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NEW POSSIBILITIES IN CLEANING OF MATERIALS AND ENVIRONMENT

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Abstract: The contribution deals with the possibilities of metal cleaning focused on environmentally friendly cleaning as laser cleaning technology of materials. The aim of this contribution is to present the new abilities of cleaning of product and tool surfaces in very short time with minimizing of waste in the future. There are mentioned and compared various material cleaning methods from classic ones to progressive ones and their influence on the environment. Laser cleaning is one of the newest progressive methods of the material cleaning. The results of this technology were recently tested and shown in the Department of Process and Environmental Engineering, Faculty of Mechanical Engineering, Technical University of Kosice together with the firm Trumpf Slovakia s.r.o. The laser cleaning technology can be used in the various fields of industry, in the production sphere, in the renovation sphere of products and materials. This technology minimizes the harmful impact on the working environment and environment as a whole area.
Keywords: environment, laser technology, cleaning, material

INTRODUCTION

Degreasing of metal materials in the mechanical industry is an important technology force leaning materials to further processing as a finishing surface treatment or as a pretreatment before surface operation of workpieces, or is used in the maintenance of machinery parts and tools. By degreasing of metal surfaces not only removes lubricant from surfaces, butal so cleans mechanical particles from dust, abrasive parts and others. With the continuously deteriorating of environment, it is necessary to use such degreasing technologies of materials that have minimal negative impacts on the environment. Also the environment protection is encompassed by standards and decrees of REACH. [1]

The cleaning technology of materials must be quick, clear and short one. We can divide the cleaning technologies from various points of view as decreasing of materials, rust removal and surface pre-treatment of materials and also according to various methods of cleaning as [2]:

- ☐ mechanical cleaning technologies,
- ☐ chemical cleaning technologies,
- ☐ progressive cleaning technologies.

The cleaning of metal materials by mechanical technologies belongs to the oldest method of the material cleaning as brushing, blasting technologies. The cleaning process takes a relatively long time and is usually dusty and noisy, with waste as used sand, metal balls. Chemical cleaning technologies requires the using of various degreasers, chemicals, which are very dangerous for the environment in terms of storage of new and pure chemicals, their utilisation, storage of the waste chemicals and their neutralisation or recycling and joined with chemical vapours and with the necessity of rinsed water operations.

PROGRESSIVE CLEANING TECHNOLOGIES

Progressive cleaning technologies as ultrasonic cleaning technology, water jet and abrasive water jet technologies, dry ice cleaning technology, laser cleaning are based on the utilisation of the physical parameters. They enable to work more quickly, save the time, effectively and can clean accessible parts of machines and tools, reduce waste, which are very important requirements of producers. Ultrasonic cleaning technology transforms the high frequency energy on acoustic mechanics oscillations. Absorbent materials and degreasing parts due to the absorption causes the change of the ultrasonic energy on the thermal energy. By effect of the temperature changes occurs between degreasing substances and dirt to the partial separation and thus the scouring medium gets between subject degreaser and the dirt. In US cleaning process we need chemicals, rinse water and also the waste occurs, which creates ballast from the environmentally point. In the Figure 1 is shown the principle of the ultrasonic cleaning of materials. This technology enables to clean also the shape complicated product with cavities, shown in the Figure 2, which is one of the advantages of this type of cleaning. [3].

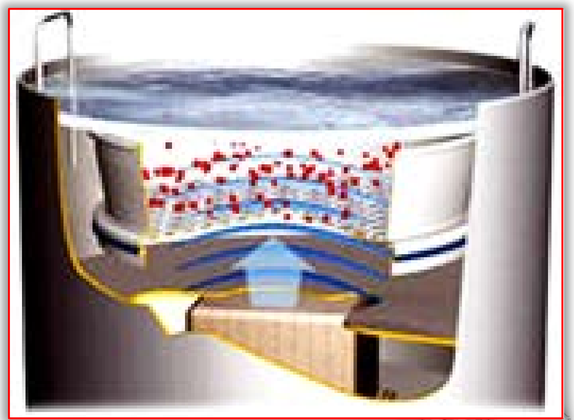


Figure 1. Principle of the US cleaning technology [3]

Figure 2. Example of US cleaning of product before and after cleaning

Dry ice blast cleaning technology utilizes a unique combination of forces to powerfully lift surface contaminants without causing of damage or creating harmful secondary waste similar to sand, bead and soda blasting. Dry ice blast cleaning prepares and cleans material surfaces by using a medium accelerated in a pressurized air stream. In the Figure 3 is shown the principle of dry ice blast cleaning [5].

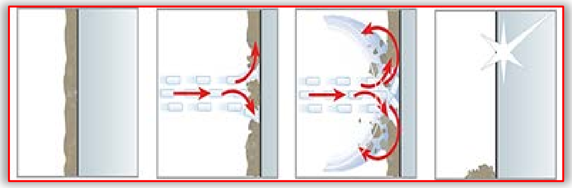


Figure 3. Principle of dry ice blast cleaning [4]

Dry ice blast cleaning offers comprehensive cleaning benefits over traditional methods, and can save up to 80% over current cleaning costs, Figure 4[6]. In the Figure 5 is shown the necessary equipment of dry ice cleaning. Except of degreasing, it can be used at the plastic cleaning from the extrusion screws at the plastic production, Figure 6.

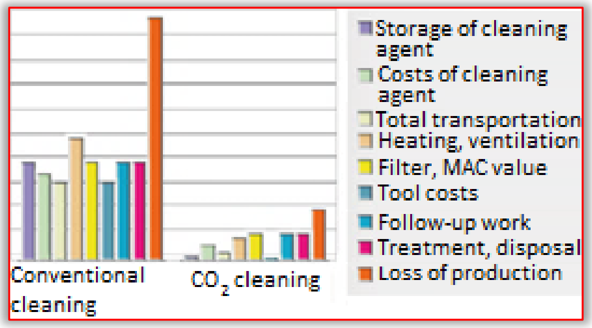


Figure 4. Incidental costs [5]

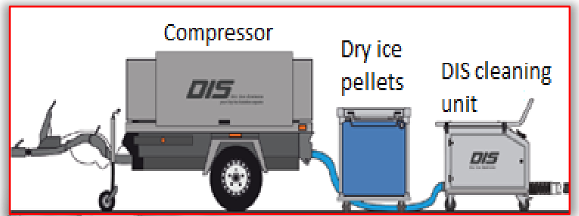


Figure 5. Equipment of dry ice cleaning [4]

Figure 6. Extrusion screws before and after cleaning operation [7]

In the Table 1 is shown the comparison of blasting technologies according to environmental requirements. Upon contact, traditional blasting materials become contaminated when used to clean hazardous substances and objects. These blasting materials are also then classified as toxic waste and require appropriate safe disposal.

Table 1. Comparison of blasting technologies according to environmental requirements [8]

Cleaning method	No secondary waste	Non-conductive	Non-toxic	Non-abrasive
Dry Ice Blasting	•	•	•	•
Sand Blasting		•	•	
Soda Blasting*		•	•	
Water Blasting*			•	•
Hand Tools	•		•	
Solvent/ Chemicals				•

LASER CLEANING TECHNOLOGY

Laser cleaning technology offers a highly selective, reliable, precise and safe cleaning method of removing layers of corrosion, pollution, unwanted paint, lubricants, other surface coatings and are environmentally friendly, using no water or chemicals and producing no effluent. Primarily laser cleaning technology is used for industrial cleaning in the automobile, aerospace, bakery, food, electronics, restoration industries and surface treatment, renovation and paint removal applications. It also removes contaminants, production residue and coatings without damaging the substrate. Metallic and reflective surfaces are ideal although other substrates can be addressed. Laser cleaning systems offer an extremely high level of control and precision. The innovative laser cleaning systems combine power and versatility, with the lowest operating cost of all industrial cleaning methods. [17], [18].

The cleaning surface reflects laser energy and is minimally affected; however, any contaminants on the surface absorb the laser energy and are quickly vaporized. The fumes or particulates are removed by an in-built filter of laser machines. When a laser beam irradiates on the material surface, it may be considered that energy flows in only one direction in a semi-infinite body. The depth the laser energy penetrated into the material surface is constrained by the duration of the laser irradiation. Increasing irradiation time will allow the laser energy to penetrate deeper so as to raise the material substrate temperature. In the Figure 7 is shown the dependence Optical absorption depths for several materials over a range of wavelengths [9].

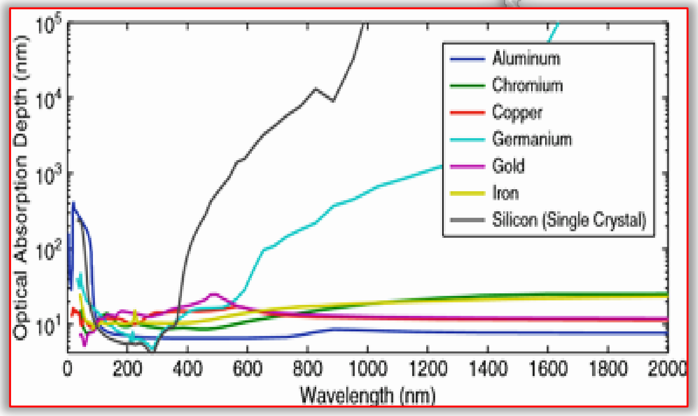


Figure 7. Optical absorption depths for several materials over a range of wavelengths [9]

The different effects of laser power flux and irradiation duration on the temperature elevation in the material can influence on the quality of laser cleaning.. For the purpose of laser cleaning, higher surface temperatures are desirable for the removal of machining debris. However, the elevation of temperature may damage the tested/ cleaned material structure, which should be prevented. Therefore, high power flux and short irradiation laser pulses are likely to be optimum for laser cleaning purposes. [10]. In the Figure 8 is shown the focus position of laser beam, which is a one way how we can prevent the damage of material structure and surface during the cleaning operation. [11].

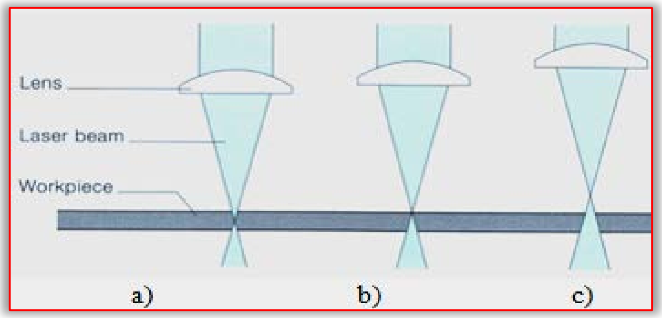


Figure 8. Focus position of laser beam: a) in the workpiece, b) on the surface, c) above the part [11]

MATERIALS AND METHODS

The realization of the experimental testing of laser cleaning was made in Technical University in Kosice together with the cooperation of the firm Trumpf Slovakia s.r.o., Figure 9. Used materials for the experiments were following:

a. Material: Steel sheet KOSMALT 190, dimension of table: 100x50 mm, thickness: 2 mm, mechanical properties were according to standard STN 038737
b. Synthetic lubrications [12],[13],[14]:

1. Berutox M21 EPK 420, temperature range: -5 °C to + 200 ~ + 220°C, viscosity of the basic oil: 490 mm2.s-1, at the temperature t = 40°C,
2. Berutox M 21 KN, temperature range: -5 °C to + 200 ~ + 220 °C, viscosity of the basic oil: 490 mm2.s-1, at the temperature t = 40 °C,
3. Beruplex LI-EP 2, temperature range: -30 °C to + 150 °C.

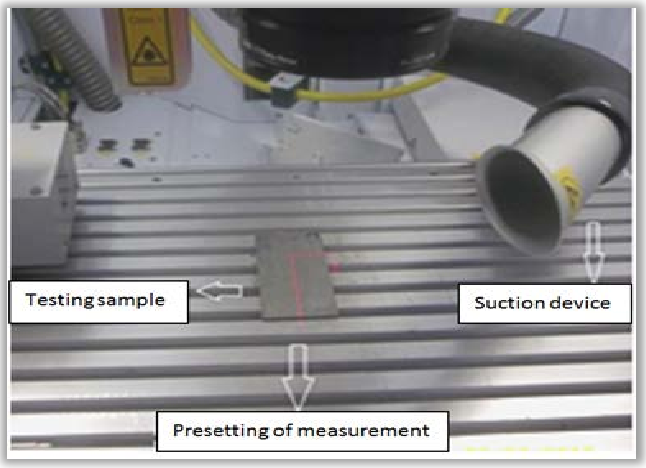


Figure 9. Laser cleaning – position of the sample

There was used 5 tested pieces for each material and lubricant combination for the experiment.

After degreasing with technical white gasoline, the tested samples were weighed on laboratory scales MS, METTLER TOLEDO. The three types of lubricants were applied on the samples by a paintbrush and were weighed again. In the Figure 10 is shown prepared tested pieces greased with three types of lubricants. The decreasing of tested samples by laser cleaning were experimentally provided on the laser compact machine TruMarkStation 5000, with the least power, to not do an effect on the surface layer of the metal by hardening.

Figure 10. Tested materials

There was used the "c" type of focus position of laser beam as it is shown in the Figure 8. The condition of the laser parameters are shown in the Table 2.

Table 2. Testing parameters of laser beam at the degreasing of testing sample

beam source	TruMark 6130
optics	F 163
wavelength λ	1604 μm
speed of the laser beam v	1000 mm/s
frequency	50 kHz
defocus	1,5 mm

In the Table 3 is shown the chemical parameters of the steel KOSMALT 190. [15], [16]

Table 3. Chemical elements of steel KOSMALT 190

Chemical element	C	Mn	$Si_{max.}$	$P_{max.}$	$S_{max.}$	Al	$Cu_{max.}$	$Ti_{max.}$
content[%]	max. 0,04	max. 0,19	0,01	0,015	0,012	0,02 – 0,06	0,060	-

RESULTS

After laser cleaning operations, the tested samples were weighted again and were found the weight loss of tested samples. The weighted values of the tested samples are shown in the Table 4.

Table 4. Examples of the values of the tested samples c leaned by laser beam

Sample	Weight of tested sample			
	Degreased sample by white gasoline	Sample + lubrication	Degreased sample by laser	Used lubricant
1	53,189	53,607	53,505	Berutox M 21 EPK 420
2	52,029	53,074	52,77	Berutox M 21 KN
3	53,972	55,518	54,593	Beruplex LI-EP2

After preparing of tested samples with three types of lubricant, Figure 11, the laser beam passed only one time through the surface samples during the laser cleaning. During the experiments we changed the setup of the laser focus on the position +2,+1,0, -1, -2 regarding to basic position (according Figure 8).

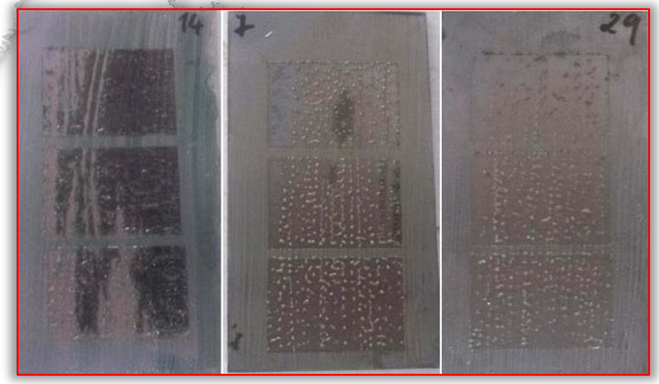
These results are shown from the Figure 12 to Figure 14.

a) b) c)

Figure 11. Tested samples No. 14, 7, 29 before degreasing by laser cleaning: a)No-14 Beruplex, b) No-7 Berutox M21 EPK/420,c) No29 Berutox M21 KN

In the Figure 13 and Figure 14 are shown the laser paths with the cleared areas and areas with the rest of lubricant. From the practice of laser testing is known, that the synthetic lubricants remove very hardly. The experiment confirmed this assumption.

The details of tested samples were examined in the microscope Olympus at mag. 50x, mag. 100x.



a) b) c)

Figure 12. Tested samples No. 14, 7, 29 after laser cleaning: a)No-14 Beruplex, b) B No-7 Berutox M21 EPK/420, c) C No29 Berutox M21 KN

In the Figure 15 and Figure 16 are shown the path of laser cleaning on the sample that can be observed as a macrostructure of tested material with the remains of lubricants in the form of drops.

In the Figure 17 are shown the examples of the microstructures of tested samples with using of two lubricants, where can be seen the laser points (as the path) and residual of lubricants drops.

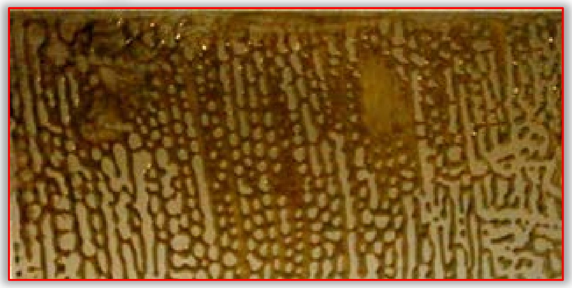


Figure 13. Sample after laser cleaning Lubricant Berutox M 21 EPK 420, mag.5 x

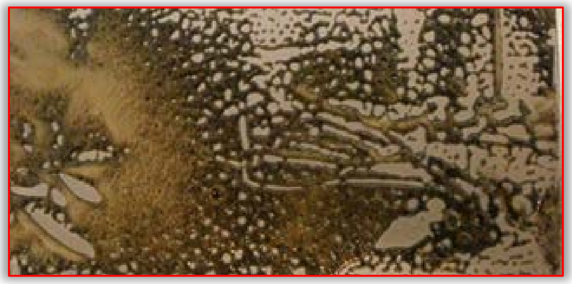


Figure 14. The sample after laser cleaning Berutox M 21 KN, mag.50x

Figure 15. The sample after laser cleaning lubricant Berutox M 21 KN , mag.50x

Figure 16. Detail of degreasing of lubricant Berutox M 21 KN, mag.50x

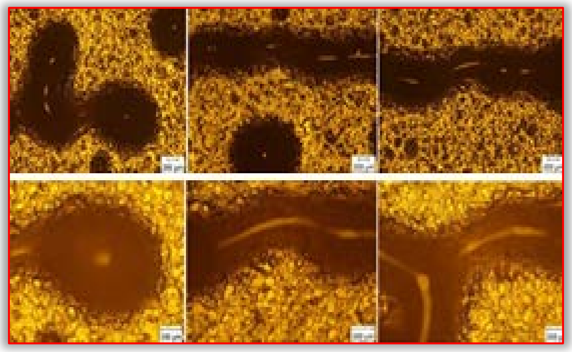


Figure 17. Samples after laser cleaning: lubricant Berutox M 21 EPK 420, mag.100x, Berutox M 21 KN, mag. 100x

The results of the comparison of the chosen tested samples weighted on the laboratory scales and cleaned by laser beam, are shown in the Figure 18.

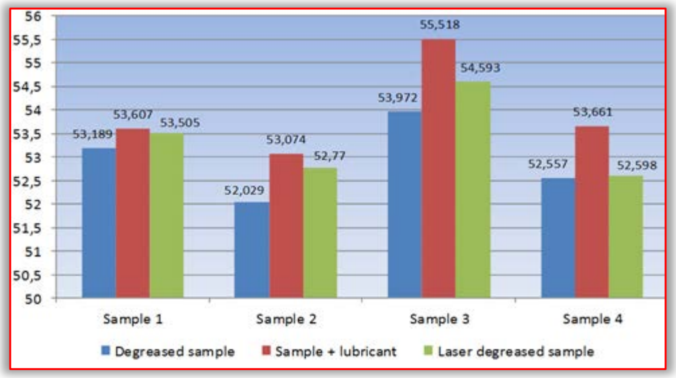


Figure 18. Degreasing of testedsample by laser beam, 1 – Berutox M 21 EPK 420, 2 – Berutox M 1 KN, 3 – Beruplex LI-EP 2, 4 – Berutox M 21 KN

CONCLUSION

Due to the ongoing problem of environmental protection of living and workplace environment, we try to find ways how to minimize production waste and reduce the number of technological operations on the products.

The engineering industry as a whole is greatly utilize the lubrication of materials for the rust protection, for technological operations and od the other hand we must degrease the workpieces before surface finishing operations . Also during the life-service of machines occurs the necessity to do the maintenance or to remove the dust from functional parts. That is why we try and look after new progressive technologies, which enable to minimize the number of technological operations, save the amount of chemicals. This is the new way how to minimize the impact on the environment. One of these ways was to try degreasing of the testing samples by laser technology and as it can being in ultrasonic machines with the using of chemicals and rinsing water.

In cooperation with TRUMF Slovakia, s.r.o., we tested and verified the possibility of cleaning of the samples with a laser beam (with the compact machine TruMark 5000) for the first time.

From the experiments, it is shown that during the laser cleaning tests of the samples, it is necessary to define the exact conditions of cleaning, how to set parameters of laser beam, to define the material properties as reflexivity, mechanical properties to reach the best results.

The samples were greased by the synthetic lubricants BERUTOX M 21 KN and the lubricant Berutox M 21 EPK 420, where the worst results were reached with the samples, which were greased by the lubricant Berutox M 21 EPK 420. Organic lubricants, as sunflower oils or fat burn during the cleaning operations that is why we did not used them.

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