14th International Research/Expert Conference
”Trends in the Development of Machinery and Associated Technology”
TMT 2010, Mediterranean Cruise, 11-18 September 2010

RESEARCH ON THE INFLUENCE OF SURFACE PARAMETERS ON TECHNOLOGICAL PROPERTIES OF POWDER DETAILS

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ABSTRACT

The present surface roughness research is based on machine parts surface cross section profile analysis. But in practical applications machine parts surface roughness behaves as a 3D object. Therefore it is necessary to create a new theoretical and practical basis for machine parts surface assessment as a 3D quantity. The results of investigation of surfaces of iron-copper details after compacting, sintering and infiltration are offered. The influence of the technological process on the surface conditions was evaluated and analyzed by comparison of the average 3D roughness parameters of iron-copper detail.

Based on the obtained surface roughness parameters and physical-mechanical properties the wear intensity of powder details surfaces was calculated using new approach offered by authors. New approach is based on the application of original contact criteria and probability theory. Calculation of wear was executed using stray field to roughness evaluation of friction surfaces. Analytical values show well accordance with practical values.

Keywords: surface roughness, powder detail, contact criteria, wear intensity

1. INTRODUCTION

Surface condition of powder details on the different stages of producing of joining elements is the important factor that influences on the choice of technological conditions of operations and end-use properties and running ability of product. Generally the roughness, porosity and microstructure determine the surface condition. The results of investigation of surfaces of iron-copper details [1,2] after compacting, sintering and infiltration (Fig.1) are listed below.

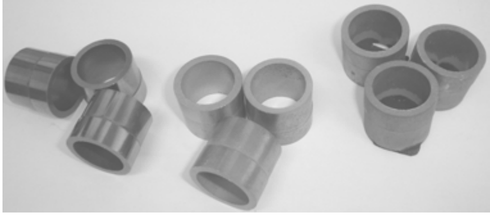

Figure 1. Iron-copper details after compacting, sintering and infiltration.

For exploring surface roughness the “Taylor Hobson Ltd” 3D measurement system has been used. Achieved 3D surface image of the iron-copper detail after compacting is given on Figure 2, after sintering and infiltration is given on Figure 3 and Figure 4 respectively.

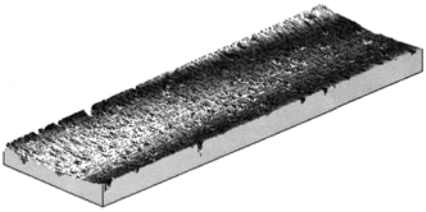

Figure 2. View of the 3D surface image of the iron-copper detail after compacting.

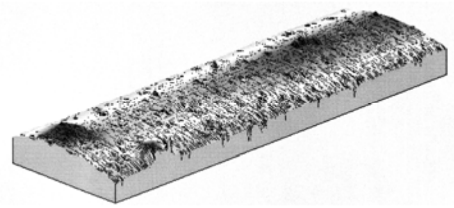

Figure 3. View of the 3D surface image of the iron-copper detail after sintering.

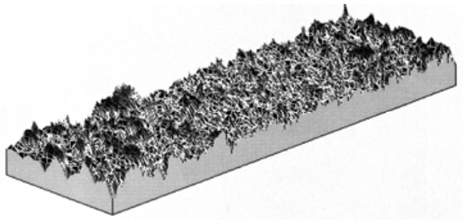

Figure 4. View of the 3D surface image of the iron-copper detail after infiltration.

2. 3D SURFACE PARAMETERS OF POWDER DETAILS

Parameters for 3D areal assessment are still under discussion by ISO and other standards organizations. However, at least 18 parameters currently defined in EUR 15178 EN. For comparison we use amplitude parameters: *Sa* and *Sq* and spatial parameters: *Sds* and *Str* [1,2]. All these parameters are defined in comparison with a mean plane obtained through levelling of the mean square plane of the measured surface and then through centring of heights around the mean: *Sds* – density of summits of the surface. This parameter is used to evaluate the density of peaks and peats in the surface; *Str* – texture aspect ratio of the surface. This parameter measures the isotropy of surface; *Sa* – average absolute deviation of the surface; *Sq* – root mean square deviation of the surface. Used to discriminate between different surfaces based on height informationa and to monitor manufactoring stability.

Comparison of the mentioned 3D parameters of iron-copper details after compacting, sintering and infiltration is given in Table 1.

Table 1. Amplitude and spatial 3D roughness parameters comparison.

Iron-copper powder details after:	Amplitude parameters		Spatial parameters	
	Sa, μm	*Sq, μm*	*Sds, Pks/mm^2*	*Str*
compacting	1.02	3.19	75.5	0.193
sintering	1.18	2.11	191.0	0.514
infiltration	2.0	2.6	218.0	0.547

As shown each step of the technological process the surface amplitude roughness parameters and spatial parameters increase as a rule. At the same time the parameter *Sq* (quadratic mean of the deviations from the mean) reduces after sintering. Especially significant changes occur with spatial parameters. Density of summits (*Sds*) increases in three times during stages of technological process: compacting, sintering and infiltration. An important point is that at the same time surface is more and more anisotropic since the value of parameter *Str* closer to 1. The reason for these changes of surface conditions is shrinkage of material during sintering and infiltration. So we can use measurement results not only for evaluation of details quality, but for prediction of shrinkage and consequently for pressing equipment design and choosing of sintering regimes.

3. ANALYSIS OF WEAR USING CONTACT CRITERIA AND PROBABILITY THEORY

Problems of friction, wear and lubrication r refer to specific field of general tribology. The main goal is to maximally minimize the energy loss and wear (minimization of changing of the geometrical parameters of details) [3]. The main problem in designing of friction and antifriction units is the choice of optimal materials and surface roughness parameters for friction details. Thereby the control of contacting process (prediction of the type of the contact: plastic, elastic or elastic-plastic) allows to solve mentioned general problems of the tribology.

To create theoretically proved method for designation of roughness and physical mechanical characteristics of the surface parameters the contact criteria (*CC*) is used. Different formulas of contact criteria are widely used in the tribology science. For elastic-plastic contact we propose to use contact criteria (*CC*) expression that is based on standard roughness parameters [4,5]:

$$CC = \frac{Rsm_1 \cdot H \cdot \Theta}{Sa}, \tag{1}$$

where Rsm_1 and Sa, are the parameters of a surface roughness; H is the microhardness of a surface layer; $\Theta = \frac{1-\mu^2}{E}$ is the elasticity characteristic of the material (E is the Young's modulus and μ is the Poisson's ratio).

Concrete numerical value of contact criteria depends on type of roughness and conditions of contact interaction: $CC = 0.70$ for mainly plastic (95%) and $CC = 1.74$ for mainly elastic contact of micro asperities. The proposed *CC* is suitable for direct engineering calculation and is correct for all types of roughness. Using of *CC* allow to select roughness parameters and technological processing on drawing with prediction of the type of the contact.

Probability approach in analysis allows considering wear process by the account of stray character of a micro contour of surfaces of wear. Full theoretical analysis of wear in the case of plastic and elastic contact using probability theory is given in [5,6]. But for practical engineering calculation of linear wear intensity I_h for mainly elastic contact we propose to use simplified expression [6,7]:

$$I_h = C_t \left(\frac{Str \cdot Sa \cdot f}{Rsm_1 \cdot Rm} \right)^t \cdot \Theta^{1-t} \cdot q \cdot \frac{A_c}{A_a}, \tag{2}$$

where C_t is coefficient depending on coefficient of anisotropy and parameter t of a curve of fatigue. Values of C_t and t are given in [6]; Str – roughness parameter, R_m – tensile strength; A_c – contour area of contact; A_a – nominal area of contact, f – friction coefficient, q – specific loading.

For mainly plastic contact [6,7]:

$$I_h = \left(\frac{5Sa \cdot Str}{Rsm_1} \right)^3 \cdot \left(\frac{q}{H} \right)^{\frac{2}{5}} \cdot \frac{A_c}{A_a}, \tag{3}$$

The maximal error of calculation using formulas (2,3) does not exceed 20% in comparison with calculations which have been carried out using full formulas [5,6].

4. CALCULATION OF WEAR INTENSITY OF IRON-COPPER POWDER DETAILS

The wear intensity of powder details surfaces after infiltration was calculated based on the obtained 3D surface roughness parameters and physical-mechanical properties [1,2]: Sa = 2.0 µm, Rsm_1=

59.11 µm, $Str = Rsm_1/Rsm_2$ = 0.547, H = 2400 MPa, Θ =$0.72 \cdot 10^{-5}$, Rm =1600 MPa, q = 0.6 MPa, A_c=0.1 A_a.
First using (1) formula the CC was calculated for prediction of the type of contact:

$$CC = \frac{Rsm_1 \cdot H \cdot \Theta}{Sa} = \frac{59.11 \cdot 2400 \cdot 0.72 \cdot 10^{-5}}{2} = 0.5$$ < 0.7, so we have mainly plastic contact.

Then the wear intensity of powder details surfaces was calculated according to (3) expression:

$$I_h = \left(\frac{5Sa\ \cdot Str}{Rsm_1} \right)^3 \cdot \left(\frac{q}{H} \right)^{\frac{2}{5}} \cdot \frac{A_c}{A_a} = \left(\frac{5 \cdot 2 \cdot 0.547}{59.11} \right)^3 \cdot \left(\frac{0.6}{2400} \right) \cdot 0.1 = 7.9 \cdot 10^{-4} \cdot 0.036 \cdot 0.1 = 0.28 \cdot 10^{-7} \cdot$$

Calculated value of linear wear intensity well according with experimental values (from I_h = $0.27 \cdot 10^{-7}$ to $0.62 \cdot 10^{-7}$) obtained according the [8], i.e. it is satisfactory for engineering practice.

5. CONCLUSIONS

1. The 3D surface roughness parameters of powder iron-copper details are measured and analyzed. It was established, that the values of amplitude and spatial parameters are increased during technological process: compacting, sintering and infiltration by copper of powder details. The reason for these changes of surface conditions is shrinkage of material during sintering and infiltration.
2. Based on the obtained 3D surface roughness parameters and physical-mechanical properties the wear intensity of powder details surfaces was calculated using new approach offered by authors. New approach is based on the application of original contact criteria and probability theory. Analytical value achieved by using simplified expression show well accordance with practical value.

ACKNOWLEDGEMENT

This work has been supported by the European Social Fund within the project “Nanotechnological research of the mechanical element surface and internal structure in mechanical engineering”. We also would like to make a special reference to Mr. Shipitsa N.A. from Institute of Powder Metallurgy of the Belarusian State Research and Production Powder Metallurgy Concern who was executed experimental investigation of the wear intensity of powder details surfaces.

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