International Conference on Economic Engineering and Manufacturing Systems
Braşov, 25 – 26 October 2007

SURFACE ROUGHNESS MODELLING AT BALL BEARING RINGS SUPERFINISHING ON THE CUTTING FLUID AND PROCESS PARAMETERS INFLUENCE

Constantin BUZATU*, Adriana BĂLĂCESCU**
* Transilvania University of Brasov, Romania
** INA Shaffler - Brasov, Romania

Abstract. The paper presents a possibility of surface roughness mathematical modeling in superfinishing on the process parameters and cutting fluid properties influence according with the friction coefficient between abrasive grains and workpiece surface. Starting on the assumptions of an abrasive grain model with spherical tip and assimilating the superfinishing process with broaching process, is obtained an equation of surface roughness parameter R_z according with the process parameters (t, s_l, A, i.e. cutting depth, feed, amplitude of reciprocal motion of tool), oscillation radius R of tool, and respectively the friction coefficient μ between tool and workpiece by the cutting fluid characteristics.

Keywords: superfinishing, roughness, cutting fluid, process parameters, constructive characteristics

1. Introduction

The quality products system became very important for the companies as a way to conceive, to modernize and to develop the manufacturing technologies; the final finishing processes are indispensable to achieve quality products [1].

Among the final finishing operations, superfinishing is one that is usually used due to its technical and economical performances on the other processes (lapping, honing). The main purpose of this process is improving surface roughness after grinding operation.

Between the factors which influence the surface quality at superfinishing, the cutting fluid is one which have a great influence due to the variation of friction coefficient μ between the tool and workpiece and that plays an important role but less studied in the literature [1, 2].

For the reasons to explain the phenomena which have taken during the process of superfinishing the authors considered a theoretical model where it is made an analogy with the broaching process because every abrasive grain is considered a tooth broach.

It can been seen that a limit of the theoretical model is the distance between two abrasive grains it is much smaller than two teeth of the broach.

This thing will make the removal evacuation of the chips harder. It is considered that the reciprocating motion of the abrasive stone permit the partial evacuation of the chips.

The authors explain the small dimension of the chips by the shorter length of the cutting stroke (the amplitude of the reciprocating motion).

The proposed model offer an explanation of the automatical interruption of the superfinishing process by the intervention of the cutting fluid. This cutting fluid has a viscosity and poluting range with influences the surface quality by the dynamic variation of the friction coefficient between tool and workpiece.

It is considered that of the beginning of the process the contact between the abrasive stone and workpiece surface is very small only on the tips.

During the process the contact surface between tool and workpiece is incresing, the pressure is decresing and the intencity of the cutting is smaller.

At the end of the process because the spaces of the grain are full with the chips the workpiece surfaces become smooth and because the pressure between tool and workpiece is very small the cutting process is automatically stoped.

Based on the above mentioned the thickness of the removed material can't be bigger than the height of the workpiece roughness before the superfinishing process.

Comparing with other theoretical models at machining this model at superfinishing take into account the influence of the cutting liquid as an active elemnt in the contact zone between abrasive tool and workpiece surface.

This cutting liquid made by oil and petrol has an important role in the interruption of the cutting process after a time wich is dependent by the friction coefficient between the tool and workpiece.

Starting on these considerations it will be shown a new approach of surface roughness modeling at superfinishing that will take into consideration also the cutting fluid.

2. Surface roughness modeling at superfinishing

The theoretical analysis of a machining process requires to make a physical model, an ideal approximation of reality, which reflects the principle based on some assumptions.

This physical model has to carry out the essential conditions of each model:

- to be very simple;
- to represent the essence of the process.

The theoretical model of abrasive machining taking into account one grain [8] was made without the influence of the cutting liquid. All the studies referred to friction, shearing and dry removing between the abrasive grain and workpiece material. For these reasons, a theoretical model at abrasion by superfinishing have to be done with the influence and characteristics of the cutting liquid:

- The machining zone which includes chip and adjacent zone are "sinking" in an environment of superfinishing fluid which consists of petrol and oil. The liquid drops have the dimensions in a renge of 0.1-1 μm and can be approximate to a small balls;
- In superfinishing process the liquid drops adhere to the workpiece surface and abrasive tool making a layer with active role in the cutting forces balance. Through this layer the dry friction between the grain and workpiece is replaced by the wet friction, which means a great reduction of friction coefficient, of the cutting forces and the heat that appears in the process;
- The cutting liquid drops are found in the same range of the chip surface and in the mass of liquid leading to a variable friction coefficient in the process;
- During the superfinishing process the heat that is generated is a small value, and the cutting liquid has a small capacity of cooling and a bigger capacity of lubrication;
- The reduction of friction between the tool and workpiece surface don't cancel the friction forces, and based on some tests [7] it is shows the influence of the friction coefficient between tool and workpiece on the surface finish.

To make mathematical modelling of surface roughness at superfinishing will start from next initial assumptions:

- it is considering the model of the abrasive grain with spherical tip [3], that is unanimous accepted in the literature (figure 1);
- on the point of view of removing chips, it is assimilate superfinishing with broaching;

The abrasive grain, with cone angle β, has the free height h_g, bottom width *b*, top radius r (obtained by wearing during machining process), *e* – the distance between grains, α and γ being the rake and relief angles of the grain.

According with the initial assumptions and with those presented in the paper [4], was deducted that the height of surface roughness (R_z criterion) it is obtained with a good approximate from the equation:

$$R_z \cong t_{g\,\max} \cdot t_g \alpha \tag{1}$$

where $t_{g\max}$ is maximum thickness of cutting on the abrasive grain, and α is the rake angle of grain.

If is taking into account that chip side area A_l removed by one abrasive grain is given by the next equation (see figure 1):

$$A_l = k_1 \cdot A \cdot t_{g\,\max} \cong \frac{h_g \cdot e}{2}, \tag{2}$$

where, *A* is amplitude of tool reciprocal motion, and k_1 is the coefficient taking into account that a small number of grains works at maximum capacity (those of roughing), the rest of them having the role of calibrating of surface.

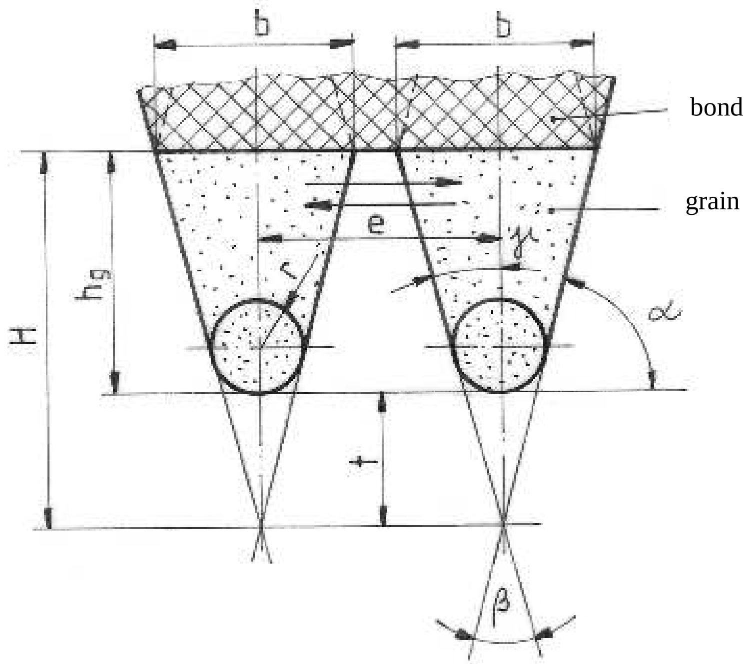

Figure 2. The spherical model of grain at machining with abrasives

Considering the condition of grain motion without sliding [5]:

$$\alpha \le \text{arctg}\,\mu, \tag{3}$$

from the equations (1)÷(3), results:

$$R_z \cong \frac{h_g \cdot e \cdot \mu}{2Ak_1} \tag{4}$$

Assimilating superfinishing with broaching (as is removed the chips), the structure of the abrasive tool is essential to provide clearance for the chips.

It results that the grain constructive parameters h_g and e (figure 1) must to have the next conditions from the broaching tool [6]:

$$e \approx p = (1.25 - 1.5)\sqrt{A}, \tag{5}$$

where p is grain pitch, and

$$h_g \cong h = 1.13 \cdot \sqrt{k \cdot a_{g\,\max} \cdot A}, \tag{6}$$

where k is a coefficient which depends of the chipshape.

Taking into account that the maximum chip thickness at superfinishing is given by the equation [3]:

$$a_{g\,\max} = \sqrt{2} \cdot s_g \cdot \sqrt{\frac{t}{R}}, \tag{7}$$

where s_g is the feed on the grain, t is the depth of cut, R is the oscillation radius of abrasive tool, results from the equations (4)÷(7):

$$R_z \approx (0,7 - 0,85)\frac{\mu}{k_1}\sqrt{k \cdot s_g \cdot \sqrt{\frac{2t}{R}}}, \tag{8}$$

Feed on the abrasive grain s_g is given by the equation:

$$S_g = \frac{s_l}{N_g}, \tag{9}$$

where s_l is the tool feed, and N_g is the grain numbers which works on the path equal with the amplitude of motion:

$$N_g = \frac{A}{(1.25...1.5)\sqrt{A}} = \frac{\sqrt{A}}{(1.25...1.5)}, \tag{10}$$

If is replacing equations (9) and (10) in the equation (8) is obtained finally:

$$R_z = \frac{(0,7 - 0,8)\mu}{k_1}\sqrt{(1,25 - 1,5)k \cdot s_l \cdot \sqrt{\frac{2t}{R \cdot A}}}, \tag{11}$$

which shows process parameters, t, s_l, A, oscillation radius R of abrasive tool, and the friction coefficient μ between tool and workpiece by the cutting fluid.

3. Conclusions

Based on the previous presented the next conclusions appear:

1) The mathematical modeling of surface roughness at superfinishing taking into account the spherical model of abrasive grain and the similitude with the broaching process, is

finding the surface roughness after the influence of many factors of machining: process parameters and cutting fluid;

2) The influence of the cutting fluid on the surface finish through the friction coefficient μ is proportional type, according with the experimental tests at machining the ball bearing rings [7].

3) The influence of the friction coefficient between the tool and workpiece surface impose a careful attention when is chosen the cutting fluid.

4) The optomization of superfinishing process impose a multicriterion approach of the factors that influence the surface quality: constructive parameters of the tool, technological parameters, properties and characteristics of the cutting fluid.

5) The modell of superfinishing process can br use also to the others finishing processes: honing, lapping, polishing.

4. References

1. Buzatu, C., Piukovici, I., Nedelcu, A., Lepădătescu, B.: *Finishing processes of the surfaces in engineering*. Lux Libris Publishing, ISBN 973-9240-47-X, Braşov, Romania, 1998 (in Romanian)
2. Buzatu, C.: *Manufacturing technologies in engineering*. “Transilvania” University Press, ISBN 973-635-238-2, Braşov, Romania, 2003 (in Romanian)
3. Crăciunoiu, N.: *Researches regarding design and new technologies for superfinishing to carbide inserts*. PhD Thesis, University of Craiova, Romania, 1997 (in Romanian)
4. Buzatu, C., Draghici, G., Secară, G., Roşca, D.: *Surface quality at broaching and the influence of various factors on it*. Scientific Bulletin of “Transilvania” University of Brasov, Seria A, vol. XXI-C-1979, Braşov, Romania, p. 35 - 40 (in Romanian)
5. Buzatu, C.: *Automation and robotics in manufacturing processes*. “Transilvania” University Press, 1988 (in Romanian)
6. Lăzărescu, I.: *Calculation and construction of cutting tools*. “Tehnică” Publishing House, Bucharest, Romania, 1961 (in Romanian)
7. Lepădătescu, B., Simon, E.A., Mareş, G.: *Surface technology*. “Transilvania” University Press, ISBN 973-635-390-7, Braşov, Romania, 2005 (in Romanian)
8. Roşca, D.M.: *Abrasive tools*. “Lux Libris” Publishing House, Braşov, Romania, 1995 (in Romanian)