THE INFLUENCE OF CUTTING TECHNOLOGY ON SURFACE WEAR HARDNESS

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ABSTRACT*: Obtaining a surface by cutting technology is characterized by a unique fingerprint in terms of precision, roughness and resulting texture. Each technology used gives a certain surface quality. Existing studies give us material wear intensity, but it only refers to material property, not to the influence of the machining technology on wear hardness. This paper presents how the machining technology influences surface wear for CuSn7Zn4Pb7-C. Through the presented results, one can appreciate the influences of machining technology quality on surface quality. The paper presents the evolution of surface characteristics from machining to surface finishing. The presented results are useful in setting the optimal cutting technology depending on what tribological expectations we have from the processed surface.*
KEYWORDS*: surface roughness, cutting operation, surface wear*

1 INTRODUCTION

In full globalization, product quality tends to equally concern all product manufactures. Because any product is obtained from one or more parts, their quality is of maximum importance. In the case of parts obtained through cutting, it is important to find the right technology to obtain dimensional accuracy, surface roughness and surface texture to meet the requirements for that surface. The problem in this case is what technology to use as certain surface quality can be obtained through several technologies as presented in (Popan et al., 2017) and (Bocante et al., 2017). In order to choose the optimal technology, we need to extend the quality term from static to dynamic. In this paper, the dynamic regime refers to how the surface quality obtained through a certain technology is maintained during the part operation. By looking at quality in a dynamic mode, we observe the wear pattern during the exploitation period. The starting paradigm of this paper is that the evolution of wear is influenced, besides material mechanical characteristics, by surface quality obtained through cutting technologies.

In cutting technology, machining is done in two stages: roughing and finishing. The roughing is used to obtain a surface as close as possible to final shape and finishing results in final surface. Therefore, the finishing stage has a particularly important role in part machining.

Numerous factors affect surface wear in the exploitation process. Mechanical proprieties of the material, material variability, surface roughness, process parameters (speed, feed), vibration, work temperature, lubrication etc. These factors all contribute to the surface wear (Budinski et al., 2010).

In this context, the main idea behind this research is to set out which finishing technologies give the lowest level of wear.

Surface wear occurs only on product parts that are moving relative to each other. There are three movement types: single or bidirectional rectilinear motion, circular motion, complex motion: linear and circular. The most common products subject to movement are: bearings, bushings, cams, jig bushings, ball joint screw, linear motion slide, guide bushes, slideways etc.

This study examines four types of surface finishing methods. The chosen surface was that of a bushing bronze.

A bronze bushing was used for this research because it provides high load carrying capacity, good fatigue properties, dimensional stability, and improved thermal conductivity.

This paper focuses on the qualitative appreciation of how machining technology influences surface quality.

2 EXPERIMENTAL PROCEDURE

The experiments were carried out by preparing specimens manufactured through different machining methods: reaming, contour milling, helical milling and head boring.

After machining the specimens were worn by following the ASTM G 77-98 procedure.

The methodology is briefly presented in Figure 1.

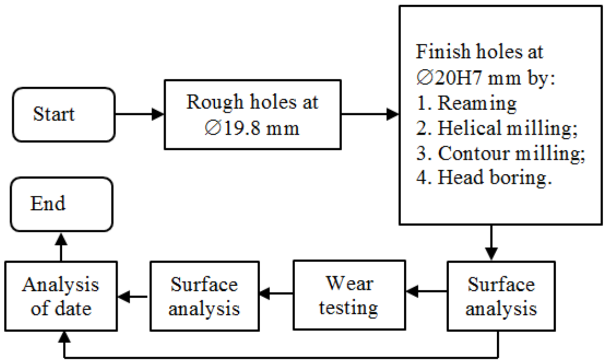

Fig. 1 Flow chart for study design

2.1 Equipment and measurements

The following equipment was used for machining and measuring the finished holes:

- Vertical milling machine Hass TM1;
- TRM50/50 Testarossa D'Andrea Boring head;
- HSS Reamer for Ø20H7;
- Ø19.80 mm drill;
- Solid carbide end mill, Ø16, z=6 mm;

The machining parameters that were used are presented in Table 1. The values for the cutting parameters have been chosen in the middle of the value range recommended by tool manufacturers.

Table 1. Cutting conditional

Method	Parameters of cutting			
	Cutting speed (m/min)	Depth of cut (mm)	Feed rate (mm /rev)	Cutting fluid
Reaming	20	0.2	0.4	Oil-water emulsion
Helical milling	220	0.2	0.36	Oil-water emulsion
Contour milling	190	0.2	0.3	Oil-water emulsion
Head boring	125	0.2	180	Oil-water emulsion

The bushing surface roughness was characterized with an Alicona IF-EdgeMaster optical 3D surface measurement system.

2.2 Material

The experiment consisted of machining precise holes in a bronze CuSn7Zn4Pb7-C part. By using four cutting methods five times, a total of twenty holes were obtained.

The physical and mechanical properties of CuSn7Zn4Pb7-C are given in Table 2.

Table 2. Physical and mechanical characteristics of CuSn7Zn4Pb7-C

Properties	Values
Tensile strength	260 (N/mm^2)
Yield stress $R_{p0.2}$	120 (N/mm^2)
Elongation A	13 (%)
Hardness	70 (HB)
Density at 20^0C	0.00891 (g/mm^3)
Thermal conductivity at 20^0C	58.2 (W/m ·°K)
Coefficient of Thermal expansion at 20-100 ^{0}C	18.0·10-6 per °C

2.3 Wear testing

After recording the roughness measured with the Alicona IF-EdgeMaster optical 3D surface measurement system, the parts were worn according to the ASTM G 77-98 block-on-ring test that was adapted for bushing / shaft tribosystems. The block-on-ring test is believed to be an accurate simulation of the bushing test because all bushings have a running clearance such that at the start there is a line contact between the bush and shaft, just like the contact that occurs in the block-on -ring test (Figure 2) (Budinski 2007)

In the case of wear test carried out in this paper, the recommended working conditions of ASTM G 77-98 were used, but the contact is not a line but a surface. It can be appreciated that in the standard the contact is only theoretically a line until the test begins and then it becomes a contact surface.

Because the block weight loss is not studied quantitatively, a comparative analysis of surface quality is made. It was considered that the methodology presented in G 77-98 can also be applied in this case.

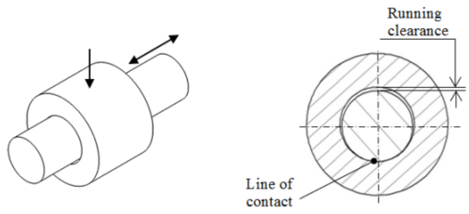

Fig. 2 Bushing test principle and line contact in bushing/wear system

The testing procedure used for bushing specimens wear was:

a) The shaft and busing were cleaned using trichloroethane to remove any scale, oil film, or residue without damaging the surface.

b) The surface texture and surface roughness measurements were made across bushing specimens' width.
c) The bushing specimen were placed on the machine and, while holding them in position, the shaft was inserted into the bushing specimens and the shaft was locked in place.
d) The bushing specimen was centered on the shaft while placing a light manual pressure on the lever arm to bring the bushing specimen and shaft into contact.
e) The required weight (2,5 kg) was placed on the load bale and the lever arm adjusted in accordance with the requirements of the wear test bench.
f) Oscillating frequency for shaft was 5.0 Hz.
g) Test duration was 16 minutes and 40 seconds.
h) Ambient temperature was 22 ±3°C.
i) Shaft hardness was 60 HRC.
j) Relative humidity was 40 to 60 %.
k) Lubrication, none applied.
l) The bushing specimen and shaft were removed, and cleaned with trichloroethane.
m) The surface roughness measurements and profilometer traces were made across the width of the bushing specimen.

3 RESULTS AND DISCUSSION

The generated surface topographies were measured directly after the machining process. They are characterized by roughness and texture values. After the wear test a further characterization of the surface topography was made to illustrate the changes in topography.

3.1 Surface topography after machining

All four machining processes lead to different surface structures concerning the roughness values as well as the bearing surface. Figure 3 and 4 present the results of surface determination.

Parameters Rp and Rv represent maximum profile peak height and valley depth. The higher the Rp's height, the lower the bearing property. It can also be assumed that wear will develop more strongly for surfaces having a high Rp parameter. It is assumed that for a better load the parameter Rv must be greater than Rp. The results show that through contour milling the surface will be more pronouncedly worn during dry friction. It remains to validate this assumption with future wear tests.

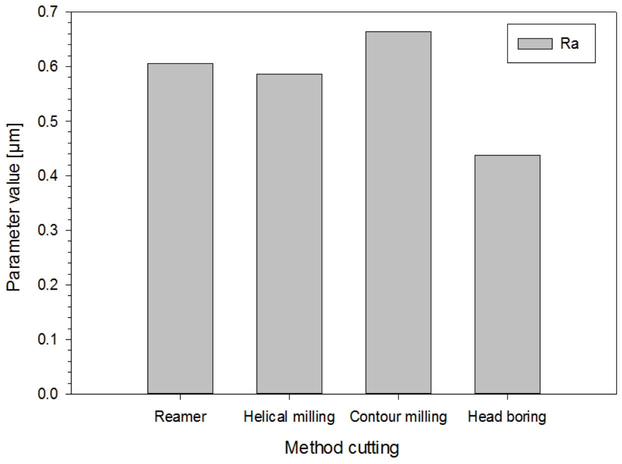

Fig. 3 Ra for machining processes

Figure 3 show that finishing operation was most effective using head boring.

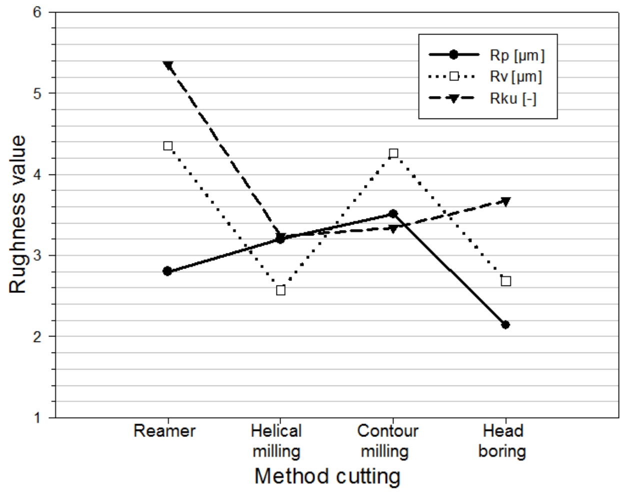

Fig. 4 Parameters Rp, Rv and Rku for method cutting

Rku is Kurtosis of the assessed profile and represent the quotient of the mean quartic value of the ordinate value Z(x) and the fourth power of Rq respectively within a sampling length. Rku is a sharpness measure of the probability density function of the ordinate values. This parameter is strongly influenced by isolated peaks from isolated valleys (ISO 1997). Figure 7 shows that in the case of bore finishing with helical milling and contour milling in terms of the Rku parameter, we have the best results. This means that there will be no isolated peaks from isolated valleys and, implicitly, the bushing surface will maintain a constant oil film. In the case of dry friction, the bushing surfaces will have a much higher bearing than when reamed or a head bored.

3.2 Texture topography after machining

Surface texture: surface texture is the pattern of the surface which deviates from a nominal surface. The deviations may be repetitive or random and may result from roughness, waviness, lay, and flaws (Hommel 1988) (ISO 2012).

Every cutting surface has some form of texture that takes the form of a series of peaks and valleys. After finishing precise holes we obtained different texture depending on the method used.

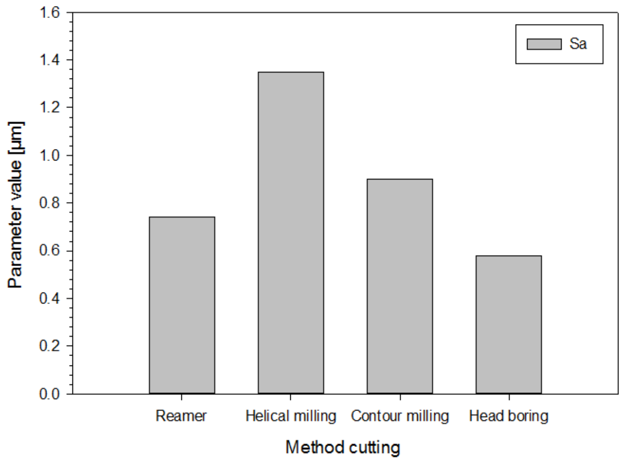

Fig. 5 Arithmetical mean height of the scale limited surface Sa for method cutting used

From a texture perspective, the finishing method by head boring and reaming is superior because the Sa parameter has the lowest values, Figure 5.

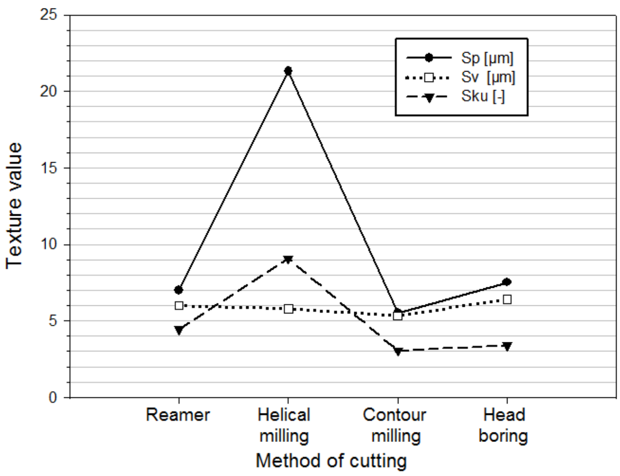

Fig. 6 Parameters Sp, Sv and Sku method cutting

Figure 6 presents other three parameters that characterize the surface texture. The maximum peak and pit height of the scale limited surface are characterized by Sp and Sv. These parameters have the largest peak height and the smallest pit height value within a defined area. Sv has minimum deviation for every cutting method. In the case of bushing finishing through helical milling, Sp is larger than for any other method used. The Sku - Kurtosis parameter of the scale-limited surface is used because it is highly influenced by isolated peaks of isolated pits. Figure 6 shows that, in the case of helical milling, the Sku parameter is the most unfavorable.

3.3 Surface topography after wear

All bushing specimens were worn under the same conditions. After wearing, bushing specimens were reassessed to determine how each surface behaved with respect to the cutting method.

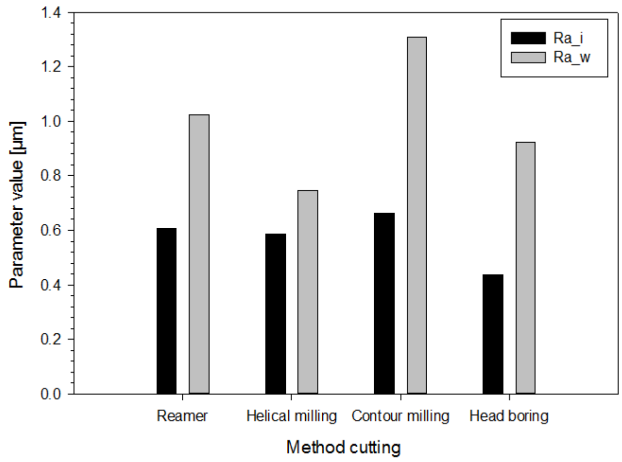

Fig. 7 Parameter Ra_i vs. Ra_w

Figure 7 shows the Ra values obtained before and after bushing specimen wear. The surface finished by helical milling has a more favorable evolution of the wear compared to the other processes. The Ra parameter increases by 27% compared to other cutting methods that exceed 50% of the initial value.

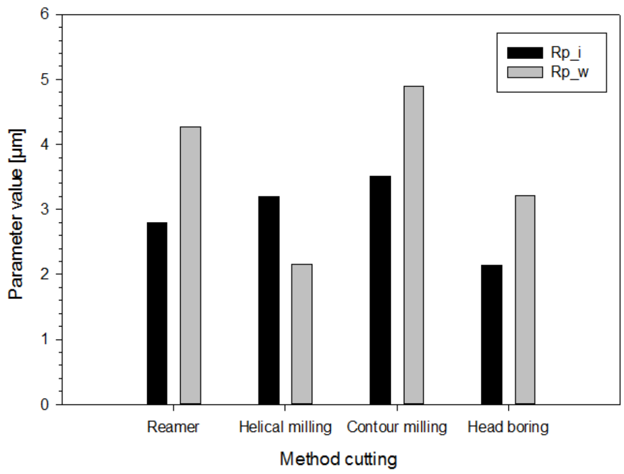

Fig. 8 Parameter Rp_i vs. Rp_w

Figure 8 shows how the maximum profile peak height evolved. There is an increase of the Rp value during wear for reaming, contour milling and head boring. However, in the case of helical milling, the phenomenon is exactly the opposite, the Rp value decreasing by approximately 32% below previous wear.

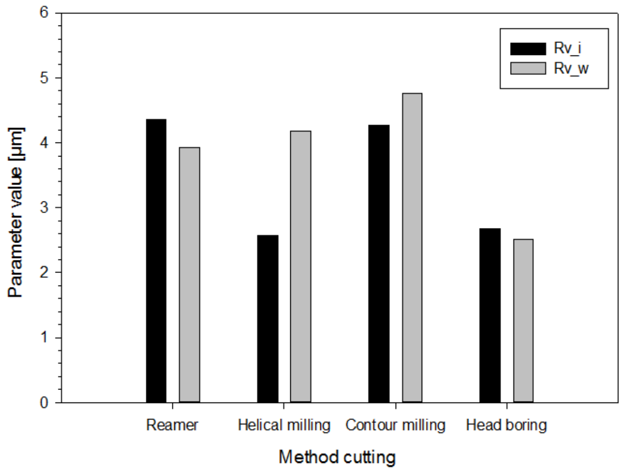

Fig. 9 Parameter Rv_i vs. Rv_w

Figure 9 shows the evolution of the maximum profile valley depth. The Rv value decreases during wear process for reaming, contour milling and head boring. This, corroborated with the growth phenomenon of Rv parameter, indicates that the wear intensity is more pronounced in these three machining methods.

Figure 10 shows the evolution of the Rku parameter. Because it is strongly influenced by isolated peaks from isolated valleys, we can assume that helical milling will have a surface that will keep the oil film more effectively. In the case of the other finishing technologies, because the Rku parameter decreases, the surface is unfeasible and the oil film will not be maintained efficiently. This highlights that the optimal tribological surface behavior will be obtained through helical milling.

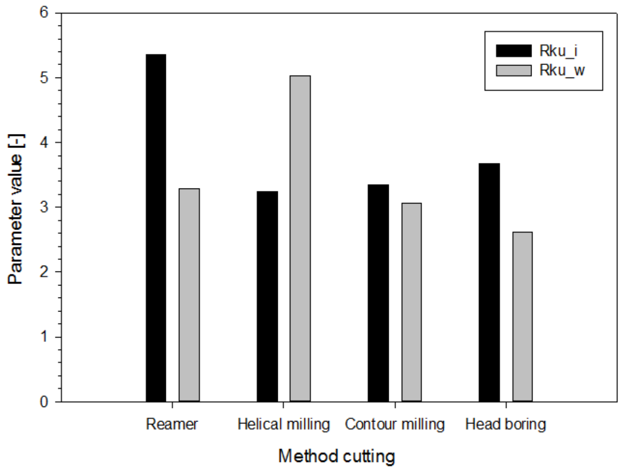

Fig. 10 Parameter Rku_i vs. Rku_w

3.4 Texture topography after wear

After the analysis of the roughness evolution, the texture topography has also been reanalyzed.

Figure 11 shows that the wear process had little influence on surface obtained through helical milling. The parameter depreciation was only 58% compared to the other cutting methods where the evolution was over 90%.

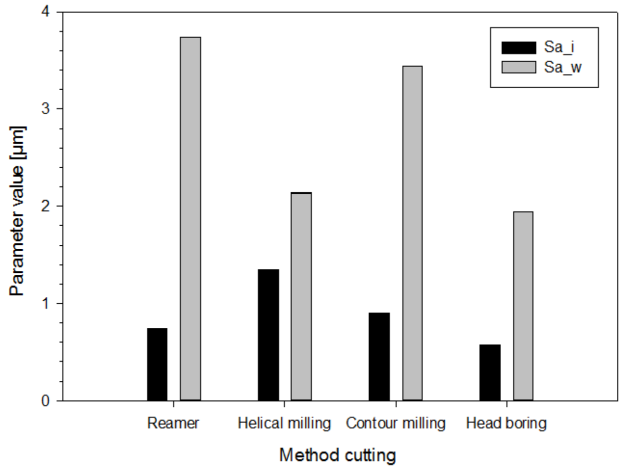

Fig. 11 Parameter Sa_i vs. Sa_w

This tendency to preserve the texture parameters is also highlighted by the Sp and Sv parameters, that change very little after wear compared to the other cutting methods (Figure 12).

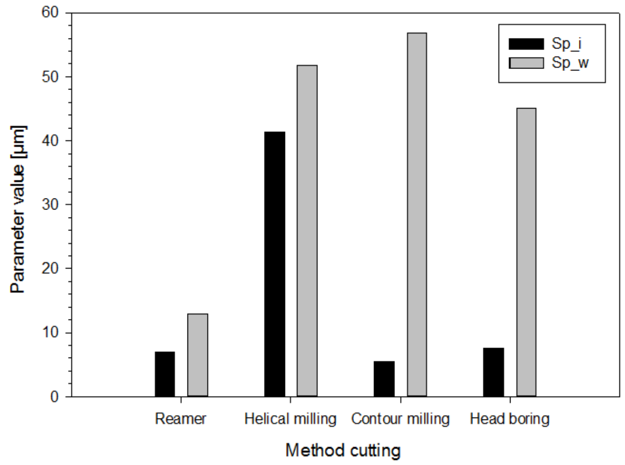

Fig. 12 Parameter Sp_i vs. Sp_w

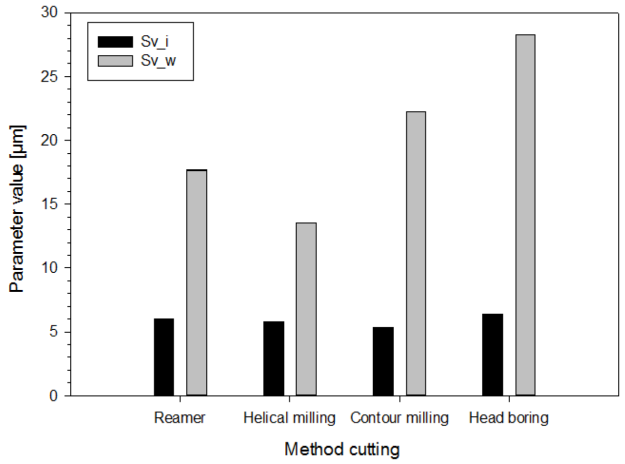

Fig. 13 Parameter Sv_i vs. Sv_w

Figure 14 shows that in the case of the Sku parameter, the evolution of bushing specimens obtained through helical milling is favorable for the existence of isolated peaks of isolated valleys. This indicates that in the case of an intensive surface wear, there will still be places where the oil film will exist. Thus, the tribological quality of the surfaces obtained through helical milling is superior to the other studied finishing methods.

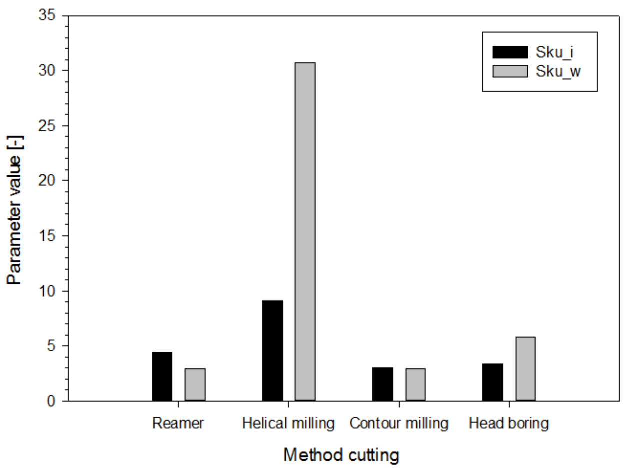

Fig. 14 Parameter Sku_i vs. Sku_w

4 CONCLUSIONS

This study focused on the influence of the finishing methods on the part behavior during the wearing process. The research was aimed at the comparative assessment of roughness and texture parameters surface.

After analyzing the data, the following conclusions were drawn:

- Finishing by head boring initially gives the best qualitative results but are not maintained during the wear process;
- Finishing by helical milling has the advantage of the most favorable tribological evolution of the surface during the wear process;
- Finishing by reaming and contour milling of surfaces with tribological role is not recommended.

Future investigations will focus on expanding research on other materials types. Surface coating will also be carried out with a lubricant to validate how the wear process influences the surface parameters.

5 ACKNOWLEDGEMENTS

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7 NOTATION

The following symbols were used in this paper:

Ra = Arithmetical mean deviation of the assessed profile;

Rp = Maximum depth of profile;

Rv = Maximum height of profile;

Sku = total area

Sa = arithmetical mean height of the scale limited surface

Sp = Maximum peak height of the scale limited surface;

Sv = Maximum pit height of the scale limited surface

Sku = Kurtosis of the scale-limited surface

Ra_i, Rp_i, Rv_i, Rku_i, Sa_i, Sp_i, Sv_i, Sku_i = parameters before wear testing

Ra_w, Rp_w, Rv_w, Rku_w, , Sa_w, Sp_w, Sv_w, Sku_w = parameters after wear testing