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STUDY OF SURFACE ROUGHNESS AT FINISHING OF RECOVERED SILICONE RUBBER

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Abstract: *The paper presents a theoretical model for establishing the roughness of finished surfaces. For model validation AFM analysis is performed on the recovered silicone rubber surface.*
Key words: *finishing, roughness, recovered silicone rubber*

1. INTRODUCTION

From cinematic point of view, the surface finishing process represents a collection of factors that determine working hypotheses for the proposed model, such as ignoring the vibrations of the abrasive tool while the workpiece changes its topography in contact with the tool. There are also neglected other phenomena related to the smooth flow of remnant grains resulted from wear at contact between tool and work surface (Suto & Sato, 1981; Malkin, 1989).

Abrasive tools contain grains with different cutting angles. The grains are distributed randomly along the cutting surface, having various positions, orientations or distribution at the cutting tool level (Tooc et al., 1987; Chen & Rowe, 1996). The topology of the abrasive tool and the cutting parameters are influenced by the interaction between the abrasive grains and workpiece (Warnecke & Zitt, 1998).

2. THEORETICAL MODEL

In order to determine the surface roughness there are considered two consecutive grains whose positions with respect to the reference system with origin in the tool mass center are determined by radiuses R_1, R_2 and angles θ_1, θ_2 (fig. 1).

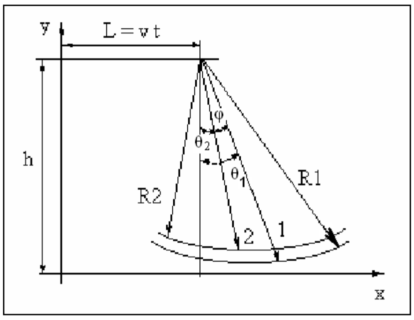

Fig. 1. Position of abrasive grains

The position of the two grains with respect to the given reference system is established by the following coordinates:

$$\begin{array}{l} x_1 \quad L \quad R_1 \sin \ _1 \\ y_1 \quad h \quad R_1 \cos \ _1 \end{array} \qquad (1)$$

$$\begin{array}{l} x_2 \quad L \quad R_2 \sin \ _2 \\ y_2 \quad h \quad R_2 \cos \ _2 \end{array} \qquad (2)$$

Where:

L – length covered by tool's mass centre during time t

v – longitudinal advance speed

θ_1, θ_2 – angular position of the grain rotation centres with respect to the tool mass centre

φ – angle between grains

Since θ_1 and θ_2 are very small, the following approximations are introduced:

$$\begin{array}{l} \sin \ _1 \quad _1 \\ \cos \ _1 \quad 1 \quad \frac{^2_1}{2} \\ \sin \ _2 \quad _2 \\ \cos \ _2 \quad 1 \quad \frac{^2_2}{2} \end{array} \qquad (3)$$

If v represents the speed of the disc centre and ω represents rotation speed of the abrasive tool, then:

$$\begin{array}{l} x_1 \quad v \quad R_1 \quad t \\ y_1 \quad R_1 \quad h \quad \frac{R_1 \ ^2}{2} t^2 \end{array} \qquad (4)$$

$$\begin{array}{l} x_2 \quad R_2 \quad v \quad R_2 \quad t \\ y_2 \quad R_2 \quad h \quad \frac{R_2 \ ^2}{2} \quad \frac{R_2 \ ^2}{2} t^2 \quad R_2 \quad t \end{array} \qquad (5)$$

The equations that describe the trajectories of the two consecutive grains on the tool circumference are:

$$y_1 \quad \frac{R_1 \ ^2}{2 \quad R_1 \ ^2} x_1^2 \quad R_1 \quad h \qquad (6)$$

$$\begin{array}{l} y_2 \quad \frac{R_2 \ ^2}{2 \quad R_2 \ ^2} \ x_2 \quad R_2 \ ^2 \\ \frac{R_2}{R_2} \ x_2 \quad R_2 \quad R_2 \quad h \quad \frac{R_2 \ ^2}{2} \end{array} \qquad (7)$$

Relations (6) and (7) represent the parabolic trajectories of the two consecutive abrasive grains.

The roughness Δ is established according to the schematic presented in fig. 2.

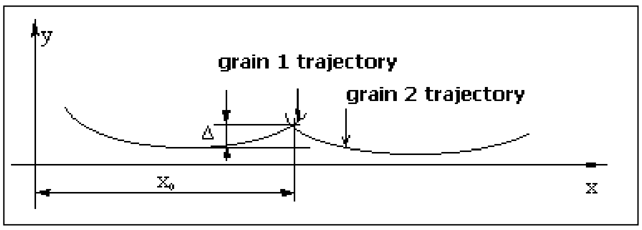

Fig. 2. Roughness Δ

The coordinates of the intersection point are:

$$x_0 \quad \frac{\quad}{2} \tag{8}$$

$$y(x_0) \quad \frac{R \quad ^2 \; ^2}{8 \quad R \quad ^2} \quad R \quad h \tag{9}$$

Denoting $r \quad \frac{\quad}{R}$ we have $\quad \frac{L^2 \quad r^2}{8R}$.

Remark: in case of silicone rubber materials, usually r = 0,035 m, L = 0.01 m, R = 0.1 m. In this case Δ = 15.3 nm.

The simulated surface profile is presented in fig. 3:

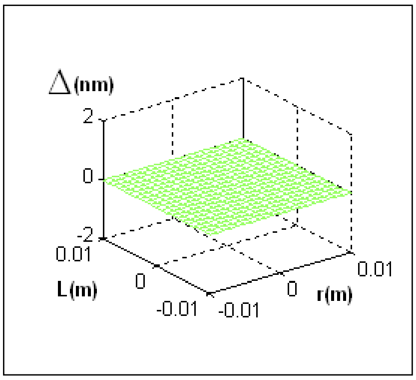

Fig. 3.Silicone rubber surface profile obtained from simulation

The values obtained for Δ from the model are smaller than the roughness in real cases.

3. ROUGHNESS ANALYSIS OF A REAL RECOVERED SILICONE RUBBER MODEL

Recovered silicone rubber was obtained from in-house research (fig. 4):

Fig. 4. Silicone rubber obtained from used rubber recycling

Its properties are similar to the properties of the original silicone rubber:

- resistant to dry temperature exposure up to 200C (using special recipes up to 300C and even 315C for short periods)
- flexible at -60C (-90C for special types)
- elastic at high and low temperatures
- resistance to wear, weatherability
- neutral smell and taste
- chemical agent resistant

In order to experimentally determine the roughness of the finished surface for the particular material it was performed AFM analysis for investigating the surface topography and quantitative description at micro and nanometric level, as well as 3D morphology in atmospheric, liquid, controlled gas and low-vacuum (10-20 torr) environments, in the following conditions: work area 100x100x10 µm, XY 0.3 nm, Z 0.6 nm, closed loop XY non-linearity < 0.15%.

The values for the working parameters are:

Total amount of samples: 262144

Max: 4971.65 nm

Min: 0.00 nm

Roughness Sy (Ry): 4971.65 nm

Roughness Sz: 2542.21 nm

Mean: 1881.88 nm

Mean roughness Sa: 282.56 nm

Root mean square Sq: 378.429 nm

Surface slope S_{sk}: 0,909317 nm

The transversal section of the profile obtained is presented in fig. 5:

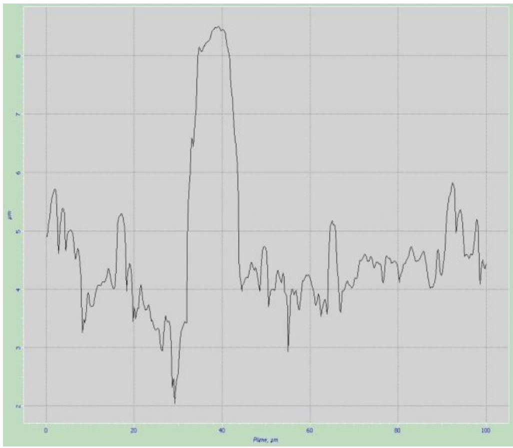

Fig. 5. Measured surface roughness

4. CONCLUSION

It can be observed that the mean measured surface roughness is close to the roughness of the theoretical model.

The difference is given by the absence of the influence of 0Y vibrations produced during processing.

This proves the validity of the theoretical model presented.

The topographic analysis of the sections under AFM analysis reveals the irregular characteristic of the surface profile.

The slightly more rugged surface profile in case of recovered silicone rubber that in case of liquid silicone rubber does not prevent from obtaining parameters as good as those of regular rubber.

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