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RESEARCH

Normal Force Influence on 3D Texture Parameters Characterizing the Friction Couple Steel – PBT + 10 % PTFE

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A B S T R A C T

This study presents the influence of the normal force on the surface quality of the friction couple steel – polybutylene terephthalate (PBT) + 10 % polytetrafluoroethylene (PTFE). There were calculated the average values of the amplitude and functional parameters, as obtained from investigating square areas on the wear tracks, with the help of a proposed methodology, for initial and tested surfaces generated on the blocks and on counterpart ring made of rolling bearing steel, for the following test conditions: three normal forces (F = 1 N, F = 2.5 N and F =5 N), three sliding speeds (v = 0.25 m/s, v = 0.50 m/s and v = 0.75 m/s) and a sliding distance of L = 7500 m. The conclusion of the research study was that the tested normal force range has an insignificant influence on the surface quality for the tested materials and parameters. This friction couple could be recommended for variable conditions (speed and load) in dry regimes.

1. INTRODUCTION

In actual application for bearings and seals in dry regime, a self-lubricating polymeric material slides on a hard surface, proved to be tribologically efficient as compared to the sliding of a polymeric material on itself [1,2]. The adhesion and abrasion components of the friction and wear processes sinergically influence themselves. For instance, extend of the junctions depends on the elasto-plastic deformation of the asperities [3-5] and they could not be separated. For the polymer-metal contact, the deterioration of the polymer by elasto-plastic deformation is more intense and the adhesion component increases for the harder surfaces [6]. The generated transfer film characteristic for the polymer-metal friction couple, also changes the surface texture, depending of the polymer nature and the working conditions [1,2,7].

There are many published studies on the tribological behavior of polymeric materials [7-9], but few of them deal with the influence of the surface texture on the tribological characteristics of the polymeric materials and even fewer reported how the working conditions affect the surface texture. In 1970, Pooley and Tabor (quoted in [1]) pointed out that for PTFE, the value of the friction coefficient is only slightly affected by the surface quality when involving relatively smooth ones, but with rough surfaces the wear and the friction are intensified. Till now, the terms "smooth" and "rough" were used only in a qualitative way and there are no recommended values of the texture parameters for particular applications.

Experimental studies proved that a change of the texture parameters could significantly affect the friction and the wear. For instance, Chowdhury et al. [10] concluded that the values of friction coefficient and wear rate are different for smooth and rough counterface pins and type of materials, therefore an appropriate level of load, sliding speed and an appropriate counterface texture of the selected materials, friction and wear may be kept to a lower value to improve the contact durability. Even static coefficient of friction is influenced by the particularities of surface texture as resulted from the manufacturing process [13].

There is why the authors of this research consider the texture evaluation, before and after testing, necessary for understanding and directing the tribological processes. Many polymeric friction couples are working with frequent starts and stops and the evolution of the surface texture is of great importance for improving the reliability and the durability of these tribosystems.

For polymeric friction couples and especially for polymer – metal contacts, the wear could be related both to the amplitude and functional parameters.

As resulted from the studied documentation [14,15], the surface quality is frequently described by parameters as S_a (arithmetic average of absolute values) and S_q (root mean squared). The authors' estimates that for studying the worn surfaces and for obtaining correlations among the surface parameters and the testing conditions, the following parameters are more suitable: the parameters related to the maximum values of the topography (S_z – the height difference between the highest and lowest heights in the investigated area, S_v – the largest pit height, S_p – the largest peak height) and the functional parameters (S_{vk} – reduced valley depth, S_k – core roughness depth, S_{pk} – reduced summit height).

2. MATERIAL AND TESTING METHODOLOGY

The friction and wear behaviour of PBT sliding against steel was evaluated with the help of a Universal Micro-Tribometer UMT-2 and a block-on-ring tribotester. The geometry of the frictional couple is given in Fig. 1.

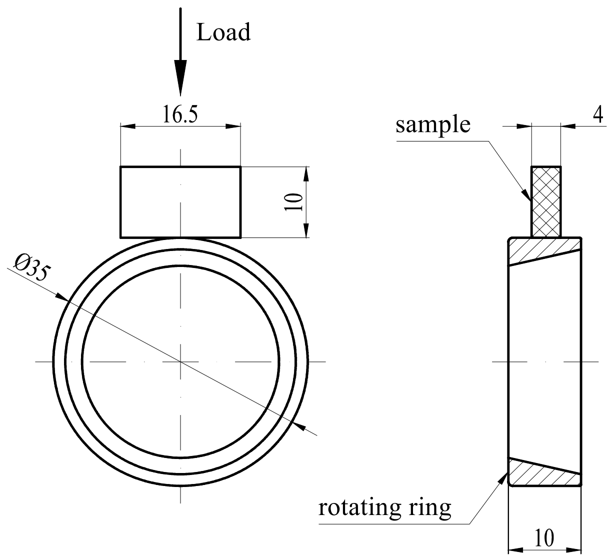


Fig. 1. The shapes and dimensions of the friction couple block-on-ring.

The polymeric blocks are prisms of 16.5 mm × 10 mm × 4 mm and they were obtained by injection at ICEFS Savinesti, Romania, according to the specifications of the producer from traction samples, cutting the blocks from the middle parallel zone of them.

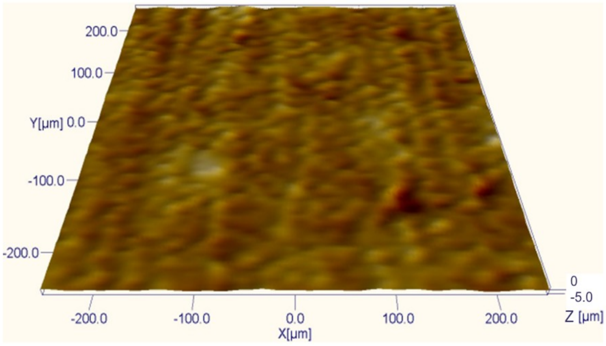
The polymeric blend has 90 % (wt) PBT, the commercial name being Crastin 6130 NC010 (as supplied in grains by DuPont) and 10 % (wt) PTFE, commercial grade NFF FT-1-1T® Flontech, having the average size of the particles ~20 μm.

The other element of the friction couple was the external ring of the tapered rolling bearing KBS 30202 (DIN ISO 355/720), having the dimensions of Ø35 mm × 10 mm and they were made of steel grade DIN 100Cr6, having 60 - 62 HRC and R_a = 0.8 μm on the exterior surface.

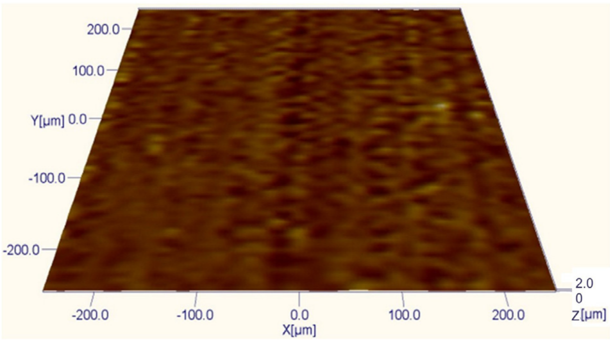
There were selected the following test parameters: three sliding speeds (v = 0.25 m/s, v = 0.50 m/s, v = 0.75 m/s), three applied loads (F = 1.0 N, F = 2.5 N, F = 5.0 N), the sliding distance being L = 7500 m for each test done at room temperature and in a laboratory environment.

In order to do this study, the profilometer Laser NANOFOCUS μSCAN [16] was used.

For parameters' calculation it was used the software SPIP 5.1.11 [17]. Fig. 2 presents a virtual (rebuilt) image of the investigated zone with the help of this software.



a) The initial surface



b) The worn surface (F = 5 N, v = 0.25 m/s, L = 7500 m)

Fig. 2. Virtual images of the polymeric blocks made of PBT + 10 % PTFE.

Measurements were done for blocks made of the polymeric blend PBT + 10 % PTFE and for the external rings of tapered rolling bearings, both elements being involved in block-on-ring tests, for both non-worn and worn surfaces.

For evaluating the 3D parameters involved in this study, there were selected three zones, each of 500 μm × 500 μm for the polymeric blocks and of 100 μm × 100 μm for the metallic rings, these being reduced for reason of the surface curvature. All 3D measurements were done with a step of 5 μm. The distance between lines for 3D measurements was also 5 μm. The 3D parameters are calculated for all the values z(x, y), measured on one area of 500 μm × 500 μm on the block and one area of 100 μm × 100 μm on the steel ring.

3. EXPERIMENTAL RESULTS

Taking into account that PTFE has lower mechanical properties as compared to PBT [11], it was considered necessary to study the influence of the normal force on the surface quality of this polymeric blend, before and after testing.

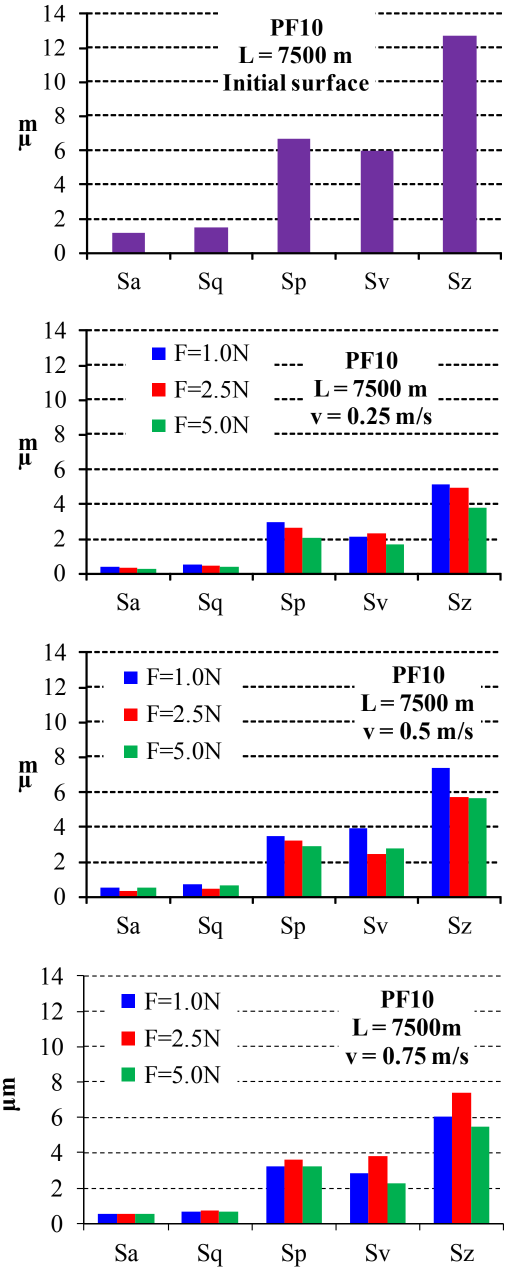


Fig. 3. The influence of the normal force on the average values of the dimensional amplitude parameters for the blocks made of PF10 (PBT + 10 % PTFE).

Figures 3, 4 and 5 present the average values of the amplitude and functional parameters, obtained with the help of the proposed methodology, for the initial and tested surfaces generated on the blocks made of PF10 (material symbol for the polymeric blend PBT + 10 % PTFE), for the tested conditions: three forces and three sliding speeds and a sliding distance of L = 7500 m.

The wear track surfaces are characterized by parametric values 2...3 times lower than those of the initial surfaces as they were obtained by the moulding technology.

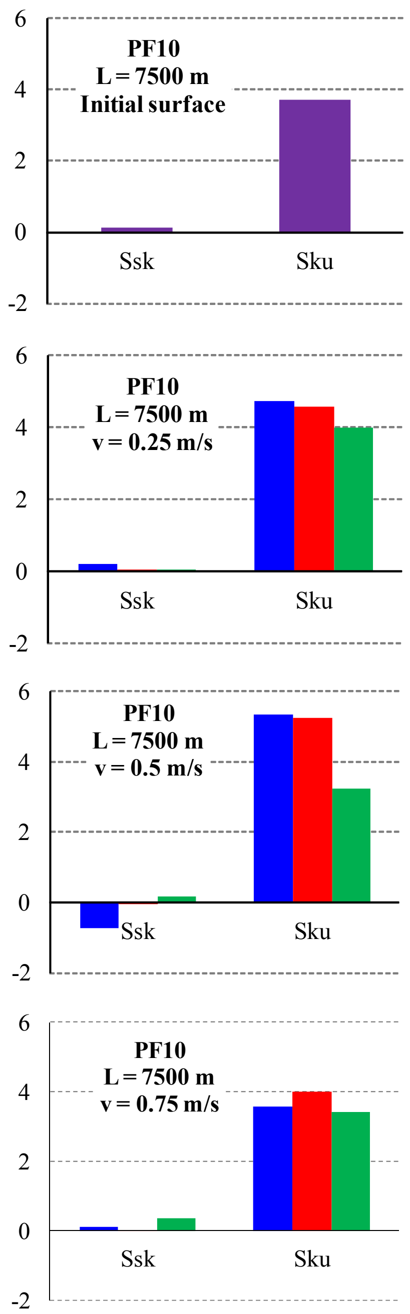


Fig. 4. The influence of the normal force on the average values of the dimensional amplitude parameters for the blocks made of PF10.

The surface quality of this material is only slightly dependent on the normal force, at least for the tested values (F = 1 N, F = 2.5 N and F = 5 N).

S_a and S_q have very close values, regardless the force values, but S_p and S_z present a slight decrease when the force increases, for the test done with the sliding speeds of v = 0.25 m/s and v = 0.5 m/s.

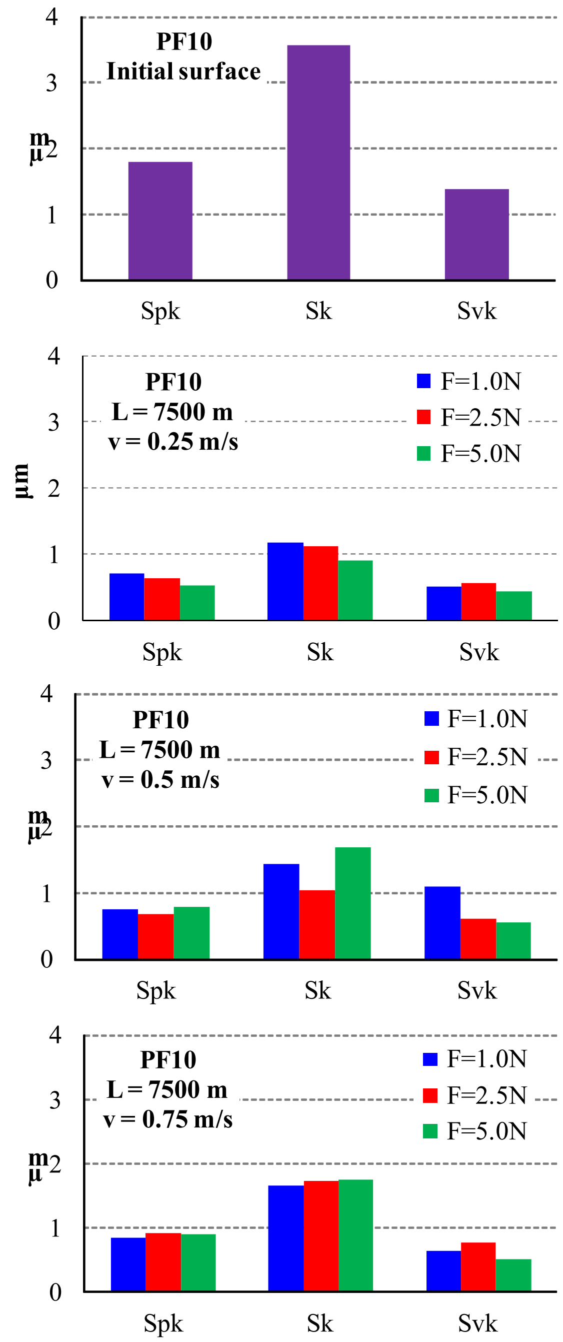


Fig. 4. The influence of the normal force on the average values of the 3D functional parameters for the blocks made of PF10.

S_{ku} (surface Kurtosis) values greater than 3.0 indicate narrower height distribution due to the particular ductile fracture of the polymer during adhesion – abrasion wear. S_{sk} (surface Skewness) has values oscillating around zero, indicating symmetric height distributions. If $S_{sk} < 0$, the bearing surface has holes and if $S_{sk} > 0$ it is a flat surface with peaks.

It was noticed a slight decrease of the functional parameters when the load increases, for tests done with the sliding speed of v = 0.25 m/s. For the other two tested speeds (v = 0.50 m/s and v = 0.75 m/s), this poor dependence on the normal force was noticed only for S_{vk}. The greater forces make this parameter to decrease and this tendency could be justified by the elasto-viscous behaviour of the polymeric blend; it is possible that the passing of the hard asperities laterally moves the softer material of the counterpart accompanied by an elevation of the valley bottoms between asperities, process also reported in [12,1].

4. CONCLUSION

For the friction couple polymeric blend PBT + 10 % PTFE sliding against steel, there was found no significant influence of the normal force on the surface quality of the element made of polymeric composite, for the testing conditions: range of force 1 N ... 5 N, range of speed 0.25 m/s ... 0.75 m/s and the sliding distance 7500 m.

The obtained results recommend the tested materials for friction couples functioning under variable conditions (speed and load) in dry sliding. Also, this research points out the importance of correlating a set of texture parameters for analysing the surface quality in tribological applications.

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