have various uses in various fields, cosmetics, textiles, food, pharmaceuticals (Yuzhu Wanga, et al., 2021). Walnut wood is very often used to make furniture and various decorations, even luxurious ones that we can find everywhere.

The harvesting period of walnuts differs from one variety to another and even from one tree to another. It can be considered that even at the level of a tree the nuts have different harvesting phases (nuts usually have a massive crown), depending on their position. Those located towards the outside of the crown, tend to get mature in a shorter period than those located in the interior of the crown. Depending on the variety that has been planted, and the geographical position of the walnut culture, distinguishes three categories of walnut ripening periods – early, semi–early and late.

In Romania the walnut harvest period can begin in the second part of August and can end at the end of October. For each variety, the period of ripening and harvesting walnuts cannot last more than two to three weeks. In general, the nuts are harvested gradually and fall on their own on the ground, then they are gathered, manually or mechanized. Another option that can be used especially for walnut plantations, especially on very large areas is the mechanized shaking of nuts with the help of self–propelled equipment, built especially for the execution of this operation. (https://cultivaprofitabil.ro).

If the second option is used for harvesting, i.e. mechanized forced shaking, a very large number of nuts will be covered by the green shell. Special equipment have to be used to remove the peel. If the harvesting and preservation of walnuts is done in strict compliance with the harvesting technologies and their preservation, can last for years without losing the taste qualities. (Charrier G. et al., 2013; Hua, et al, 2021; Maoa, 2021).

MATERIALS AND METHODS

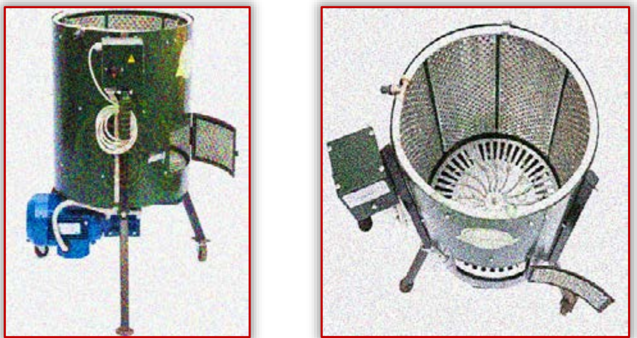
Walnuts are usually harvested depending on the weather, at the beginning of autumn. If there is a small number of fruits, they can be harvested manually, in several stages. In this option, only the nuts that have come off the green cover and fallen to the ground will be harvested. If aim for a faster harvest, then can opt for shaking the nuts. In the industrial system, nuts are being harvested by manual shaking and for very large areas mechanized shaking.

If the shaking process is performed manually or mechanically, a large part of the nuts will fall to the ground with the green coating as can be seen in Figure 1 a) and after cleaning with a special machine, Figure 2 b).

(a) (b)

Figure 1. Green walnut cleaner a) before cleaning, b) after cleaning (https://nuttechnology.com)

The green walnut peeler Figure 2 a) and b) can remove the green shell of the walnuts in a very short time, leaving the whole bark of the walnut without cracks or fissures. The capacity of such an equipment is 100 kg / h.



(a) (b)

Figure 2. Overview of a variant of the green walnut cleaner a) overview, b) the cleaning basket of the equipment (https://nuttechnology.com)

As can be seen, the equipment is driven by an electric motor mounted on the inferior part, which rotates the bottom of the container, which will engage the nuts in a rotating motion. The walnuts are introduced in the container from figure 2 b) that has a walnut watering system (figure 1 a). Therefore, due to the conditions created by rotating and watering the nuts, and due to friction between them and the walls of the container, they will separate from the peel (Figure 1 b).

Another constructive solution for cleaning walnuts is found in figure 3, where the following components can be identified: the housing of the machine with the movable opening system, the feeding basket with green nuts, adjustment system according to the material to be cleaned, the device start stop of the machine, the gutters for the evacuation of green shells and cleaned nuts, the wheel system.

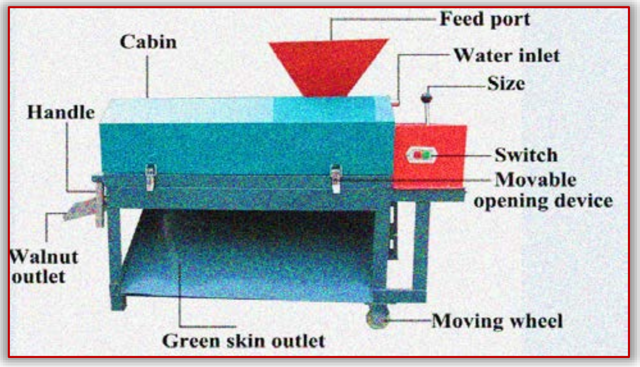


Figure 3. Green walnut peeler (https://wuhanhdc.en.made–in–china.com)

As can be easily seen, by describing the components of the machine, the green–shelled nuts are inserted into the cleaning container, and by adjustment, rotation and friction the separation occurs as can be seen in Figure 4 a) and b).

(a) (b)

Figure 4. Green walnut peeler cleaning system a) Gutter for peeled walnuts, b) Gutter for green peel (https://wuhanhdc.en)

Throughout this process of cleaning the nuts, water is also introduced, which improves the process of peeling, washing and evacuating the nuts and green shells from the container. The productivity of such an equipment is 800–1000 kg / hour. The rate of mechanical damage to walnuts is up to 1% and the rate of removal of green shells is 99%. Compared to the option of removing green shells by hand, with the help of this machine the work efficiency is amplified by more than 20 times. The equipment has the following technical characteristics, presented in Table 1.

Table 1. Technical characteristics

Model	JY – 100
Power	0.75 – 2.2 Kw
Capacity	600 – 1000Kg/h
Overall dimensions	950x450x850 mm
Weight	75 Kg

The power supply of the machine can be 220 V or 380 V, (https://wuhanhdc.en.made–in–china.com/product/)

Another model of green walnut peeling machine is presented in Figure 5, named AK 10 having a capacity of up to 800 kg / h. It is an equipment with a portable power supply of the driving motor for small nuts.

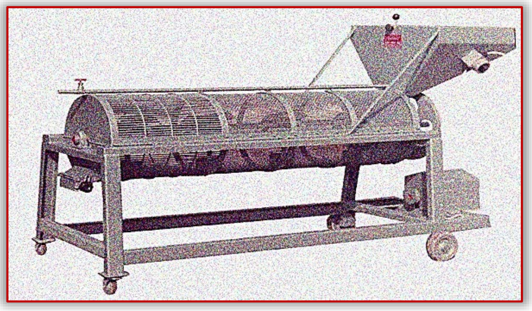
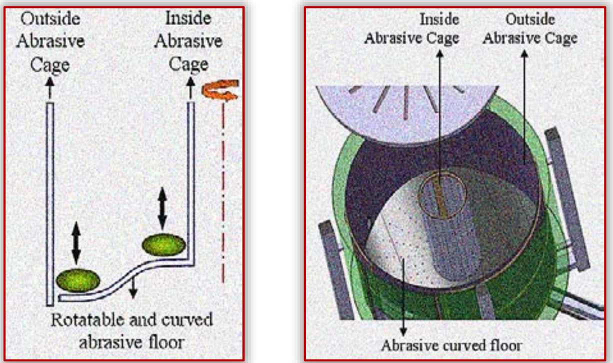


Figure 5. AK 10 green walnut peeling machine (https://www.bionot.gr)

In figure 6 a) and b) can be seen schematically, the floor of the container where the nuts are peeled, the abrasive shape and the side walls of the tube which are abrasive, and contributes to the quality of walnut cleaning.



(a) (b)

Figure 6. Green walnut cleaning system a) with abrasive and sloping floor, b) abrasive exterior walls (Mohammad Younesi Alamooti and Esmail Mahmoodi, 2015)

In conclusion, a centrifugal mechanism is used for the options of green walnut cleaners. It should be mentioned that all the equipment described above have a constructive solution and a simple assembly and easy maintenance. They can be equipped with automation systems that increase productivity and cleaning quality. They can also be used for other products such as pistachios or other nuts. Various adjustments can be made to improve the quality of walnut cleaning by using a curved floor of the container (figure 6 a), by changing the spinning speed of the container, using abrasive surfaces inside the container in different geometries (Alamooti, 2015).

RESULTS

Before processing, the nuts have to be first shaken and collected from the ground. This operation of harvesting nuts can be performed manually or mechanized. For the mechanized option, one of the companies that produce harvesting and cleaning equipment for harvesting walnuts is the company Glampi. This company produces self–propelled combines for harvesting walnuts, almonds, hazelnuts, etc. In figure 7 a) and b) we have the self–propelled combine designed to harvest various types of nuts (walnuts, almonds, hazelnuts) called FUTURA100, in the working position figure 7a) and in the transporting position figure 7 b).

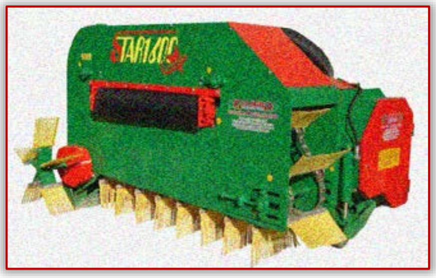
(a)

(b)

Figure 7. FUTURA 100 Self–Propelled Combine, a) in working position, b) in moving position (https://utilajenucifere.wixsite.com)

During travel, the FUTURA 100 self–propelled combine develops 2 gears, the first up to 8 km / h and the second gear up to 35 km / h. It has 4x4 traction, the engine that equips this combine is of Kubota type and develops a power of 55.4 KW, the working width varies from 2.20 to 5 m. The total weight of the equipment is 3160 Kg, and the harvesting capacity is 2500–3000 kg / h.

Giampi also produces STAR 1600 nut harvesting machines, figure 8 a), and STAR 2000 from figure 8 b), a machine that can be attached to all types of tractors that can tow a weight greater than 550 kg, (STAR 1600) respectively 642 kg as the STAR 2000 machine has. The average harvesting speed for these models is 1 –3 Km / h and the gathering capacity of the nuts is 700–1500 Kg / h.



(a)

(b)

Figure 8. Walnut harvesters (https://utilajenucifere.wixsite.com/giampi)
a) STAR 1600 nut harvesting machines; b) STAR 2000 nut harvesting machines

The harvesting with this type of equipment is performed entirely mechanized with the help of a transverse brush. The rotational movement of 540 or 1000 rpm is taken from the power take–off of the tractor towing the machine. Transverse brush movement can also be done using a hydraulic system that contains an oil pump, an oil tank and an oil cooling radiator. In addition, the harvesters can be equipped with a side collector.

Another constructive solution for harvesting nuts is found in the STAR 211 and STAR 311 models that we can see in figure 9 a) and b), manufactured by the same manufacturer, Giampi.

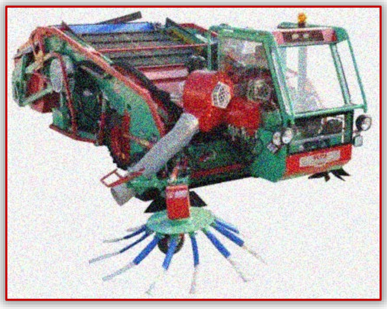
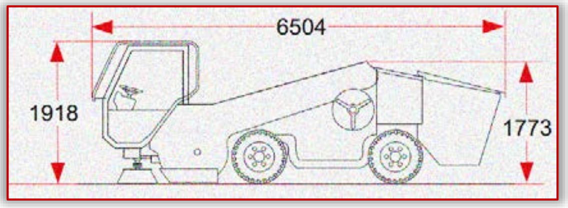

(a)

(b)

Figure 9. Nut harvesting equipment a) STAR 211. b) STAR 311 (https://utilajenucifere.wixsite.com/giampi)

In this type of equipment, the harvesting is performed using a turbine with a pipe, having variable diameters between 120–140 mm and lengths of 6/12/24 m. This constructive solution allows harvesting a wide range of products (walnuts, almonds, hazelnuts), on harder to reach lands. The power required to operate such a machine is 35 Kw, weighs 750 Kg and requires 2 operators during functioning. The machines are driven from the power take–off of the tractor which drives a suction turbine. Depending on the size of the harvested products, the diameters of the sieves change.

Another company from France, named AMB ROUSSET offers a wide range of products for harvesting nuts, cider apples, hazelnuts, almonds, sweet chestnuts. In figure 10 a) and b) is presented the self–propelled walnut harvester R 19, figure 10 a) and the dimensions of the equipment, figure 10 b).


(a)


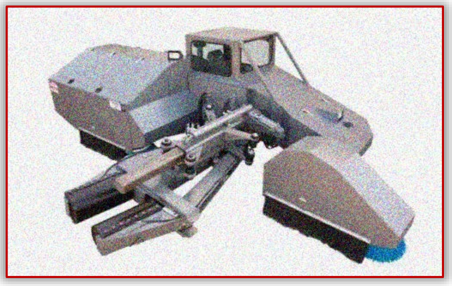
(b)

Figure 10 Walnut harvester R 19 a) Overview, b) overall dimensions of the walnut harvester R19 (https://www.amb–rousset.com)

In addition to the R19 self–propelled combine model, we also find other variants of the same French manufacturer such as: R17, R22, R23, R35. The engine for these types of self–propelled combines is German (Deutz, 90Kw power), offering increased reliability. The fact that all four wheels of the equipment can be turned, offers conditions for making complex maneuvers in walnut plantations that can be found on hard to reach lands. The tires are also wide in size, to limit the footprint on the ground. It is approved for driving on public roads. Due to the lifting height of the hopper, which is 2.90 m, it can be unloaded in any type of trailer (means of transport) or storage container.


Figure 11. Walnut shaker AMB Rousset

Founded in 1967, Orchard–Rite is a leading manufacturer in the orchard harvesting equipment industry, having very good quality and reliability products. Bullet nut shaker is a towed model that can be attached to any type of tractor. (https://www.cat.com)


(a)

(b)

Figure 12. Bullet nut shaker, a) Overview, b) Working (https://www.agriexpo.online)

The nut shaker produced by Orchard–Rite and presented in Figure 12 (a) and (b) is a self–propelled machine that shakes both the trees and gathers the nuts from the ground. The shaker head is rotated up to 50 degrees and the fact that is equipped with lights, helps harvesting at night. The reliability of the equipment ensures a quality shake that leads to a very small loss of unharvested nuts. The multiple shaking frequencies, the high–performance shaking head lubrication system offer special protection to the trees and make this machine a very high–performance one. (https://www.agriexpo.online).


(a)

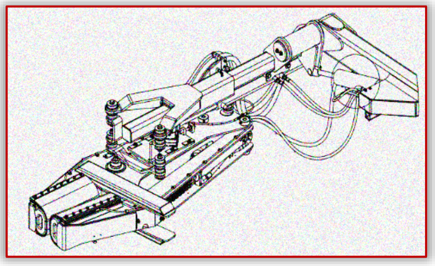

(b)

Figure 13. Monoboom nut shaker a) Overview, b) Shaker sketch

In figure 13 another model produced by the Orchard–Rite company is presented, having similar performances and reliability as the equipment presented before. Sicma – TR80 shaker, shown in figure 14 a) and b) can be coupled to any type of tractor with a minimum power of 90 hp.


(a)


(b)

Figure 14. Sicma TR 80 shaking machine, a) With tarpaulin to be collected in the transport position, closed, b) With tarpaulins to be harvested in the working position, open (https://www.agromaquinaria.es)

The lifting and lowering ensembles and the vibrating head are operated by means of a remote–control system. The arm has a freedom of rotation of 90 degrees. The collection tarpaulin configured in a convex position has a diameter of 5 or 6 m. The vibrating head has an opening of up to a maximum of 480 mm and is equipped with a self–braking system. The fastening system of the tractor is in three points and with two support wheels (semi–worn), (https://real–deal.ro).

CONCLUSIONS

Due to the very high demand on the market, the development of a walnut plantation business on large areas can become very attractive. The profit that can be obtained from such a plantation, the longevity of a plantation, the easiness in maintenance may other good reasons why setting up a walnut plantation can become very profitable. Considering that young walnuts have the crown formed without the intervention of the human factor, we have new evidence that walnut plantations are easy to maintain compared to other types of plantations. In cases where the plantations are established on large areas, there are machines and equipment for harvesting the nuts that can do all the mechanized harvesting operations. There are internationally companies that produce nut harvesters, self–propelled, towed, semi–mounted. There are also machines and equipment for shaking nuts, on the ground or on various tarpaulins placed around the trees. Other self–propelled walnut harvesters can perform both the shaking operation and the ground nut collection operation in the combine hopper. One of the advantages of using mechanized harvesting is that the shaking of walnuts can be performed in a single pass, compared to manual harvesting where the process takes more time.

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[14] https://utilajenucifere.wixsite.com/giampi/utilaje–de–recoltat–nucifere;
[15] https://ro–ro.facebook.com/AMBRousset/photos;
[16] https://www.amb–rousset.com/en/produit/macadamia–nuts–harvester–r19/;
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[1.]Marian VINTILĂ, [1.]Mariana TOMA, [2.]Cristian SORICĂ, [1.]Ionel-Lucian DUMITRESCU, [1.]Nicusor MANOLE, [1.]Angela MOHORA, [1.]Daniela VERINGĂ

ASPECTS OF THE USE OF OZONE IN FRUIT PROCESSING TECHNOLOGY

[1.]Institute of Research – Development for Processing and Marketing of Horticultural Products – Horting, Bucharest, ROMANIA
[2.]National Institute of Research Development for Machines and Installations Designed to Agriculture and Food Industry – INMA Bucharest, ROMANIA

Abstract: In response to increased consumer demand for healthful food products, finding sustainable and eco–friendly technologies became a true challenge. Based on the latest regulations of the relevant authorities, the ozone treatment into the sector of horticultural products capitalization and food industry was unanimously recognized as wholly safe for humans. Due to ozone property to be converted into oxygen by autolysis, it is used in the ecological technologies as disinfectant, antimicrobial and pesticides residues remover in the contact food applications. The study aims to demonstrate the ozone efficiency in apple juice processing line at ICDIMPH – Horting and to exhibit the prototype of ozone preparation in aqueous solution.
Keywords: apple, juice, ozone, equipment

INTRODUCTION

The food industry targets to develop innovative technologies to launch healthy, natural and sanogenous products, richer in nutrients and higher in sensory characteristics, in order to fulfil consumer's expectation. In accordance with the standards and good agricultural practice, new technologies in the field of horticultural crops protection & capitalization are currently being implemented, which, however, are struggling to remove the pesticide active compounds residues. Pesticide residues are long–lasting and are slowly reduced in plant tissues (Nowacka, 2009). Residue levels of benomyl, carbendazim, methyl thiophanate and thiabendazole in apples stored at 0–2° C were found even after 140–150 days when the active ingredients have reached a level of 36–60% from their initial concentration (Holland, 1994).

To reduce impurities, washing the fruits with certain detergents is commonly used. Such methods are able to remove pesticide residues that are transferred to the washing solution.

Washing efficiency depends on several factors, such as the place of the residue on fruit surface, elapsed time since exposure to the active ingredient and water solubility to a particular residue. The temperature and washing type have an impact on this process, as well. The use of additional detergents or cleaning agents and the temperature of washing solution can considerably influence the efficiency of the process (Holland,1994). This way, the active compounds of pesticide are released into the water, air and soil (Tiwari B.K.2009), empoisoning the environment. The side effects of such method is a weapon turned against life & wellness, in all its dimensions.

Technologies using ozone have expanded in the recent years, due to the fact that it promotes disinfection, virus inactivation, deodorization, bleaching (decolorization), decomposition of organic matter, degradation of mycotoxins and others (Balawejder M., 2013). Ozone (O3) is a natural gas in the atmosphere, one of the most powerful antimicrobial products that acts against a wide range of microorganisms. Ozone is an allotropic form of oxygen that is a strong oxidant (E0 = 2.07 V) which allows the oxidation of many organic compounds.

Fruits and vegetables are usually/ commonly sprayed with aqueous ozone solution or passed through into such solution in the processing line. The use of the ozone solution is possible due to its solubility in water, which is about 0.105 g in 100 cm3 at 0º C. If ozone is applied in aqueous solution, contaminants oxidation is based on direct oxidation of ozone molecules or indirect free radicals' oxidation. Catalytic oxidation of ozone leads to the generation of very strong oxidants (E0 = 2.8 V) and hydroxyl radicals (•OH). The hydroxyl group produces radical reactions with organic compounds of hydrogen extraction or electrophilic dependence on double bonds (Chiron S., 2000).

A wide range of pesticides are used in the treatments of agricultural crops. Ensuring an efficient washing of fruits and vegetables to remove the pesticide active compounds' residues, is done by meeting the following requirements:

≡ the generation source of ozone is the atmospheric air;
≡ the achievement of an optimal O3 concentration in the washing water;
≡ the flow adaptation of the ozonated solution to the working capacity of the washing equipment.

MATERIALS AND METHODS

In order to implement the ozone treatment to the horticultural products, the scientists of ICDIMPH–Horting and INMA Institutes have developed a practical equipment. The engineers have shared their ideas and they succeeded to create a new vision of technology. The concept and the prototype of ozone preparation equipment represents a bridge of their practical knowledge and joint efforts in the field. The washing phase of the raw material (apples) from the current technology used at Horting Institute to obtain apple juice, has been adapted / transformed so that the washing is done with ozonated solution. The scheme of the technological plant is shown in Figure 1.

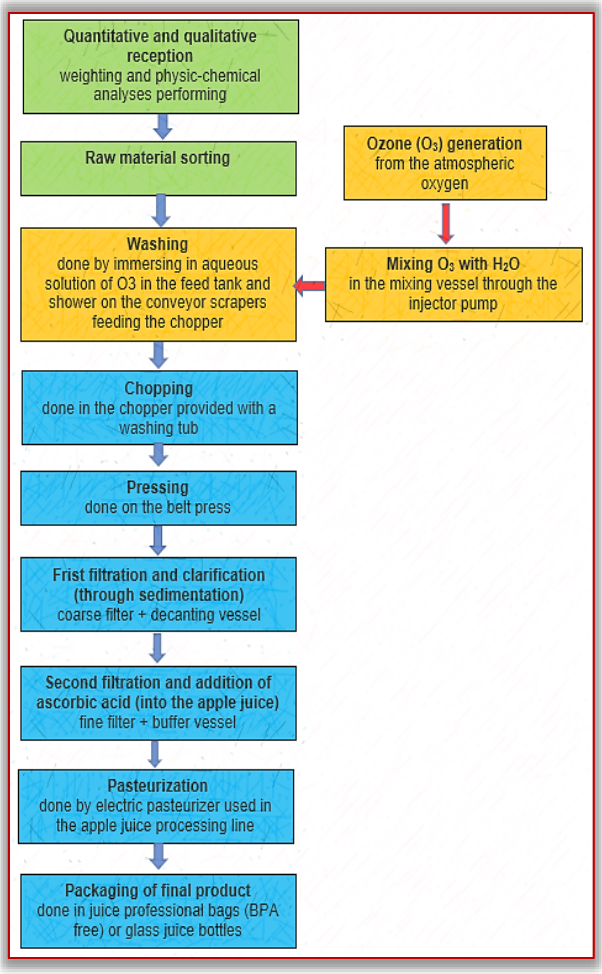

Figure 1 – Technological scheme of ozone plant applied at ICDIMPH – Horting

Starting from the main scheme of ozone solution preparation, presented in figure 2, the research team has realized the equipment's design of ozone preparation in aqueous solution – EOP (Figure 3).

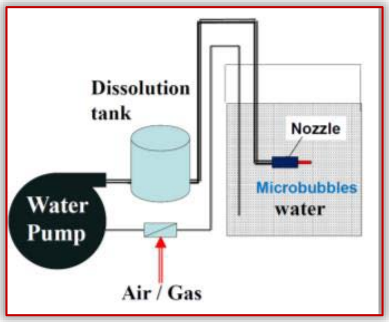

Figure 2 – Obtaining the ozone solution (Janyawat T. Vuthijumnonk and Warawaran Shimbhanao. 2019)

The EPO installation represents a prototype of an experimental model of a plant able to produce and distribute the ozonated water solution required for the washing plant existing to the apple / tomato juice production lines at ICDIMPH–Horting within the Experimental Base for the Processing of the Horticultural Products.

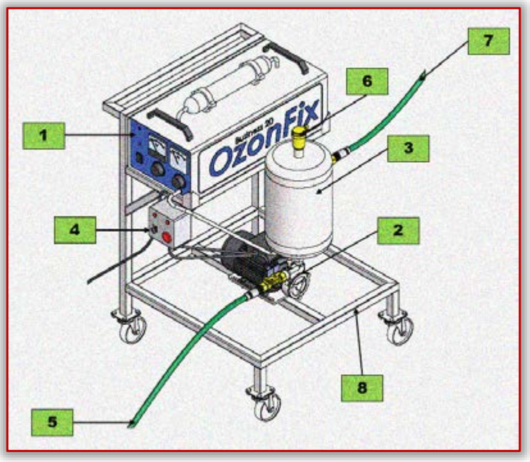

Figure 3 – General drawing of ozone preparation equipment (EPO)
1 – ozone generator; 2– drive motor + injector pump; 3 – mixing vessel; 4 – control panel; 5 – water supply connection; 6 – safety valve; 7 – ozonated water distribution connection; 8 – fitting frame

The aqueous ozone solution equipment (EPO) is supplied with water through the connection no. 5, directly from the drinking water supply network of the working point or from a buffer tank. The injector pump driven by an electric motor (2) takes up the ozone gas supplied by the generator (1) by means of the special connection intended for this purpose and disperses it in the volume of water circulated in the pump, from the inlet to the discharge.

The main elements of the aqueous ozone preparation (EPO) equipment are: (i) ozone generator; (ii) injector pump; (iii) pump drive motor; (iv) mixing vessel; (v) fitting frame.

The ozone generator (Figure 4) is a technical equipment designed to produce the gaseous ozone through the effect of "Corona" – type electric discharge with atmospheric air supply. The generator has an ozone gas production of up to 20 g / h and a lifespan of up to 20,000 hours of operation.

The injector pump (Figure 5) is the element that converts the mechanical power supplied by the motor drive into hydraulic power, while aspirating and dispersing the ozone gas from the ozone generator, through the "Venturi" type injector whose components parts are in the water.

The pump drive motor (Figure 6) represents the source of mechanical power required to operate the injector pump, for the purpose of dispersing gas ozone in water and transferring it to the additional mixing vessel, for better homogenization and supply of ozone in aqueous solution to the distribution system on the external surfaces of /, used to clean and treat the horticultural products.

Figure 4 – Ozone generator

Figure 5 – Injector pump

Figure 6 – Pump drive motor

Figure 7 – Pump drive motor

The mixing vessel (Figure 7) is a stainless steel vessel, provided as an additional means of homogenizing the gas–water mixture. It is made of a cylindrical ferrule and two semi–ellipsoidal bottoms. A fitting is provided at the top to fit an automatic valve breather required for the discharge of excess ozone gas if it would accumulate above the liquid ozone gas and water mixture.

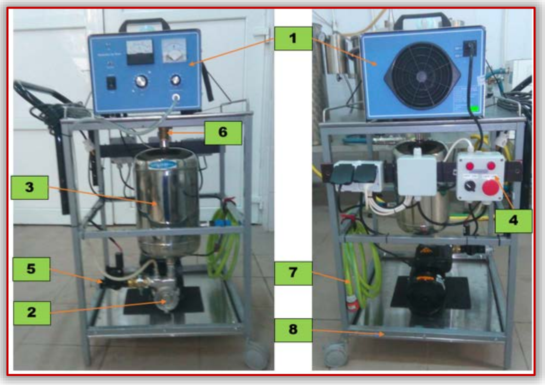

Figure 8 – Pump drive motor
1– Ozone generator; 2– Injector pump; 3– Mixing vessel; 4– Control panel; 5– Water supply connection; 6– Safety valve; 7– Ozonated water distribution connection; 8– Fitting frame

A fitting is provided at the bottom for the inlet of the ozone gas–water mixture from the injector pump. An additional homogenized exhaust connection to the ozone gas–water mixture distribution system is provided on the surface of the cylindrical ferrule.

The experimental model / prototype of the Ozone Preparation Equipment (EPO) in aqueous solution made at INMA – Bucharest is presented in Figure 8.

The ozone preparation equipment (OPE) in aqueous solution was installed on a wheeled transport frame, which allows it to be moved for coupling to the washing systems of the processing lines.

The fruit experiments aimed to test—the equipment's functionality in real production conditions.

Jonagored (derived from *Jonagold*) and *Florina* apple varieties provided by the Research–Development Station for Fruit Trees Cultivation (SCDP) – Baneasa were used in the experience. The phyto–sanitary protection of the apple species consisted in the application of four treatments during the vegetation period and one during the rest period, as follows:

1. Vegetative rest stage (December–February): treatment with *Bordeaux mixture*, in concentration of 3–5%, applied to reduce the spores' population of the most aggressive pathogenic fungi, such as, *Venturia sp*., *Erwinia sp*., *Podosphaera sp., etc.*
2. Bud break – "mouse ear" stage (March–April): treatment with Bordeaux *mixture*, in concentration of 0,5%;
3. End of flowering – 75% of petals are fallen (April–May): treatment with *Folicur* solo *250*, in concentration of 0,04% and *Vantex*, in concentration of 0,01%;
4. Fruit growing stage (May–June): treatment with *Score 25 EC*, in concentration of 0,02%, *Karate zeon*, in concentration of 0,02% and Fertitell, in concentration of 0,5%;
5. Fruit ripening (July–August): treatment with *Captan*, in concentration of 0,2%, *Karate zeon*, in concentration of 0,02% and Fertitell, in concentration of 0,5%.

The phyto–sanitary treatments carried out during the vegetation (Figure 9) rest period aimed to protect trees against the attack of the main pathogens (*Venturia sp., Erwinia sp., Podosphaera sp.*) and pests (*Eriosoma sp., Aphis sp., Cydia sp., Quadraspidiotus sp.*).

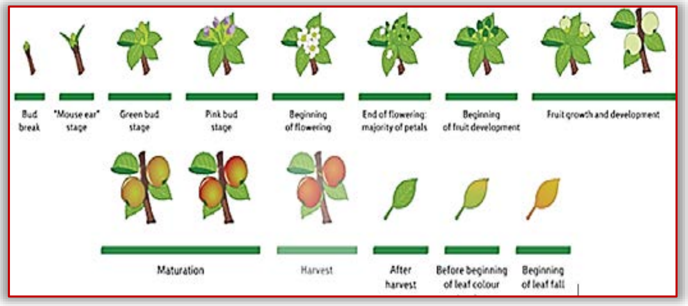

Figure 9 – The state of vegetation in the apple (https://intermag.eu/crop–farming/crop–guides/)

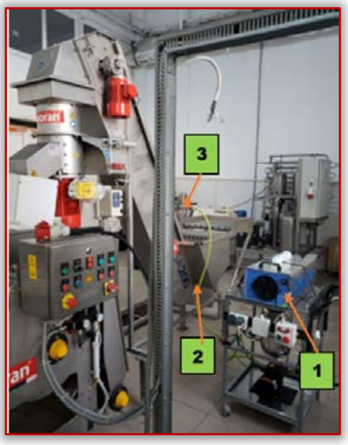

Figure 10 – Coupling the OPE to the processing line: 1–ozone preparation equipment; 2–supply hose for aqueous ozone solution; 3–washing ramp with showers

The way to connect the installation to the shower wash ramp is shown in figure 10.

During the experiments, the apples were washed by showering (Figure 11) and by immersion (Figure12), within the processing installation for natural apple juice, existing in the endowment of Horting Institute.

Figure 11 – Washing with showers

Figure 12 – Immersion wash

CONCLUSIONS

Following the experiments performed, the following aspects resulted:

≡ when the aqueous ozone tank is fed from the tank, due to the fact that the pump discharge circuit remains under pressure due to the pressure exerted by the weight of the volume of liquid remaining in the mixing vessel and the drain hose, and the pump inlet circuit is blocked by the flow valve, the liquid is forced out of the pump through the ozone inlet connection. This increases the pressure and the level of the liquid in the ozone supply hose and increases the risk of the hose breaking or the failure of the special one–way valve for ozone–gas circuits. In this context, it is recommended to install a one–way valve immediately after the pump discharge connection, so that when the system is switched off, the liquid remaining on the discharge does not enter the pump;

≡ in the case of the evacuation of the aqueous ozone solution to the nozzle ramp of the fruit washing machine, the problem previously identified and presented, became even more pronounced. This problem is due to the fact that the pump discharge circuit remains under pressure due to the pressure accumulated on the section from the nozzle ramp, and the pump inlet circuit is blocked by the direction valve, the liquid being forced out of the pump through the connection ozone inlet increasing pressure and fluid level in the ozone supply hose. As a result, the previous recommendation regarding the installation of a one–way valve immediately after the pump discharge connection is all the more stringent.

The parameters and factors that influence the effectiveness of ozone treatment are: (i) water quality (pH, organic matter, pressure and temperature); (ii) air quality (relative humidity); (iii) the treatment itself (method of application, duration of treatment and concentration); (iv) horticultural product characteristics (cultivar, weight, product surface characteristics); (v) microbial load (microbial strains, physical state of bacterial strains, natural microflora, artificially inoculated microorganisms and population size).

Note: This paper was presented at ISB–INMA TEH' 2021 – International Symposium, organized by University "POLITEHNICA" of Bucuresti, Faculty of Biotechnical Systems Engineering, National Institute for Research-Development of Machines and Installations designed for Agriculture and Food Industry (INMA Bucuresti), National Research & Development Institute for Food Bioresources (IBA Bucuresti), University of Agronomic Sciences and Veterinary Medicine of Bucuresti (UASVMB), Research-Development Institute for Plant Protection – (ICDPP Bucuresti), Research and Development Institute for Processing and Marketing of the Horticultural Products (HORTING), Hydraulics and Pneumatics Research Institute (INOE 2000 IHP) and Romanian Agricultural Mechanical Engineers Society (SIMAR), in Bucuresti, ROMANIA, in 29 October, 2021.

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We are extremely grateful and heartily acknowledge the kind of support and encouragement from all contributors and all collaborators!

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