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INFLUENCE OF GEOMETRIC SURFACE STUCTURE FEATURES ON WEARING PROCESS AFTER ELECTRICAL DISCHARGE MACHINING

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Abstract: *The following paper discusses the geometric surface structure (GSS) features obtained with electro-erosive machining and their unique emphasis on its directivity. The impact of the GSS on the wear process has been analyzed. The results of carried out tests on a designed and constructed test stand have been also presented and they apply to the influence of the GSS features on wearing process intenseness. The test results have confirmed the significance of examined factors on the intensity of given process.*

Keywords: Geometric surface structure, Wear process, Electrical discharge machining.

1. Introduction

Numerous studies, e.g. (Krawczyk, 2010; Ligaj and Soltysiak, 2016; Matuszewski et al., 2017; Musiał et al., 2017, 2018; Muślewski et al., 2015; Trzos, 2011; Wirwicki and Topoliński, 2014) have shown a close relationship between the state of the surface layer machine elements and the tribological features of these elements. It is to conclude that the surface layer condition decisively determines the functional characteristics of the entire machine.

The surface layer characteristics are determined, to the greatest extend, by parameters describing the stereometric surface structure more frequently called the geometric surface structure (GSS). This structure is created by surface unevenness, i.e. odds and dimples which are wavy finish of realized processing or effects of the wear process. Depending on the distribution of the GSS characteristic elements, the surface may be either anisotropic or isotropic. The basic parameters describing the geometric surface structure are (Nowicki, 1991; Thomas, 1999; Wieczorowski et al., 2003): surface roughness, wavy finish directivity, waviness, defects in geometric surface structure.

Mainly, the two firstly mentioned parameters have an impact on the tribological characteristics of cooperating machine elements surfaces. Surface roughness and surface structure directivity depend on adopted processing parameters and their type. Surface roughness arises from the simultaneous interaction of many independent factors, both random and determined. As a result, it has very composite microgeometry. In case of electro-erosion machining it depends on factors such as e.g.: cut-off current, its passage time, the properties of electrode material and the type of used dielectric liquids, etc. (Horng et al., 1995; Matuszewski, 2017; Mikołajczyk et al., 2016; Zhu et al., 2003).

Due to the need of minimization of resistance to motion and thus friction the aim is to obtain the lowest values of roughness. By erosion machining the roughness of work surfaces may be obtained within values ranging from a few micrometers to even a few tenths of a micrometer (Nowicki, 1991; Tomczak, 1990).
The second factor, which significantly affects the functional characteristics of the constituted working surface of machine elements, i.e. the directionality of the structure and it basically occurs only

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in combined machining. Surface anisotropicity is particularly evident in hybrid machining combining erosion machining with machining - Fig. 1a.

In the case of “pure” erosive treatments, the surfaces are obtained with a substantially isotropic haracter, i.e. without a privileged structure directivity. An example of such a structure is shown in Figs. 1b and 1c.

The surface structures shown in Fig. 1. has been subjected to tribological tests, which have been characterized in the following part.

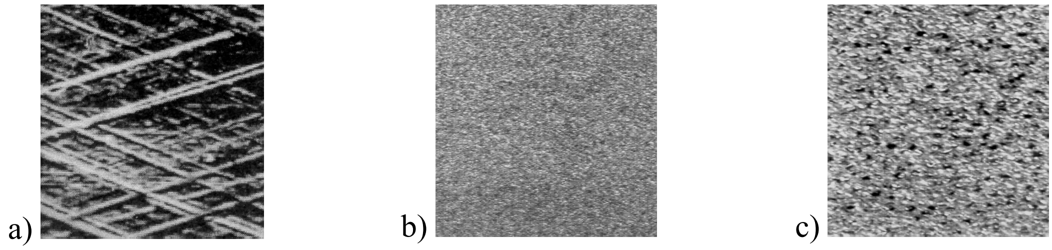

Fig. 1: Surface structure after erosive treatment: a) after electrochemical abrasive honing; b) after electro-erosion treatment at 1 A discharge current and 3.2 μs discharge time; c) after electro-erosion treatment at 6 A discharge current and 100 μs discharge time.

2. Investigations of the influence of the geometric surface structure character obtained by erosion treatments on wear process

Properly generated surface layer in a machine elements manufacturing processes assures the maximum resistance for wear process results and thus high operational durability of cooperating friction pair elements. As previously mentioned, for wear process the essential element of GSS is its directivity, especially for conformal contact of cooperating kinematic pair elements surfaces.

2.1. The aim and the methodology of experimental tests

The assumption of experimental investigations was to determine the influence of distribution and orientation of the machining traces after erosive treatment, which followingly depend on the kind of machining process, as well as the assumed parameters and on the intensity of wear process of exanimated surfaces. They were conducted in two ways, i.e. the first part of tested surfaces had an anisotropic character, obtained as the result of electro-erosive abrasive honing, however the second one was isotropic - after EDM. These surfaces have cooperated with counter-specimen of which the structure has an anisotropic character. There were also visibly oriented machining traces.

In order to conduct the aim of investigations, a special test stand has been designed and built (Musial, 2018). In case of which the surface structure of specimens surfaces has an anisotropic character the relative movement of counter-specimen was reciprocating (Fig. 2a), however, in case of isotropic structures of surface, the relative movement was oscillative (Fig. 2b).

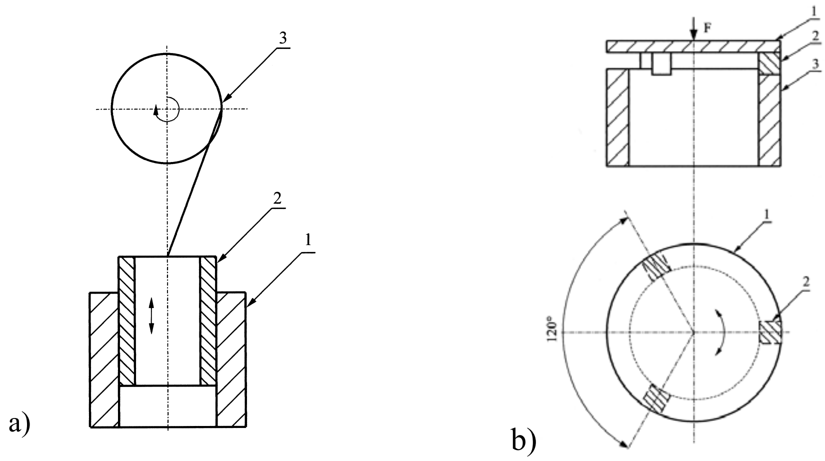

Fig. 2: The idea of cooperating frictional surfaces during experiments; the movement of counter-specimen is given: a) reciprocating; b) oscillate.

In variant I (Fig. 2a) tested specimen (1) is motionless and connected to the base, however counter-specimen (2) - reciprocating motion is obtained by means of slider crank mechanism (3). Association (fit) of specimen regard counter-specimen is H7/f6. In variant II (Fig. 2b) in locating bush (3) three specimens (2) have been fixed motionlessly and have cooperated with oscilating counter-specimen (1). The load of specimen has been processed by spring tension. This way the pressure of counter-specimen to tested specimens has been processed by tension force 450 N, which fulfils the theoretical pressures in contact area 1.5 MPa.

The changes of geometric surface structure condition for anisotropic structures were observed for three values of angles (α) of machining traces intersection (the angle of honing): α = 0 ° - one-way transverse honing, α = 45 ° - two-way honing, and α = 180 ° - one-way longitudinal honing. For isotropic structures observation of this wear process was conducted for two different structures (Fig. 1b and 1c) which were characterized by different values of initial roughness.

The specimens for first variant were made of steel C45 and characterized by hardness 30 HRC, the counter-specimen, of 41Cr4 steel, hardness 60 HRC. For the second one, the material of specimens has also been made of C45 steel, and counter-specimen 102Cr6 steel. Their hardness was respectively: 40 and 60 HRC. In both variants the hardness of counter-specimen was decidedly greater than hardness of the samples in order to observe the changes of geometrical surface structure condition to occur first in specimens surface layer.

In both cases specimens have cooperated with counter-specimen in fluid medium, which was the machine oil. The velicity of relative movement during investigations for the first case was 0.017 $m \cdot s^{-1}$, and for the second one was 0.05 $m \cdot s^{-1}$.

2.2. Experimental tests results

The results of experimental tests have been presented in the form of graphs – Figs, 3 and 4. The change of the geometric surface structure condition has been described by the change of the surface roughness parameter Ra value as a function of the friction path. Fig. 3 shows the results for the obtained honed surface structure - Fig. 1a. Whereas Fig. 4 shows the results for the surface structures obtained by electro-erosion treatment and presented in fig. 1b and c. The structure of Fig. 1b on the graph (Fig. 4) has been designated as “structure A” and the structure of Fig. 1c on the graph (Fig. 4) as “structure B”.

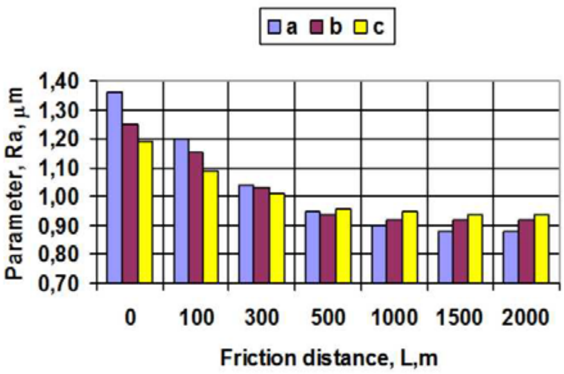

Fig. 3: The values of roughness parameter Ra as a function of friction path for surfaces after honing and for the following angles of marks after treatment: a) α = 0 °; b) α = 45 °; c) α = 180 °.

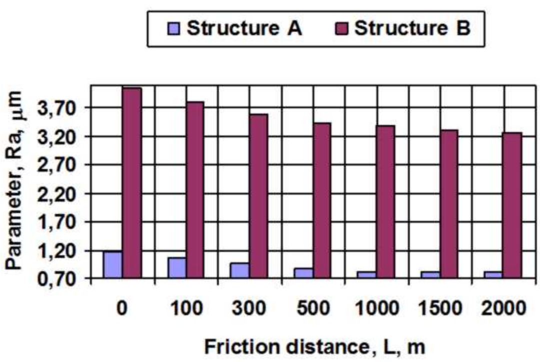

Fig. 4: Surface roughness Ra parameter value as a function of friction path for surfaces after electrical discharge machining.

The research shows that the change in the value of the surface roughness parameter Ra depends on the angle α of the intersection of marks after treatment. The most significant changes take place for the 0 ° angle, whereas the most diminutive for the 180 ° angle. For all three cooperation conditions, it may be observed that in the initial period there is an intense change of the surface roughness parameter value and in the following one the intensity of these changes decreases, and the stabilization is observed. This corresponds with assumed wear process mechanism.

Fig. 4 shows that the change of surface roughness Ra parameter value in the initial period of cooperation is intense and the intensity of these changes decreases whereas the path of friction increases. In case of structure A (lower roughness), faster stabilization of surface roughness parameter value changes may be observed comparable to structure B with higher initial roughness. This is consistent with the assumed wear process.

3. Conclusions

The experimental tests have showed that the intensity of the wear process depends on geometric surface structure features shaped at the manufacturing process. It has also been found that the EMD parameters not only affect the condition of the technological surface layer, but also significantly determine the tribological characteristics of elements and influence the nature of the wear process. In order to know the details of quantitative relationship between the examined factors a full cycle of tests is to be implemented. The set of result quantities should be also extended by the other parameters characterizing the geometric surface structure and of the direct wear measures (e.g. weight loss, macrogeometric changes). Obtained tests results will contribute to expanding knowledge about the wear process mechanisms. By knowing the regularities and mechanisms that occur when friction pair is worn, it will be possible to choose the optimal (with tribological criteria) method of treatment due to the location of traces after treatment. Obtained in this way characteristics of the surface layer should provide minimal changes in the surface layer during operation and at the same time the longest possible period of work with unchanged, assumed constructional characteristics of friction pair.

References

Horng, J. H., Lin, J. F., and Li, K. Y. (1995) Effect of surface roughness on steel roller scuffing, Wear, 184, pp. 203-212.

Krawczyk, J. (2010) Tribological properties of selected structural steels, Tribology, 4, pp. 223-233 (in Polish).

Ligaj, B. and Sołtysiak, R. (2016) Problems of Equivalent Load Amplitude in Fatigue Life Calculations, Polish Maritime Research, 23, 1, pp. 85-92.

Matuszewski, M. (2017) Transformation of surface layer and surface isotropy changes, in Proc. 58th Int. Conf. on Machine Design, Prague, pp. 230-235.

Matuszewski, M., Mikołajczyk, T., Pimenov, D.Yu. and Styp-Rekowski, M. (2017) Influence of structure isotropy of machined surface on the wear process, International Journal of Advanced Manufacturing Technology, 88, 9, pp. 2477-2483.

Matuszewski, M. and Styp-Rekowski, M. (2008) Kinematics of components and determination of the friction path in tribological research on a friction pair, Tribology, 3, pp. 115-124 (in Polish).

Mikołajczyk, T., Fąs, T., Kłodowski, A., Matuszewski, M., Olaru, A. and Olaru S. (2016) Computer Aided System for Superfinishing Process Control, in Proc. 9th Int. Conf. INTER-ENG 2015, Book Series: Procedia Technology, 22, pp. 48-54.

Musiał, J., Polasik, R., Kałaczyński, T., Szczutkowski, M. and Łukasiewicz, M. (2018) Milling efficiency aspects during machining of 7075 aluminium alloy with reference to the surface geometrical structure, Proc. 24th Int. Conf. on Engineering Mechanics, Book Series: Engineering Mechanics, pp. 569-572.

Musiał, J., Szczutkowski, M., Polasik, R. and Kałaczyński, T. (2017) The influence of hardness of cooperating elements on performance parameters of rolling kinematic pairs, in Proc. 58th Int. Conf. on Machine Design, Prague, pp. 260-265.

Muślewski, Ł., Pająk, M., Grządziela, A. and Musiał J. (2015) Analysis of vibration time histories in the time domain for propulsion systems of minesweepers, Journal of Vibroengineering, 17, 3, pp. 1309-1316.

Nowicki, B. (1991) Geometrical Structure. Roughness and Waviness, WNT, Warsaw (in Polish).

Thomas, T. R. (1999) Rough surfaces. London: Imperial College Press.

Tomczak, J. (1990) Electrolytical Polishing, in Proc. of EM'90, Bydgoszcz, pp. 249-258 (in Polish).

Trzos, M. (2011) Variability in the reproducibility and reproducibility of tribological characteristics, Tribology, *6*, pp. 227-239 (in Polish).

Wieczorowski, M., Cellary, A. and Chajda, J. (2003) Guide to measurement of surface roughness, roughness and not only, Publishing House of Poznan University of Technology (in Polish).

Wirwicki, M. and Topolinski, T. (2014) Zirconium dioxide - static test on glued connections, Proc. 20th Int. Conf. on Engineering Mechanics, Book Series: Engineering Mechanics, pp. 724-727.

Zhu, H., Ge, S., Huang, X., Zhang, D. and Liu, J. (2003) Experimental study on the characterization of worn surface topography with characteristic roughness parameter, Wear, *255*, pp. 309-314.