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RESEARCH ON THE POWER CONSUMPTION IN SANDING PROCESS WITH ABRASIVE BRUSHES, COMPARED TO THE WIDE BELT SANDING

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Abstract
This paper presents the modelling of over-finishing grinding with abrasive brushes and also a comparative study between the absorbed power when over-finishing grinding the beech, the spruce and the MDF with this kind of tools as compared to the absorbed power when over-finishing grinding under similar conditions using the wide belt sanding (grinding) technology, presenting the advantages of reconsidering such a technological process.

***Key word**: absorbed power; over-finishing grinding process; abrasive brushes.*

PROBLEM STATEMENT

It is well-known the fact that a wood surface becomes fibrous after grinding. Its image is "unclear" due to the occurrence of fine raising fibres (Beganu 2001). The reason for such a phenomenon is on the one hand the geometry of the cutting tools, and on the other hand the kinematics and dynamics of the grinding process. The abrasive granules have cutting edges resulted from the intersection of random plane surfaces that generate variable cutting angles, and the grinding kinematics generates dust, which loads the surface of the part and of the tool, clogging it (Badescu 2000, Badescu *et al*. 2011, Beganu 2001). This phenomenon negatively affects the specific productivity of the abrasive belt, contributes to power absorption increase and last, but not least, to the damage of the grinded surface by the occurrence of fine fibre. In case of varnishing or patina finishing, tensions occur within such fibres, inducing their raise of the surface. The final result is a fibrous surface, which represents a manufacturing defect. For correction, a repeated over-finishing grinding is necessary, using the wide belt grinding machinery which uses abrasive belt with granulation 200 up to 240 in certain cases. Hence, the current wide-belt over-finishing grinding technologies are high power and abrasive tools consumers, as well as generators of dust particles with micron sizes extremely dangerous for environment and humans.

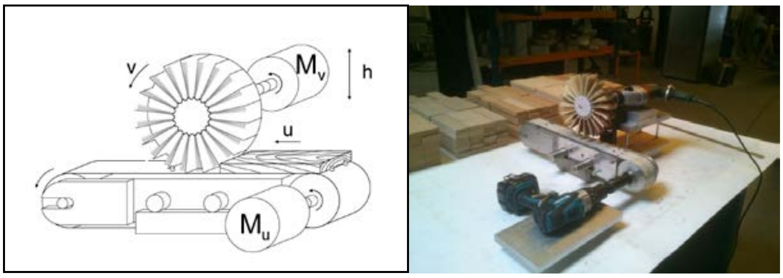
OBJECTIVES

The purpose of these research was to demonstrate the efficiency and the necessity of replacing the abrasive belts with abrasive brushes when over-finishing the wooden surfaces also in terms of power absorption.

THE EXPERIMENT – METHOD AND MATERIALS

During the last decade, new solutions for the over-finishing grinding occurred on the grinding technology market, all consisting in the use of abrasive brushes. However, these new technologies are timidly implemented within production due to the fact that the grinding conditions providing surfaces with both evenness and complete absence of fine fibers are unknown. Studying and designing new technologies using abrasive tools which remove wooden fibres and, in the same time, reduce the dust emissions through the process's kinematics itself became a serious subject and a research topic with industrial applicability.

In order to perform a thorough study on this topic, a test bench (Fig. 1) (Badescu 2000, Darii 2011, Madan 2014, Madan and Badescu 2015) was set up, consisting of a mobile table driven by an electromotor **M_u** (of direct current, 18 V, speed of 0 – 2000 min^{-1}), which moves the wooden part (a sample with the advance speed **u)** placed on it. The abrasive brush used in the experiment is independently driven by an electromotor **M_v** (of 800 W connected to the 220 V alternative current mains, developing a speed of 0 – 3000 min^{-1}) fasten up vertically on a mobile table, allowing the height adjusting of the abrasive brush depending on the part's position.



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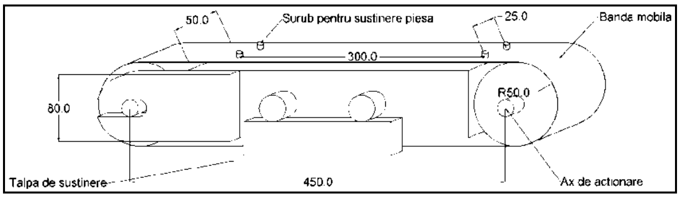
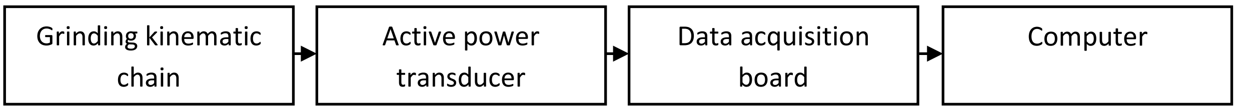


b

Fig. 1.
Tangible modelling (Badescu 2000) for active power measuring
a – Test bench for grinding using the Uniflex® abrasive brush; b – The geometrical characteristics of the mobile table performing the part's advance

The kinematic and dynamic parameters of the process have been adjusted using a device fitted with an adjustable ring. The work rates used within the experiment aimed certain comparative studies related to power absorption and dust emissions (dust concentration) when changing part's advancing speed, when changing the grinding speed and the contact length between the abrasive brush and the part being grinded, the study being performed for various types of wooden material and various types of abrasive tools (material and geometry). Each time after adjusting the speed, measured with an Elma DT 2236 tachometer, the process parameters have been checked, then the parameters monitored within the study have been recorded with a data acquisition board connected to a computer according to the block scheme presented in Fig. 2a. The test data recording equipment (the data acquisition board connected to computer and the active power transducer) is shown in figure 2b.



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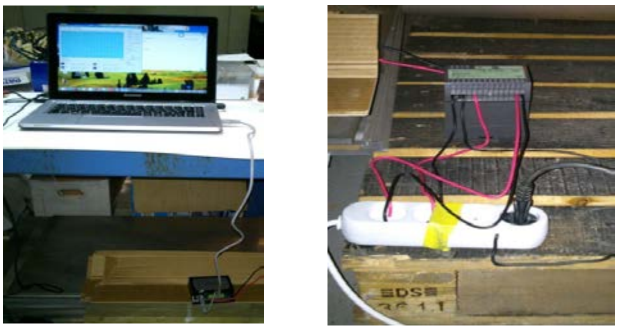


b

Fig. 2.
a – Test bench block scheme; b – Test data recording equipment (data acquisition board connected to computer and SINEAX P530 active power transducer with the related connections)

The database was obtained using the acquisition board software "Velleman Pc_Lab2000se v3.03", and its processing was performed using the Microsoft Office – Excel software. (Fig. 3).

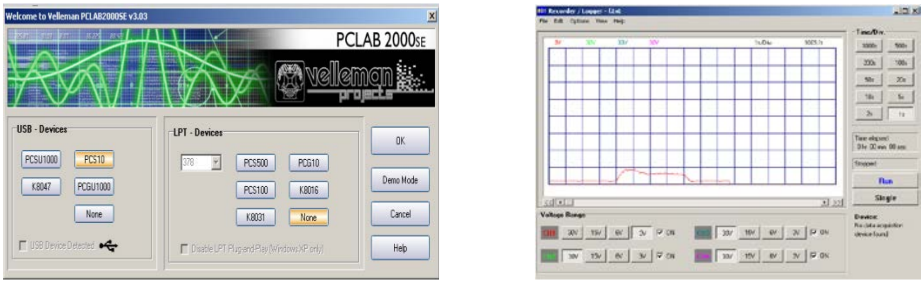
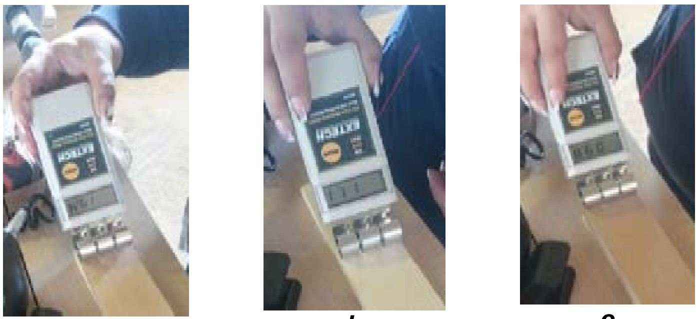


Fig. 3.
Velleman Pc_Lab2000se v3.03 acquisition board software

Before starting the experiments, the moisture content of the cut samples was measured with a digital humidity measuring device of Extech M0400 (0) type.



a ***b*** ***c***

Fig. 4.
Moisture measurements performed on the marked wooden samples (Madan 2014): a – Beech sample; b – Spruce sample; c – MDF sample

In the same time, the samples were marked for identification, using codes for each parameter being studied, as it follows. Three types of materials were tested: beech, spruce and MDF, for which the following symbols were used: Beech =**F;** Spruce **=M;** MDF **=MDF.** Three values for the overlapping height of the abrasive wires with the part were adjusted: Hci = **18; 11; 9;** [mm] The tests were performed for two different rotational speeds, i.e.: n = **450; 700** [rpm] and two different advancing speeds: u = **3; 6 [m/min].** Two types of abrasive granules were used**:** Granules type =***ALO*** (aluminum oxide); ***SiC*** (silicon carbide) and three grit sizes for each type of abrasive: Granulation = **P180; P150; P220.** The following codification model resulted (example):

code **F 9 450 6 AlO 220** this means: Beech, Hci=9mm, n=450, f=6m/min, Aluminum oxide, P220

code **MDF 18 700 3 SIC 150** this means: MDF, Hci=18mm, n=700rpm, f=3m/min, Silicon carbide, P150

code **M 11 450 6 SIC 220** this means: Spruce, Hci=11mm, n=450, f=6m/min, Silicon carbide, P220

Before processing the samples with abrasive brushes, the wooden parts were grinded with wide belt, (Badescu 2000, Fotin *et al*. 2008, Javorek 2006, Samolej and Barcik 2006) i.e.: For grinding with the brush of P150 granulation, the samples were processed with wide belt having a granulation of 80–120–150. For grinding with the brush with granulation of P180, the samples were processed with wide belt with a grit size of 80–120–150–180. For grinding with the P220 brush, the samples were processed first with wide belt with a grit size of 80–120–150–180–220.

RESULTS AND DATA PROCESSING

Table 1 includes the values of the absorbed power obtained when grinding 5 beech samples at a rotational speed of 450rpm, advancing speed of 3m/min and abrasive wires overlapping height of hci=18mm, using aluminium oxide abrasive wires with a granulation of P150.

Table 1.

Value of power consumption registered for a each type of sample

CODE	E1*[W]*	E2*[W]*	E3*[W]*	E4*[W]*	E5*[W]*	Em*[W]*
F184503ALO150	1.0626	1.0652	1.0647	1.0611	1.0618	**1.0631**

The absorbed power upon grinding was determined using the following formula:

$$Pa = Em - Ci, \quad [Kw] \qquad (1)$$

where*: Em* is the average of power absorption equal to the arithmetic mean of the total absorption power for the 5 values obtained following measurement (E1…E5) and it is calculated with the formula 2.

$$Em = \frac{(E1+E2+E3+E4+E5)}{5} \quad [kW] \qquad (2)$$

And ***Ci*** is the average of power absorption registered for grinding machine at idle speed, with the following calculation formula (3):

$$Ci = \frac{(C1+C2+C3+C4+C5)}{5} \qquad (3)$$

where C1………C5 represent the values of power absorption with the grinding machine at idle speed.

The statistical processing was performed using the MedCalc software. The following tests were applied: Chi-Squerd, Shapiro-Wilk, Kolmogorov-Smirnov and Shapiro-Francia and D'Agostino-Pearson.

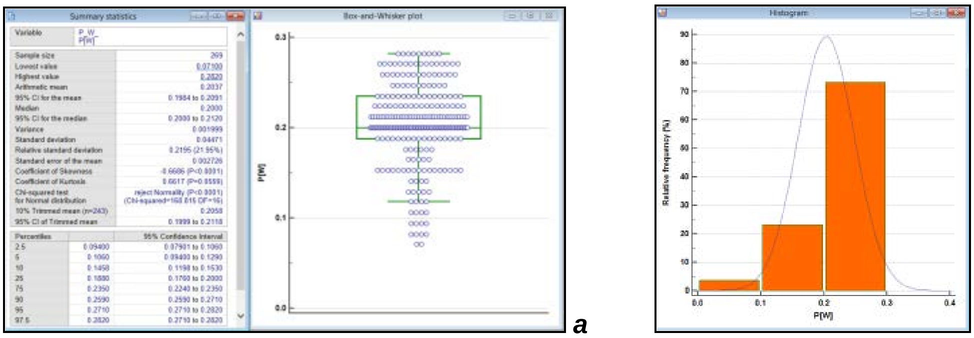


Fig. 5.
a - Shapiro-wild test for data validation; b - Histogram of data

Table 2 includes the average values of power absorption for the initial contact height of 18*mm and the power absorbed upon grinding with wide belt under the same conditions,* (Badescu *et al*. 2011, Darii 2011, Madan 2014, Madan and Badescu 2015) and Fig. 6 graphically represents such values.

Table 2

Comparison between the absorbed power upon brush grinding and absorbed power upon wide belt grinding

<table>
<tr><td rowspan="4">Grit size Brush</td><td rowspan="4">Hci [mm]</td><td rowspan="4">Type of grits</td><td>Wooden material</td><td colspan="4">Absorbed power mean value (W)</td></tr>
<tr><td>Rotation /Speed</td><td colspan="4">700 rpm /11.8m/s</td></tr>
<tr><td>Feed Speed</td><td colspan="2">3m/min</td><td colspan="2">6m/min</td></tr>
<tr><td>Wood Species</td><td>P [w]</td><td>% (of absorbed power upon wide belt grinding</td><td>P [w]</td><td>% (of absorbe d power upon wide belt grinding</td></tr>
</table>

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P150	**18**	**Aluminium Oxyde**	Beech		1.7986	**8.91%**	2.0424	**7.48%**
			Spruce		2.1482	**17.66%**	1.9596	**11.77%**
			MDF		2.0102	**39.82%**	1.8814	**29.62%**
Wide belt	**Sanding depth [*mm*]**		Rotational Speed		**1500rpm / 18 m/s**			
			Feed Speed		P belt [w]			
					4.5 m/min		***9 m/min***	
P150	**0.1 k=250**	**Aluminium Oxyde**	Beech	Pb	5041		6818.2	
				Pb/k	**20.164**		**27.2728**	
			Spruce	Ps	3085		4.1602	
				Ps/k	**12.34**		**16.6408**	
			MDF	Pmdf	1261.8		1589	
				Pmdf/k	**5.0472**		**6.356**	

The work rates for the experimental model (Badescu 2000), were chosen so that the same ratio between the parameters ***v*** and ***u*** is maintained***.***

If the ratio is $\frac{v}{u} = 240$ upon wide belt grinding with minimum advance (f-3m/min), when grinding with the experimental model with brush the ratio is $\frac{v}{u} = 236$ this means 98,3% from practical value. For the maximum advance (f=9m/min) upon wide belt over-finishing grinding the ratio is $\frac{v}{u} = 120$, and $\frac{v}{u} = 118$ (98,33% from real value) for the experimental value at the maximum advance in case of brush grinding.

Moreover, $\frac{v}{v_{ex}} = \frac{u}{u_{ex}} = \frac{D}{D_{ex}} = 1{,}5$.

The ratio between the absorbed power upon wide belt grinding and brush grinding does not keep the same coefficient anymore, the latter varying due to the much lower grinding forces in case of brush grinding as in case of wide belt grinding.

As it may be noticed in Table 2, the absorbed power values in case of grinding with a P150 granulation with brushes, and belt respectively, significantly vary. The comparison was made taking into account that the surface being grinded in that two situations complies with the following relation:

$$S_{belt}=k \cdot S_{brush} \qquad (4)$$

where: *k*=262.7 (for the case being studied) is an amplification coefficient (Madan and Badescu 2015) for the power obtained upon abrasive brushes grinding, so that the absorbed power may be reported to the same surface in both situations. It results that in case of brush grinding, the power absorption is between 8% and 40% as compared to the absorbed power when grinding with wide belt for the advance of 3m/min and between 7% and 30% for the advance of 6m/min, depending on the type of material being grinded. Moreover, it is interesting that brush grinding involves the highest absorption power in case of MDF, as compared to wide belt grinding where the highest absorption power occurs in case of beech. The explanation could be the sizes of contact surface. The same width being grinded is divided on wires when using brushes, the forces being thus distributed, as compared to the case when a belt is used, where the contact is continuous and thus the forces aggregate.

Furthermore, brush grinding dynamics facilitates the tool automatic cleaning, unlike when a belt is used where cleaning the dust is more difficult as it pressed on the sanded surface on a bigger length.

The absorbed power when grinding with abrasive brushes as compared to the absorbed power when grinding with wide belt - P150 granulation is presented in Fig. 6

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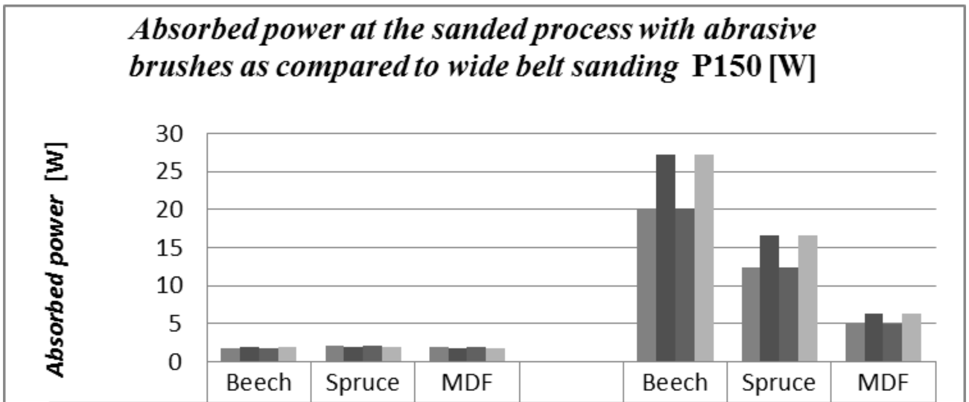

	Beech	Spruce	MDF		Beech	Spruce	MDF
f= 3m/min	1.7986	2.1482	2.0102		20.164	12.34	5.0472
f= 6 m/min	2.0424	1.9596	1.8814		27.2728	16.6408	6.356
f= 3m/min	1.7986	2.1482	2.0102		20.164	12.34	5.0472
f= 6 m/min	2.0424	1.9596	1.8814		27.2728	16.6408	6.356

Fig. 6.
The graphical representation of the absorbed power, experimentally obtained for sanding with P150 granulation the beech, spruce or MDF samples with abrasive brushes as compared to wide belt grinding, in the same work conditions

CONCLUSIONS AND DISCUSSIONS

- The over-finishing operation is compulsory in order to perform a high quality grinding, which entitles us to believe that this operation may be successfully performed using abrasive brushes.
- The abrasive brushes represent an alternative to manual grinding of profiles, rounding of edges, but also to over-finishing of the plane surface parts. These processes are increasingly demanded on the market, this being the reason why this research finds a high applicability in the industry, contributing to the ecological design of the over-finishing grinding technologies.
- Compared to the absorbed power upon wide belt grinding, the power absorbed when grinding using brushes is 60% lower, reaching even 90% in certain cases (Madan 2014, Madan and Badescu 2015).
- The power absorbed when grinding using abrasive brushes may be optimized depending on the grinding rate and the type of abrasive material. Thus, for a speed increase from 3 to 6 m/min when grinding using aluminium oxide based abrasive, the power consumption decrease is by 5% for beech massive wood, by 13% for spruce and by 10% for MDF, and when the grinding using silicon carbide, the decrease is by 10% for beech, by 1% for spruce and by 3% for MDF.

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