ACTA TEHNICA CORVINIENSIS – Bulletin of Engineering
Tome VIII [2015] Fascicule 1 [January – March]
ISSN: 2067 – 3809

[1.] Eva ŠEBELOVÁ, [2.] Josef CHLADIL

STUDY OF THE TOOL WEAR PROCESS IN THE MACHINING OF NON-METALLIC MATERIALS

[1.] Department of Furniture, Design and Habitat, Faculty of Forestry and Wood Technology, Mendel University in Brno, Zemědělská 1, Brno 613 00, CZECH REPUBLIC
[2.] Institute of Manufacturing Technology, Faculty of Mechanical Engineering, Brno University of Technology, Technická 2896/2, Brno 616 69, CZECH REPUBLIC

Abstract: The issue of tool wear in the machining of non-metallic materials is a very under-researched area. The theory is based on the findings known in metals and is extended by interaction of the tool with wood-based materials. These materials have completely different properties, most of them are characterized by poor thermal conductivity and a different behaviour in different directions of load (axial, radial and tangential). The course is based on a tool wear in the wear curves. Criterion wear defines the maximum wear – a period corresponding to the working state of edge. Studying the process of wear is monitored mainly due to determine dependencies between the durability of the cutting tool and the cutting speed. Addiction is characterized by Taylor's relationship. Determination of tool life vs. cutting speed (T - vc) is the starting basis for determining machinability . It is a material property that characterizes its suitability for machining. Measurement of tool wear in metal materials was carried out mainly on the back or top rake. However, for non-metallic materials, this wear is negligible and difficult to measure. This article is focusing on the issue of defining and measuring the radial edge wear.
Keywords: cutting tool, wear, machinability, tool-life, non-metallic materials

INTRODUCTION

The cutting process of wooden materials and wood-based materials is different from the process of cutting metal materials, mainly in the fact that they are materials with very different properties especially in terms of deformation processes. Materials made of solid wood, but also agglomerated and laminates have significantly different properties in different directions of loading - axial, radial and tangential [5, 6].

In terms of the cutting process and degree of cutting tool wear, wood based materials can be divided into materials that can cause abrasive effects of the cutting tool and materials which cannot cause the abrasive. Furthermore, most of the non-metallic materials have a poor thermal conductivity.

When viewing their work in the cutting process it is always necessary to consider also their effects onto the cutting tool. Here significantly different characteristics in terms of their effect on the tool wear processes are reflected. Unlike metals, where tool wear is most frequently observed on the clearance plane, such wear is hardly traceable on wood based materials [6, 9].

The cutting process and effects of the work material on the cutting tool in terms of its dulling relates to its machinability. The machinability of the material expresses its suitability for machining. Experiments may serve to machinability determination, in which the tool life time in relation to the selected cutting conditions is observed. From the resulting dependencies – the tool wear curves are also made for machinability evaluation [7, 9].

METHODOLOGY

Methodology of machinability determination of wood-based materials was used to determine the material properties in cutting process. For this methodology was necessary to choose the most widely used materials in the woodworking industry - laminated chipboard (DTD-L) and medium density fiberboard (MDF). Selected materials were assigned to the group of materials marked by the free letter for marking material groups "w" due to determination of their machinability. Both materials were tested on the same machine center - SCM Tech 99 by left-hand flat-end-mill with two teeth (D = 19 mm) and replaceable blades made of sintered carbide HW 29.5x12x1.5 4s T04F at the same working conditions (Table1). Conventional milling was chosen for testing. [1, 7].

Measuring device

The gauge Passametr Somet was used for measuring tool wear in machining process of chosen materials. This is a comparative gauge measuring the deviation from the set-up of original blade dimension. The gauge had the micron range $\langle +25;-25 \rangle$ with one movable contact, when the other was fixed with a screw and the movable one was connected to a built-in dial indicator.

Table 1: *Cutting conditions*

Cutting conditions	*Symbol*	*Value*	*Units [-]*
Diameter of the tool	*D*	*19*	*mm*
Number of teeth	*z*	*2*	*-*
Feed per tooth	f_z	*0.05*	*mm*
Depth of cut	*H*	*9.5*	*mm*
Depth of milled layer	a_{pmax}	*9.5*	*mm*
Machine speed	*n*	*8000 12000 15000 18000*	$rev{\cdot}min^{-1}$
Feed rate	v_f	*800 1200 1500 1800*	$mm{\cdot}min^{-1}$
Cutting speed	v_c	*477 716 895 1074*	$mm{\cdot}min^{-1}$

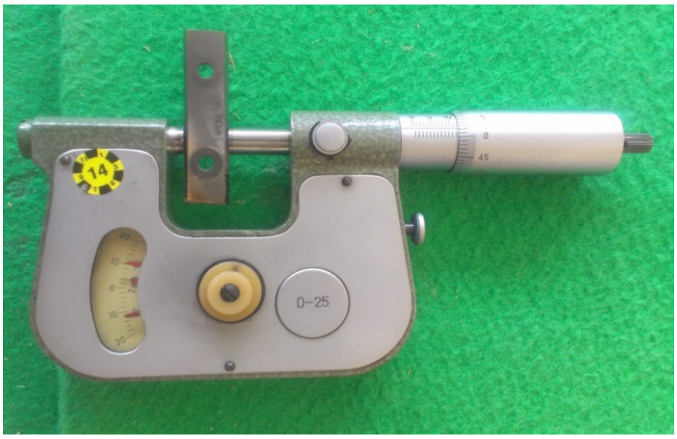

Figure 1: *Comparative gauge Passametr Somet*

Curves of radial tool wear - KR

The measured values were processed in the form of diagrams for both materials in a plot wear vs. machining time [3, 8, 10]. Individual curves of tool wear were in colour differentiated according to the cutting speed, respectively machine rpm. The radial tool wear rate (criterion) 10 μm from the original size of blade was determined for both materials and this value was highlight into the curves of wear diagram. On the x-axis individual life-times of the tool were subsequently plotted with following condition: $v_{c1} < v_{c2} < v_{c3} < v_{c4}$; $T_1 > T_2 > T_3 > T_4$ *(Figure 2 and Figure 3) [11, 12].*

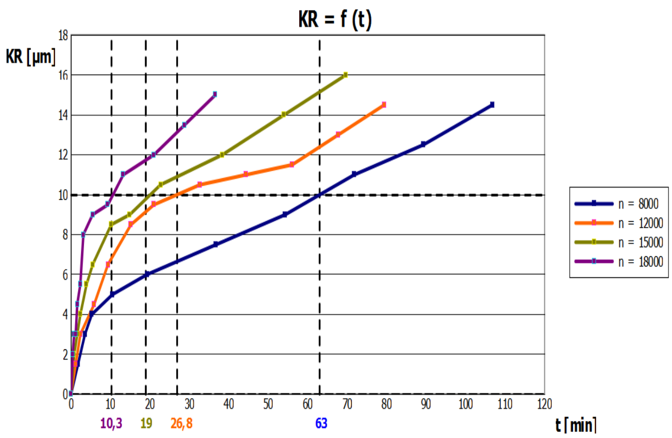

Figure 2: *Tool wear curves of laminated chipboard - KR = f (t)*

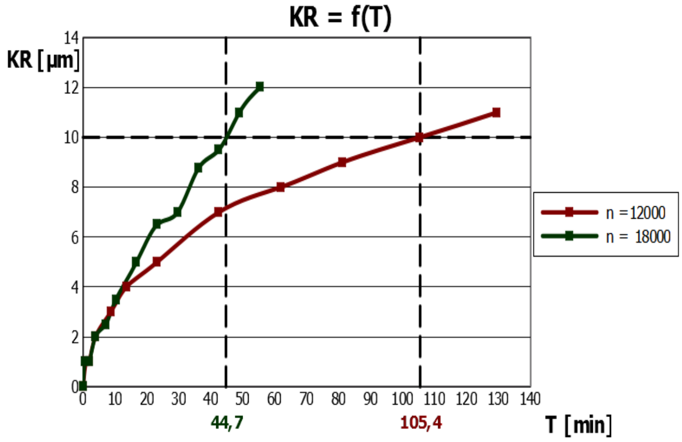

Figure 3*: Tool wear curves of medium density fiberboard- KR = f (t)*

Taylor's equation

There was also determined the relation between tool life-time and the tool wear rate by dependence life-time vs. cutting speed (T - v_c) which is characterized by Taylor's equation [2, 3, 10]:

$$T = C_T \cdot v_c^{-m} \quad [\mathrm{min}] \tag{1}$$

where the (T) is the life-time, (C_T) is the constant, (v_c) is the cutting speed and (m) is the exponent.

Individual life-times T1, T2, T3, T4 were converted to logarithms and were plotted to the $T = f(v_c)$ diagram due to expression the linear dependence. Then the statistical method - linear regression was applied where individual life-times of the tool were line interpolated with the gradient a [4]:

$$f(x) = a \cdot x + b \;\Rightarrow\; f(x) = -m \cdot \log v_c + \log C_T \tag{2}$$

where the (m) is the exponent, (v_c) is the cutting speed and (C_T) is the constant.

Both tested materials (DTD-L, MDF) were inserted into the diagram $T = f(v_c)$. Then it was necessary to define a tool life time and highlight this value in the diagram. The line corresponding to the selected tool life-time $T \approx 44.7$ min ($\log T \approx 1.65$) was plotted and cutting speed values ($\log v_c$) were determined on the x-axis (Figure 4, Table 3). Graphical representation of dependence between life-time and cutting speed the angle α (exponent m) indicates [2, 3, 10]:

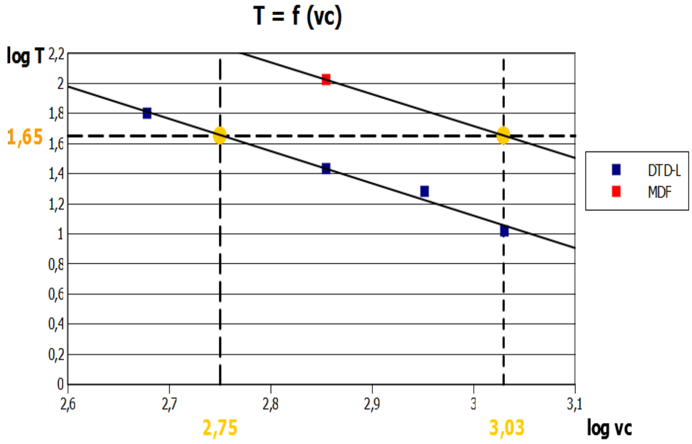

Figure 4*: Dependence $T = f(v_c)$*

Index of kinetic machinability

From those tested materials the laminated chipboard was selected as reference sample for further comparison. Index of kinetic machinability determines assigning material to the class of machinability whose mean value represents the suitability of the material for machining due to reference sample. The rule applies that materials with a lower number of machinability classification than the reference sample have worse machinability; materials in classes with higher number have better machinability. Index of kinetic machinability is calculated as follows [8, 10]:

$$K_V = \frac{v_{c(T)}^{\text{tested material}}}{v_{c(T)}^{\text{reference sample}}} \quad (3)$$

where the (K_V) is the index of kinetic machinability, $(v_{c(T)})$ is the cutting speed v_c corresponds to the selected tool life-time T.

Material classification

The classes of machinability are marked by a number situated before the letter of each material group. This classification is defined according to the index of kinetic machinability K_V which is determined by interval with mean value of K_V in relation to reference sample. Reference sample has a value of $K_V = 1{,}00$ [3, 8, 10].

Table 2: *Index of kinetic machinability values for material classification*

Median Kv	Interval Kv	Class of machinability
0.32	0.29 – 0.35	6
0.40	0.36 – 0.44	7
0.50	0.45 – 0.56	8
0.63	0.57 – 0.71	9
0.80	0.72 – 0.89	10
1.00	**0.90 – 1.12**	**11**
1.26	1.13 – 1.41	12
1.59	1.42 – 1.78	13
2.00	1.79 – 2.24	14
2.50	2.25 – 2.82	15
3.15	2.83 – 3.55	16

The following table consist of reference sample and tested material cutting speed values correspond to selected tool life-time based on diagram $T = f(v_c)$ (Figure 3).

Table 3: *Values of cutting speed v_c corresponds to life-time T*

	T [min]	$v_{c\,\text{ref.sample}}$ [mm·min^{-1}]	$v_{c\,\text{tested mat.}}$ [mm·min^{-1}]
log x	1.65	2.75	3.03
x	44.7	562	1074

Index of kinetic machinability was calculated using equation (3) and its result is $K_V = 1.91$.

The result corresponds to the range (1.79 to 2.24) and the mean value of $K_V = 2.0$. According to the table of index of kinetic machinability values, the MDF material is assigned to the 14th class of machinability. This material is thus better machinable than the reference sample (DTD-L) [11, 12].

Table 4: *Results of material machinability*

Material	Class of machinability
DTD-L	11w
MDF	14w

CONCLUSION

The tool wear process in the machining of non-metallic materials is based on the methodology of wood-based materials machinability determination. This methodology is based on the measurement of tool wear during cutting materials and monitoring the process of wear depending on the machining time. Material machinability determination deals with defining of a selected material as a reference sample for comparison with another material. Next step is focused on determination of dependence between tool life-time and cutting speed. The final material classification to the class of machinability is based on the kinetic machinability calculation - K_V. K_V is expressed by the ratio of material cutting speeds: it means tested material at the chosen tool life-time and reference sample at the same tool life-time (3). The resulting value is assigned to the corresponding interval of K_V and the material is classified to the appropriate class of machinability.

Next step will reduce time-consuming process of measuring which will be based on the change of tool wear measurement principle without disassembling blades from milling cutter. It will be used a new measurement jig for determination of radial tool wear to ensure and improve measurement accuracy. It will be consist of stand for dial indicator and fixture part for stabilization of whole flat-end mill. This would significantly reduce the time needed to complete the experiment.

ACKNOWLEDGMENT

The work has been supported by Internal Grant Agency (IGA) 33/2012 of Mendel University and by the Department of Trade and Industry of the Czech Republic under grant FR–TI4/247.

REFERENCES

[1.] Bumbálek, B. Material Machinability – Decisive Factor for Development of Machining Technology and Creation of Technological Databank Informations. Manufacturing Technology, 2001, vol. 1, no. January 2001, pp. 3-10. ISSN 1213-2489.

[2.] Csanády, E.; Magoss E.. Mechanics of wood machining. 2nd ed., New York: Springer, 2012, pp. 199, ISBN 978-3-642-29954-4.

[3.] Davim, J. Paulo. Machining: fundamentals and recent advances. London: Springer, c2008, xiii, 361 s. ISBN 978-1-84800-212-8.

[4.] Dowdy, S., Wearden S.; Chilko D. Statistics for research. 3rd ed. /. Hoboken, N.J.: Wiley-Interscience, c2004, xvi, pp. 627. ISBN 04-712-6735-X.

[5.] Chladil J. Problems of cutting tool design for wooden shaped surfaces, In: Annals of DAAAM for 2005 & Proceedings „Intelligent Manufacturing & Automation", pp. 067-068,

DAAAM International Vienna, Opatia, 2005, ISBN 3-901509-46-1.

[6.] *Chladil, J. Otupení nástrojů při obrábění materiálů na bázi dřeva. In: Nástroje 2006 - V. International Tool Coference. 1. vyd. Zlín: UTB Zlín, 2006, pp. 1-5, ISBN 80-7318-448-6.*

[7.] *Chladil, J. Rychlostní poměry při CNC obrábění rovinných křivek. Strojírenská technologie, 2010, roč. XV., č. 3, pp. 48-51. ISSN 1211-4162.*

[8.] *Forejt M., Piška M. Teorie obrábění, tváření a nástroje, vyd. 1., Brno: Akademické nakladatelství CERM, 2006, pp. 225, ISBN 80-214-2374-9.*

[9.] *Kocman, K., Prokop, J. Cutting Tools for Hard Material Turning. Manufacturing Technology, 2004, vol. 4, no. October 2004, pp. 5-10. ISSN 1213-2489.*

[10.] *Shaw, M.C. Metal Cutting Principles, 2nd ed., Oxford university press, New York, Oxford, 2005, pp. 651, ISBN 0-19-514206-3.*

[11.] *Šebelová, E., Chladil, J. Tool Wear and Machinability of Wood-based Materials during Machining Process. Manufacturing Technology. 2013. sv. 13., č. 2., s. 231--236. ISSN 1213-2489.*

[12.] *Šebelová, E., Kopecký, Z. Problems of tool wear while cutting wood-based materials. In FORTECHENVI 2013. 1. vyd. Novotného lávka 5, Praha 1: Origit, s.r.o., 2013, s. 220--221. ISBN 978-80-02-02467-5.*

ACTA Technica CORVINIENSIS
BULLETIN OF ENGINEERING

ISSN:2067-3809