INVESTIGATION OF TRIBOLOGICAL PROPERTIES OF LASER-SINTERED AND COATED PARTS

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SUMMARY
The paper deals with the laboratory investigation of tribological properties of selective laser-sintered and laser coated parts. The investigations were made in connection with using of laser-sintered prototype tools for injection molding of plastics. These tools should be able for the production of small badges. On a pin-on-ring machine we investigated the friction and wear properties of uncoated parts. In the next etap of our investigations we focused on edges and inlets where wear is more severe, and therefore improvement of the surface by coating is required. We produced Mogul and FeB surfaces by laser alloying on the sintered work pieces and we tested them on special cylinder-on-cylinder tribometer against high performance plastics. It was found, that the coated specimens had better wear resistance characteristics and slightly lower coefficient of friction.

Keywords: friction, wear, laser sintering, coating, rapid prototyping

1 INTRODUCTION
Rapid prototyping is a modern method for producing new models fast and relatively cheap. With selective laser sintering, parts with complex geometry can be made even within a few hours applying various powders. The structure and the mechanical properties of laser-sintered parts from powders are more homogeneous in comparison with parts produced by conventional powder metallurgical technology. In the available literature there is a lot of data about thermal stability, mechanical and other properties, but only a very few data can be found about tribological properties of laser-sintered parts [1, 2, 3]. The aims of this research is the investigation of surface properties, measurement of friction coefficient and wear rate, and determination of reliability of coated laser sintered parts aimed for being used as prototype tools. Furthermore the increase of wear resistance by using different laser coatings.

The specimens and the counter bodies were made in Hungary and the laboratory tests were carried out in Austria.

2 EXPERIMENTAL
Injection molding of plastics with reinforcing glass or carbon particles result a severe, mainly abrasive wear of dies especially on edges and inlets. During pressing process of injection molding machines the working tool pressure is about 100 N/mm², the injection speed is 0.7 m/s and the melting temperature might be 200...250 °C. In our model tests we tried to exceed these limits.

As counter bodies we chose three different kinds of plastics reinforced by short glass- or carbon particles so that the ploughing, abrasive action of the hard fibers result a great wear. With the use of cylinder-on-cylinder method with perpendicular axis, the pressure on the surface starts from an extremely high value, and by time decreases according to a quadratic function.

It means that in the beginning the pv values are 25 to 45 – respectively in the cases of 50 N and 100 N loads -, and at the end of the measurements these values were between 10 and 15 (N/mm²)* (m/s). According to the quadratic decrease of pv values, the increment of the contact surface will grow by this function. For this reason – on grounds of pre-tests - in the laboratory tests we tried to model the loading conditions of the injection molding tool during the injection process.

2.1 Model Test with Pin-on-Ring Machine

2.1.1 Specimens and Counter Parts

The specimens were sintered with CO₂ laser from Ni-alloyed phosphorous bronze powder (EOSINT M Cu 3201). The porosity throughout the whole specimens at any directions was constant (5…10 %). The surface structure of the laser-sintered parts is shown on Fig. 1. The frictional surface of the specimen was prepared by lathe machining and smoothed with emery paper. The hardness of the prepared surface was HB 60 – 80, Ra = 1…2 µm.

The counter body was glass-fibre-reinforced polyamideimid. The active surface of the polyamide was Ra = 4…6 µm.
2.1.2 The Test Rig and Testing Method

We used a modified pin-on-disk machine. The schematic arrangement of the test method is shown on Figure 2. and Figure 3.

The tests were carried out with the following limits:
Normal force: 100...1500 N (2.5...37.5 N/mm²),
Velocity: 0.016...0.048 m/s.
Temperature: 23...180 °C.
The duration of each test with a certain set was 20...60 minutes. During the tests we did not use any lubricant. The ambient temperature was 23 °C and the humidity was approximately 60 %.

2.1.3 The Results of Pin-on-Disk Tests

During the tests the wear of sintered specimen and the wear of counter body in turn of normal forces, in turn of temperature and in turn of frictional speed were measured. The characteristic values are shown on Fig. 4. and Fig. 5.

The coefficient of friction changed between 0.1 and 0.25. The friction coefficient at low temperature up to 80 °C is slightly increasing with normal force, but over 80 °C the µ value is decreasing with normal force. The wear rate of plastic pins - in comparison with the laser-sintered rings - is high. This wear rate is increasing rapidly with the normal force, with the speed of friction and with the temperature [4].

2.2 Model Test with Cylinder-on-Cylinder Tribometer

2.2.1 Specimens and Counter Parts

The specimens were the same sintered bronze as used earlier coated by CO₂ laser applying the special cladding laser head with adjustable powder supply in BAYATI. For coating we used the Co-based alloy – Mogul, and the glassy-like FeB powder (Fig. 6.).
Fig. 6. The surface of the FeB coated specimen after laser processing

The pieces were grinded, the surface roughness therefore was 0.6 – 0.7 µm. Surface hardness of Mogul coating was about 1000 HV and the FeB was 850 – 1100 HV.

As counter bodies, we used three different types of high performance plastics:
- KRECA CHOP M-107T,
- DSM KETRON PEEK – GF 30,
- DSM PEEK – CF 70 % carbon fibers (45° ply).

The frictional surface of the polymers was machined on turning-lathe. The roughness of the machined surface was Ra 1 – 2 µm.

2.2.2 The Test Rig

For the investigation of friction and wear properties of the layers with high hardness we used the special cylinder-on-cylinder laboratory rig. The scheme and measurement method is shown on Fig. 7-8.

Fig. 7. The scheme of the special tribometer with the layout of measurement of wear and coefficient of friction

For the measurements a special clamping unit was prepared (Fig. 8.).

The tests were carried out with the following limits:
Normal force: 50; 75 and 100 N,
Velocity: 0.3; 0.6 and 1.2 m/s.

The duration of each test with a certain set was 5 minutes. During the tests we did not use any lubricant. The ambient temperature was approximately 23 °C and the humidity was approximately 60 %.

2.2.3 Result of Cylinder-on-Cylinder Measurements

During the tests we measured the frictional coefficient (Fig. 9.) and after the tests we measured the wear of contact area by the measurement of the diameters under the objective of a light microscope. We set up diagrams of wear in turn of normal force and in turn of velocity (Fig. 10-11.).

Fig. 9. The change of the frictional coefficient in function of normal load (FeB coating against KETRON PEEK – GF 30)

Fig. 10. Wear area on the sintered body with original surface worn by Kreca Chop M-107T
3 DISCUSSION

The wear rate of the coated specimens was much smaller than that of the original sintered surface, as the diagrams clearly reflect. As an addition, specimens coated by FeB were somewhat better in wear resistance, than those coated by Mogul. The main wear mechanism is abrasive due to the ploughing action of fibers. The wear rate increases rapidly with the normal force and with the velocity. The wear rate of plastic cylinders - in comparison with the laser-sintered parts - is high.

The coefficient of friction changed between 0.3 and 0.45. The friction decreases with normal force, probably due to partial melting of the matrix. It was also found that the coatings provide lower frictional coefficient values than the original sintered surface.

Although the sintered material resists well the wearing effect of the reinforced polymers, an additional wear resistant coating is an advantage where the parts are exposed to higher local frictional load. For this purpose there is possibility to improve the sintered base material with coating having better such characteristics. Mogul and FeB coatings meet the mentioned requirements and - according to our results - are suggested to improve local wear resistance of the rapid prototype.

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5 REFERENCES