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CHOICE OF MATERIAL FACTOR IN ENSURING THE MACHINED SURFACE ROUGHNESS THROUGH SUPERFINISHING PROCESS

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Abstract: *The evolutions of stresses in mechanical transmissions are not uniform. It was being developed analysis techniques and tests to find the influence of random efforts on the fatigue life, wear, etc. Processed material adopted in the design of products for reasons of durability and reliability, require generally for surfaces of machine parts of great importance (eg. bearings), and require a high-quality surface that is obtained by superfinishing process with tools from composite abrasives.*
The paper presents mathematical models and graphical dependence of the bearings raceway surface roughness upon the influence of the cutting parameters. There are also presented some recommendations concerning the superfinishing process optimization.
Key-words*: tool material, bearing, mathematical model, roughness, superfinishing*

1. INTRODUCTION

A technical system, as a bearing, which is used in most of the machine components, and that is well designed and tested, would not presents failure in function, if don't appear random factors during function. Studies shown that even the best technical systems that were follow all the factors regarding the quality, can have failure during their life because of the influence of random factors that are hard to predict.
During bearing service life, transmitting of forces for different cinematic parameters imply relative displacements (between the moving elements) and of the forces that act vectorial. Being phenomena which exist in any bearing, defects caused by the wear have influence on their reliability and can appear because of [6], [7]:
- machining processes, assembly processes, setting of elements which are in friction process;
- constructive solutions as bad choosing of material and lubricants;
- quality and characteristic of function environments (temperature, impurities);
- exploitation conditions – deviation from parameters those were set;

Between these factors, the geometrical and dimensional accuracy and surface roughness have a great influence on the bearings reliability.
Superfinishing process was first used by Chrysler Company in 1934. After grinding, is altered the microstructure and hardness of part material, which can modify dimensional and surface imperfections such as waviness and chatter. Through superfinishing, because low temperature during machining, these imperfections of part surface don't appear.
With the purpose of analyzing and optimizing a technological process should be taken into consideration the following [3]:

- the great number of parameters which have an influence on the performances of the process which is analyzed;
- the occasional or circumstantial influence of some factors;
- the importance of the separate influence of different factors to the performances of the technological system;
- the impossibility to drive the most of the parameters in a desired direction.

2. REPRESENTATIVE TOOL MATERIALS USED IN SUPERFINISHING PROCESS

Tool material has a great importance in the performance of the superfinishing process. The most used material in superfinishing are aluminum oxide, silicone carbide, CBN, graphite and synthetic diamond.
Aluminum oxide is made by refining ores and can be found as sintered white aluminum oxide and fused white aluminum oxide which is used for "roughing" process.
Silicone carbide is obtained by combining petroleum coke, pure white quartz, sawdust and salt in an electric furnace. It can be green silicon carbide and black silicon carbide being used in finishing operations.

CBN and diamond materials are used in superfinishing ceramic and other materials in orthopedic implants, automotive parts and bearings.
Graphite is used to improve the visual appearance of the part and sometimes is combined with aluminum oxide to improve cutting performance.
The roughness of the radial ball bearings raceways has a great importance to their quality and durability. In the followings will be presented the theoretical and practical results obtained at the raceway superfinishing with abrasive stones of white aluminium oxide EK1
(for rough superfinishing) and silicium carbide SC9 (for fine superfinish).

3. MATHEMATICAL MODEL OF THE ROUGHNESS OBTAINED AT THE SUPERFINISHING OF BEARING RACEWAYS

The superfinish process has a lot of factors of influence. For designing the mathematical model, was analyzed the influence of the working parameters: the pressure of the superfinish stone, the oscillation frequency, the work piece rotation speed and the superfinish time.
It was done an experiment in which was made a variation for only one of the above factors, and then for another one, and for each trial were done about 8-10 measurements. The graphical dependences are illustrated in the Figs. 1-to 4.
With the support of a statistical program were calculated 11 regression curves (linear, quadric, logarithmic, cubic, exponential, inverse, power, logistic, compound, S, grow). Their equations are listed in Table1.

Table 1: Regression curves

Type of the curve	Equation
Linear	$Y = b_0 + b_1t$
Quadric	$Y = b_0 + b_1t + b_2t^2$
Logarithmic	$Y = b_0 + b_1\ln t$
Cubic	$Y = b_0 + b_1t + b_2t^2 + b_3t^3$
Exponential	$Y = b_0e^{b1t}$
Inverse	$Y = b_0 + b_1/t$
Power	$Y = b_0e^{b1t}$
Logistic	$Y = 1/[1/u + (b_0)^{bt1}]$
Compound	$Y = b_0b_1$
S	$\ln Y = b_0 + (b_1/t)$
Grow	$\ln Y = b_0 + (b_1t)$

The work piece was the internal ball bearing ring 6203. The work piece were superfinished on a superfinish machine Thielenhaus KM 85.

3.1 Mathematical model of roughness influenced by the pressure of the honing stone

The observed curve from the Figure 1 shows the experimental values. The best fit curve of regression was obtained for S –model (Rsq = 0,885).
Sig = 0,000 < 0,005, that means we can say with an error less than 5 % that the model is good.
The graphic from Fig.1 shows that, at very low pressure values, R_a of the superfinished work piece is high. When the pressure grows, the roughness decreases very mach.
The S –curve equation is:

$$\ln(R_a) = -4{,}0283 + \frac{0{,}0170}{p} \qquad (1)$$

where R_a is the average surface roughness [µm] and p - the superfinish stone pressure [MPa]

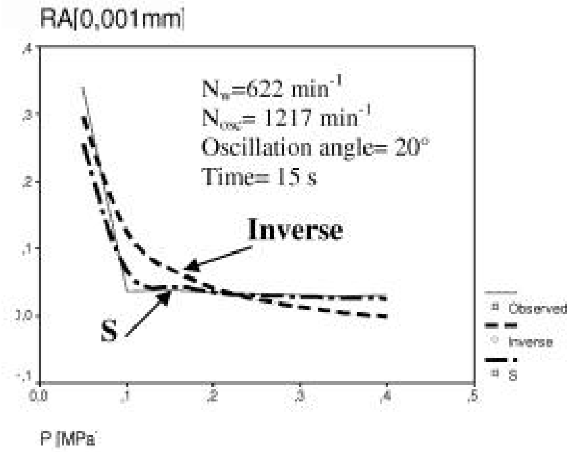

Figure1: The influence of honing stone pressure to R_a.

3.2 Mathematical model of roughness influenced by the oscillation frequency of the honing stone

The graphics from Fig.2 give the observed curve and the best regression curves (inverse, cubic, S). The best fit curve is the cubic curve of equation (2) which is obtained for R_{sq} = 0,977:

$$R_a = 0{,}0704 - 0{,}0002 N_{osc} + 1{,}7x10^{-7} N_{osc}^2 - 5x10^{-11} N_{osc}^3 \quad (2)$$

where R_a is the average surface roughness [µm], N_{osc} – the oscillation frequency of the stone [min^{-1}].

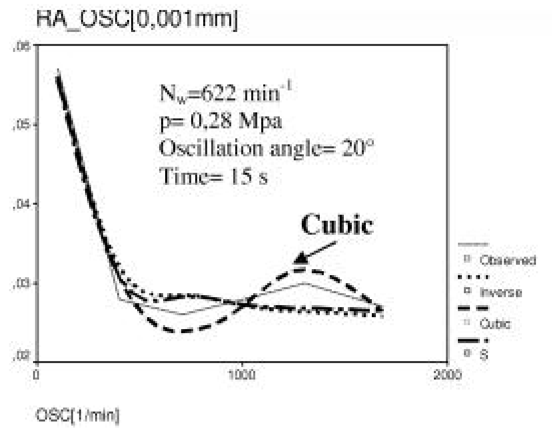

Figure2: The influence of oscillation frequency on R_a.

3.3. Mathematical model of roughness influenced by the rotational speed of the workpiece

Between the work piece rotational speed (N_w) and the speed of the work piece (v_w) there is following relationship (3):

$$v_w = \frac{\pi\, N_w D_w}{1000} \quad (3)$$

where v_w is the speed of the work piece [m/min]; N_w – the rotational speed of the work piece [min^{-1}]; D_w – the diameter of the raceway [mm].

The graphics from Fig.3 give the observed curve and the best regression curves (quadratic and cubic) for the relationship between the average surface roughness and the work piece rotational speed.

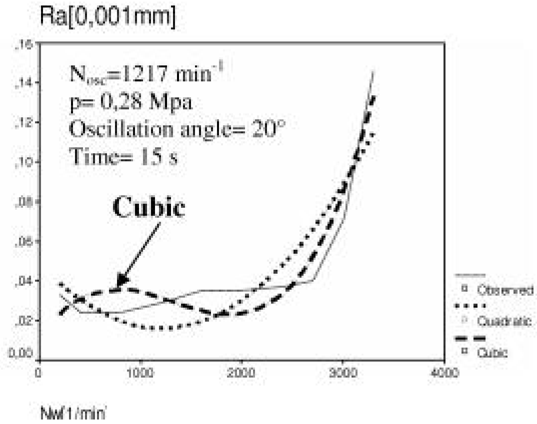

Figure3: The influence of work piece rotational speed on R_a.

The best fit curves is the cubic curve (4), which is obtained for R_{sq} = 0,916.

$$R_a = 0{,}01303 + 7{,}7x10^{-5} N_w - 7x10^{-8} N_w^2 + 1{,}8x10^{-11} N_w^3 \quad (4)$$

where R_a is the average surface roughness [µm]; N_w – the work piece rotational speed [min^{-1}].
Sig = 0,001 < 0,005, that means we can say with an error less than 5 % that the model is good.

3.4. Mathematical model of roughness influenced by the superfinishing time

The graphics from Fig.4 show the observed curve and the best regression curves (inverse, cubic and S).

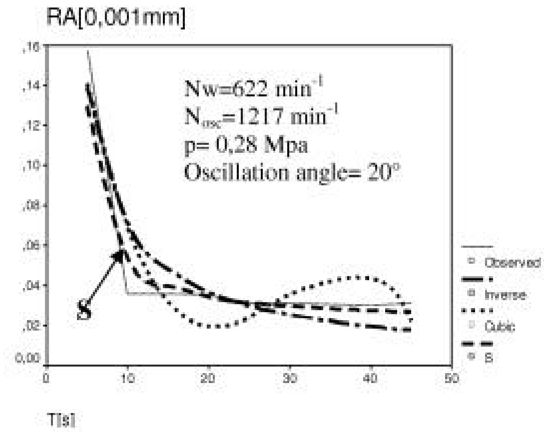

Figure 4: The influence of the superfinishing time on R_a.

The best fit curve is the curve S of equation (5), which is obtained for R_{sq} = 0,893.

$$\ln R_a = -3{,}81997 + \frac{8{,}8934}{t} \quad (5)$$

where R_a is the average surface roughness [µm]; t – the superfinishing time [s].
Sig = 0,000 < 0,005, that means we can say with an error less than 5 % that the model is good.

4. CONCLUSIONS

1. As the stone pressure increases, the roughness of the surface is smaller, because the superfinish process is more intensive. When the pressure is bigger than 0, 3-0, 4 MPa, the roughness is not better. The stone clogs itself with metal chips. At very big pressure values, there is a great probability of breaking the stone [1], [4].
2. As the oscillation frequency increased, the average surface roughness decreased. the optimized values are 1000-1100 min^{-1}. When the oscillation frequency is too high, inertial forces are developed. These may cause vibrations and also a high wear of stone [1], [4].
3. When the work piece rotational speed increases, the average surface roughness increases, because of the smaller value of the traverse overlap ratio.

4. When the superfinish time increases, the quality of the surface is better, and hence the average surface roughness decreases. After a certain value is reached, the roughness remains almost stable. the peaks of the surface are cut down and now the stone is acting like a grinding stone, removing a quality of material from the work piece [2].
5. In analyze of every displacement point on the contact surfaces between the bearing rings and balls, tensions are dependent from the pressure distribution on the contact surface, and that are influenced by the bearing ratio obtained through superfinishing process.
6. To optimize analyze of bearings reliability it must taken into consideration the new theoretical models of machining through superfinishing proposed in [5], which explains the cutting fluid and impurities action that are sedimented in surface micro channels and that conduct to hardening of the surface layer on the depth of 1 μm.
7. The superfinishing process has a number of significant benefits, such as:
- decreased wear rates;
- higher load bearing surfaces;
- improved sealing capabilities;
- increased part life.

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