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INFLUENCE OF TECHNOLOGICAL FACTORS UPON OF THE ROUGHNESS OF THE EXTERNAL CYLINDRICAL SURFACES PROCESSED WITH VIBRATORS ABRASIVE BELT

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Abstract. Finishing and superfinishing active surfaces of workpiece are expensive operation which requires a judicious choice of working parameters. This paper presents the results of research conducted on vibro finishing external cylindrical surfaces using the abrasive belt. The processing was performed using a vibro-smoothing device mounted on a lathe. It was analyzed the influence of the abrasive belt grain, normal force, the rotation speed of the workpiece and the work time for piece roughness. Based on a 2^4 factorial experiment it was obtained a matrix model which allowed the analysis of factors and their interaction influence on roughness. The results have shown that the most important factor is the belt grain, followed by working time and the speed of workpiece rotation.
Keywords: vibro finishing, superfinishing, abrasive belt, roughness, matrix modeling.

1. Introduction

Smoothing of the active surface processing of parts in contact is the basic concern of many industrial units. The quality of a product is determined by the quality of the components, the surface roughness as understanding the nature and characteristics of the superficial layer, as well as dimensional accuracy and form.

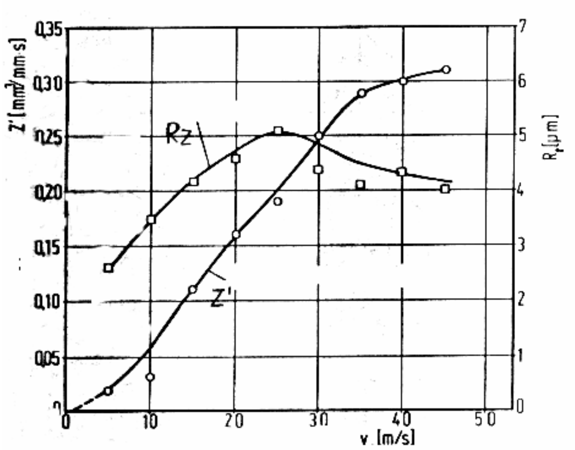

Fig. 1 Influence the belt speed on the roughness and productivity

Superfinishing is one of the operations of smoothing the surface, originally used in the automotive industry, where it was introduced vibratory superfinishing with abrasive belt. Was conducted researches regarding the influence of belt speed on the roughness and productivity [1, 3, 4], figure 1, the influence of abrasive grain material on the roughness [1,2,4], figure 2, and the specific normal force influence on the productivity and surface roughness [1,5], figure 3.

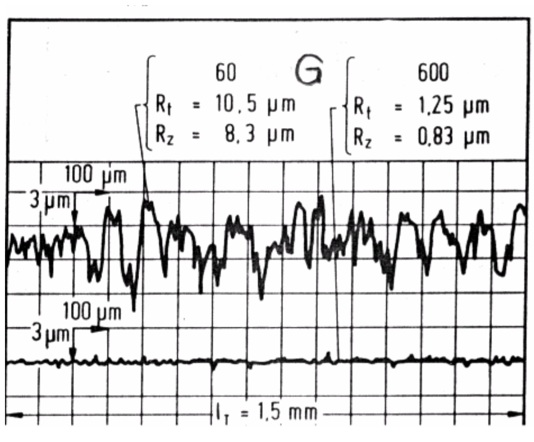

Fig. 2 Influence of abrasive grain G on the roughness

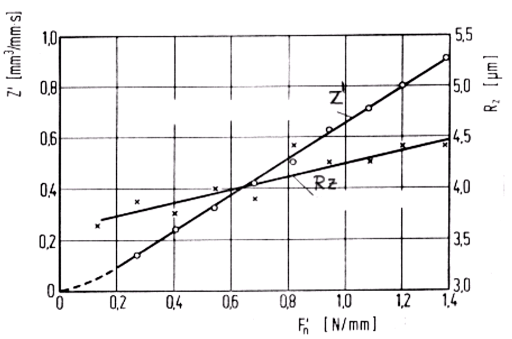

Fig. 3 Influence of normal force on the roughness and productivity

2. Experimental conditions

For experiments was used superfinishing device with vibrating abrasive belt mounted on a normal type lathe SNA 450, figure 4, were used abrasive belt with width of 80 mm and P240 and P500 grain FEPA by, producer company Starck.

The researches was conducted on OLC45 and RUL1, diameter 34 mm with an average roughness Ra = 2.94 ?m obtained by turning.

Surface roughness was measured with Surtronic 3 +, and forces was measured with dynamometer KMB M - Germany.

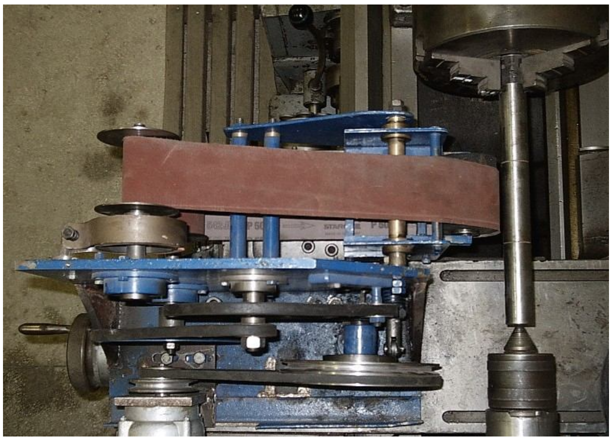

Fig. 4 Superfinishnig device with abrasive vibratory belt

3. Experimental results

3.1. Influence of processing time on the roughness

Processing was performed on two materials, RUL1 and OLC45 steel, with the following conditions:

- Normal force ……………………..24.5 daN
- Pinch rollers …...…………………40 shore hardness
- Amplitude vibration band…………..6 mm
- Tangential speed of the belt ………2.2 m/min
- Frequency …………………………12 Hz

The results of processing are shown in figure 5 for material OLC45 with grain of abrasive material P240, in figure 6 for P500 grain abrasive material and in figure 7 material processing RUL1 with P500 abrasive grain material.

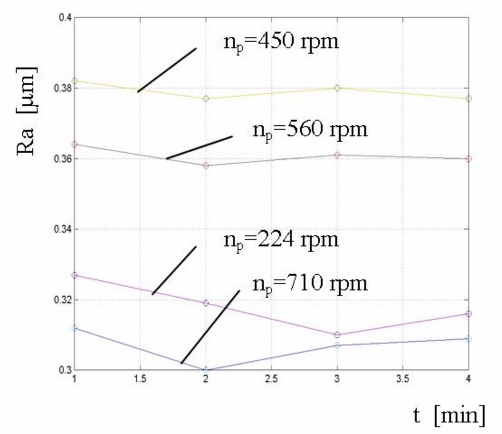

Fig. 5 Roughness depending on processing time and number of rotations of workpiece, np, for grain P240, OLC45

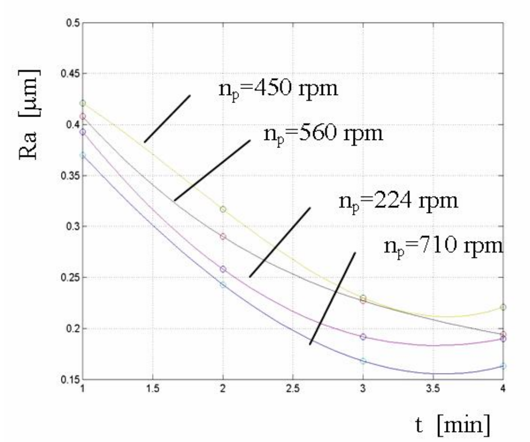

Fig. 6 Roughness depending on the time processing and number of rotations of workpiece, np, for grain P500, OLC45

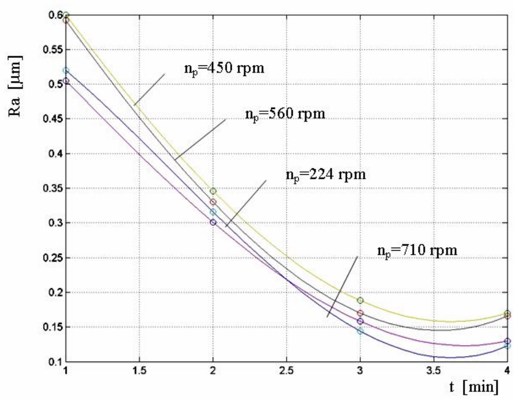

Fig. 7 Surface roughness according to the processing time, t, for various number of rotations of workpiece, np, RUL1, P500

Analyzing the experimental results presented in figures 5-7 result that while roughness decreases to a value of the process depends on other factors as tending to stabilize fluctuating within certain limits. The peripheral speed of the workpiece and the processing time is higher the more processed surface roughness decreases. Thus from 0.37 μm at speed of 710 rpm decreased to 0.16 μm for the processing time of 4 min for the material and to 0.52 μm OLC45 to 0.135 μm for material processing RUL1 under the same conditions.

Table 1 presents mathematical models that describe changes in roughness with time for processing conditions presented.

Table 1
Mathematical models of roughness with time

Piece material	**Number of rotations** [rot/min]	Mathematical model Ra = f(t)	**Correlation coefficient**	**Co-ments**
OLC 45	224	$Ra = 0,504 \cdot e^{-0,29 \cdot t}$	0,96	$t \in [1, 4]$
	450	$Ra = 0,528 \cdot e^{-0,245 \cdot t}$	0,98	
	560	$Ra = 0,521 \cdot e^{-0,267 \cdot t}$	0,99	
	710	$Ra = 0,497 \cdot e^{-0,326 \cdot t}$	0,97	
RUL 1	224	$Ra = 0,84 \cdot e^{-0,516 \cdot t}$	0,99	
	450	$Ra = e^{-0,527 \cdot t}$	0,98	
	560	$Ra = 0,966 \cdot e^{-0,51 \cdot t}$	0,975	
	710	$Ra = 0,902 \cdot e^{-0,547 \cdot t}$	0,99	

4. Matrix modeling the roughness

Set two values for input parameters and experiments were performed after full factorial experimental plan 24, the values presented in table 2.

Table 2
The values of input parameters

Level	**Belt grain**	**Normal force** F_N [daN]	**Number of rotations of workpiece** n_p [rpm]	**Proces-sing time,** t [min]
1	P240	24,5	224	1
2	P500	41	450	3

With the data input parameters were performed roughness measurements for two materials - OLC45 and RUL1 - using the pressure roller 40 shore hardness, table 3.

The mathematical model of the experimental roughness is:

$$\begin{aligned}
Ra = {} & 0.3428 + [0.04219 \;\; -0.04219] \cdot [A_{x1}] + \\
& + [-0.0123 \;\; 0.0123] \cdot [A_{x2}] + [-0.0238 \;\; 0.0238] \cdot [A_{x3}] + \\
& + [-0.0267 \;\; 0.0267] \cdot [A_{x4}] + [A_{x1}] \cdot \begin{bmatrix} -0.0212 & 0.0212 \\ 0.0212 & -0.0212 \end{bmatrix} \cdot [A_{x2}] + \qquad (1) \\
& + [A_{x1}] \cdot \begin{bmatrix} -0.0102 & 0.0102 \\ 0.0102 & -0.0102 \end{bmatrix} \cdot [A_{x3}] + [A_{x1}] \cdot \begin{bmatrix} -0.0252 & 0.0252 \\ 0.0252 & -0.0252 \end{bmatrix} \cdot [A_{x4}] + \\
& + [A_{x2}] \cdot \begin{bmatrix} -1.88 \cdot 10^{-4} & 1.88 \cdot 10^{-4} \\ 1.88 \cdot 10^{-4} & -1.88 \cdot 10^{-4} \end{bmatrix} \cdot [A_{x3}] + \\
& + [A_{x2}] \cdot \begin{bmatrix} -0.0238 & 0.023 \\ 0.0238 & -0.0238 \end{bmatrix} \cdot [A_{x4}] + + [A_{x3}] \cdot \begin{bmatrix} -0.0021 & 0.0021 \\ 0.0021 & -0.0021 \end{bmatrix} \cdot [A_{x4}]
\end{aligned}$$

where x_1 is grain parameter, the parameter x_2 is normal force, number of rotations of workpiece is the parameter x_3 and x_4 is the processing time.

Table 3
The roughness Ra

No.	**Factors level**				**Piece material OLC45**
	Belt grain	**Normal force, F_N [daN]**	**Number of rotations of workpiece, n_p [rpm]**	**Time, t [min]**	**Roughness Ra, [μm]**
1.	1	1	1	1	0,328
2.	1	1	1	2	0,315
3.	1	1	2	1	0,383
4.	1	1	2	2	0,38
5.	1	2	1	1	0,383
6.	1	2	1	2	0,378
7.	1	2	2	1	0,452
8.	1	2	2	2	0,461
9.	2	1	1	1	0,393
10.	2	1	1	2	0,19
11.	2	1	2	1	0,42
12.	2	1	2	2	0,235
13.	2	2	1	1	0,287
14.	2	2	1	2	0,278
15.	2	2	2	1	0,31
16.	2	2	2	2	0,292

Using relation (1) have calculated theoretical responses Ra_t and corresponding residues values, table 4 and the changes in mathematical model is shown in table 5.

It follows that all factors are independent, in order of importance for levels considered being abrasive grain belt (x1), processing time (x4), number of rotations of workpiece (x3) and normal force (x2).

Table 5
Analysis of variance for the mathematical model of roughness

Factor / interaction	**Variance**	F_{max}	F_T	**Significance**
x_1	0.028476563	18.5992	6.61	S
x_2	0.007425563	6.88423		S
x_3	0.009072563	7.92566		S
x_4	0.011395563	9.44291		S
x_1-x_2	0.007182563	6.69123		S
x_1-x_3	0.001660563	1.08458		NS
x_1-x_4	0.010150563	7.62975		S
x_2-x_3	5.625E-07	0.00037		NS
x_2-x_4	0.009072563	6.92566		S
x_3-x_4	6.80625E-05	0.04445		NS

Residual variance V_R = 0.001531063

Significant interaction between the effects: abrasive grain belt - normal force (x1-x2), abrasive grain belt - processing time (x1-x4) and number of rotations of workpiece -time processing time (x3-x4). The average effects of these four parameters independent studies upon the roughness Ra, are represented graphically in figure 8.

This shows that the reduction of P240 to P500 grain roughness decreases, the same effect having it increase the time.

Table 4
Roughness measured and theoretical responses residues

No	Factors level				Ra [μm]	Ra_t [μm]	r [μm]
	Belt grain	Normal force F_N [daN]	Number of rotations of workpiece n_p [rot/min]	Processing time, t [min]			
1.	1	1	1	1	0.328	0.34469	-0.0166875
2.	1	1	1	2	0.315	0.28994	0.0250625
3.	1	1	2	1	0.383	0.40894	-0.0259375
4.	1	1	2	2	0.38	0.36244	0.0175625
5.	1	2	1	1	0.383	0.36444	0.0185625
6.	1	2	1	2	0.378	0.40494	-0.0269375
7.	1	2	2	1	0.452	0.42794	0.0240625
8.	1	2	2	2	0.461	0.47669	-0.0156875
9.	2	1	1	1	0.393	0.37344	0.0195625
10.	2	1	1	2	0.19	0.21794	-0.0279375
11.	2	1	2	1	0.42	0.39694	0.0230625
12.	2	1	2	2	0.235	0.24969	-0.0146875
13.	2	2	1	1	0.287	0.30844	-0.0214375
14.	2	2	1	2	0.278	0.24819	0.0298125
15.	2	2	2	1	0.31	0.33119	-0.0211875
16.	2	2	2	2	0.292	0.27919	0.0128125

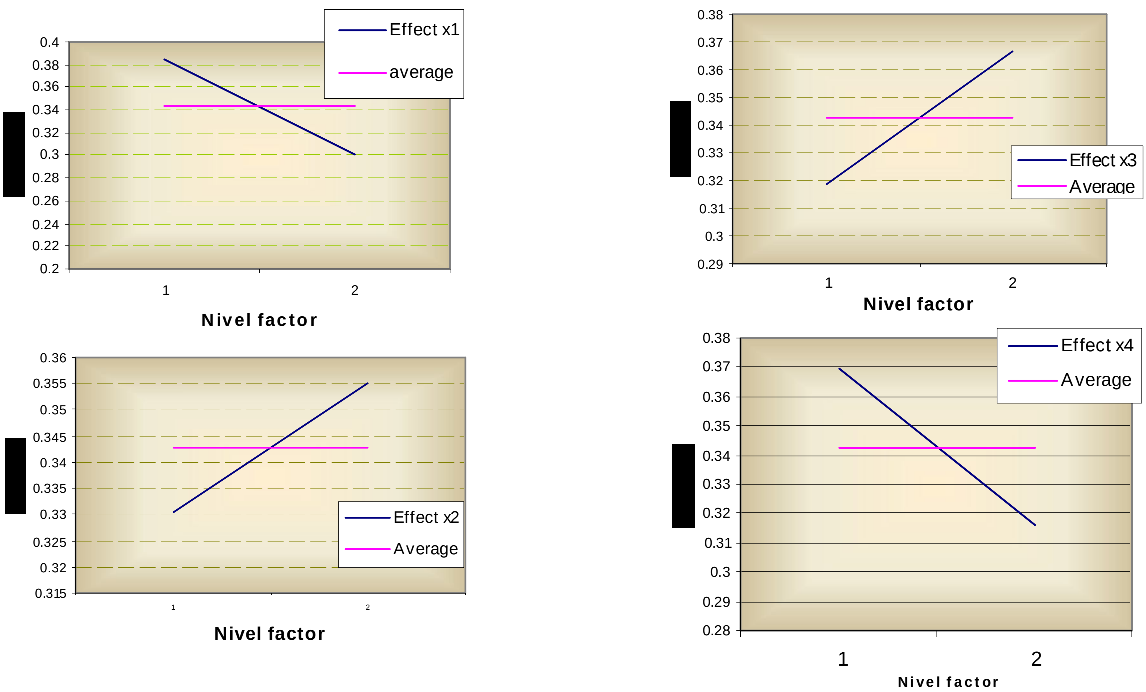

Fig. 8 Effects of independent factors on roughness x_1-abrasiv grain, x_2 - normal force, x_3 – number of rotations of workpiece, x_4 - processing time

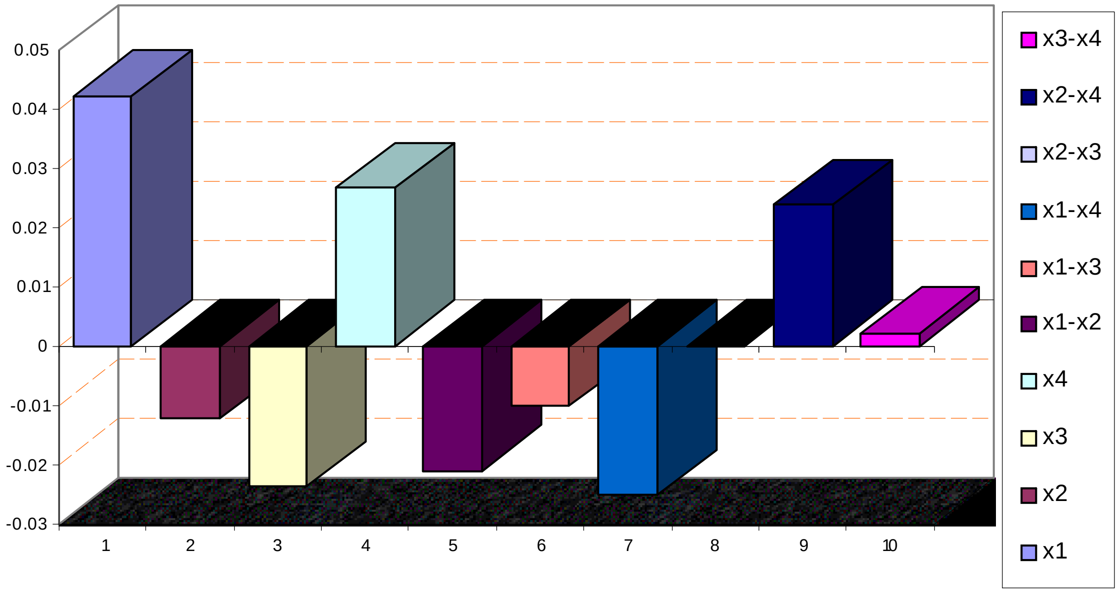

Fig. 9 Effects of factors and interactions between factors on roughness Ra: x_1 – abrasiv grain, x_2 - normal force; x_3 – number of rotations of workpiece; x_4 – processing time

Increase speed and normal force track roughness increases. Figure 9. presented in graphical form the effects of independent factors and the average interaction, which can allow the hierarchy and determining their effect on roughness direction.

5. Conclusions

The results presented show that in a relatively short time, (1-3 min), the superfinishing operation the surface roughness can be reduced of 5-15 times (from Ra ≈ 3 μm), which supports the productivity of this process.

- Prevision of working parameters (number of rotations of workpiece, amplitude and oscillation frequency) to meet the requirement of orthogonality of grain speed (traces angle 45 °) allows increasing the cutting process, thus reducing processing time and obtain low roughness,
- The material of superfinishing piece comes through the surface hardness meaning that an increase in surface hardness, require increased processing time, but also allows to obtain lower surfaces roughness,
- Reducing the abrasive grain belt, reduces productivity process (requiring greater processing time), but ensure the implementation of small surface roughness,
- Increasing the normal force, increases the cutting abrasive belt (by increasing surface contact with the workpiece, so the number of granules and time as they cutting) that reduces processing time, but in terms of obtaining higher roughness of surfaces.

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