Measurement and Characterisation of Microstructures made by Cutting Processes

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Abstract

Modifying highly loaded surfaces of cylinders of piston engines is a method of minimizing wear and friction. There already exist coatings like ALUSIL which are used in the cylinders of some BMW and Porsche engines. The advantages of these coatings are very hard silicon particles that protrude from the aluminium matrix in which the silicon is embedded. Below the silicon particles is volume to store oil, improving the tribological performance.

Another new method of modifying a surface for this purpose is a special cutting process that can produce structures with a scale from few micrometers to some millimetres.

1 Introduction

Within the research group "microstructuring of thermomechanically high stressed surfaces", financed by the German Research Foundation (in German: Deutsche Forschungsgemeinschaft, abbreviated DFG) as research group 476, several aspects of microstructures like simulation, production and characterisation are researched [1, 2]. In this paper measurement and characterisation methods for these microstructures are discussed. Based on measurements with an optical roughness measuring device the microstructures are segmented, several characteristics are computed and correlated with tribological experiments.

2 Measurement with Chromatic Sensor

In order to gauge large measuring fields a punctual sensor is integrated into a coordinate measuring machine. With the used coordinate measuring machine Mahr OMS 553 HA (see figure 1) measuring fields up to 50 cm x 50 cm are possible but only a few square centimetres are necessary for this purpose, avoiding huge measuring data [3].

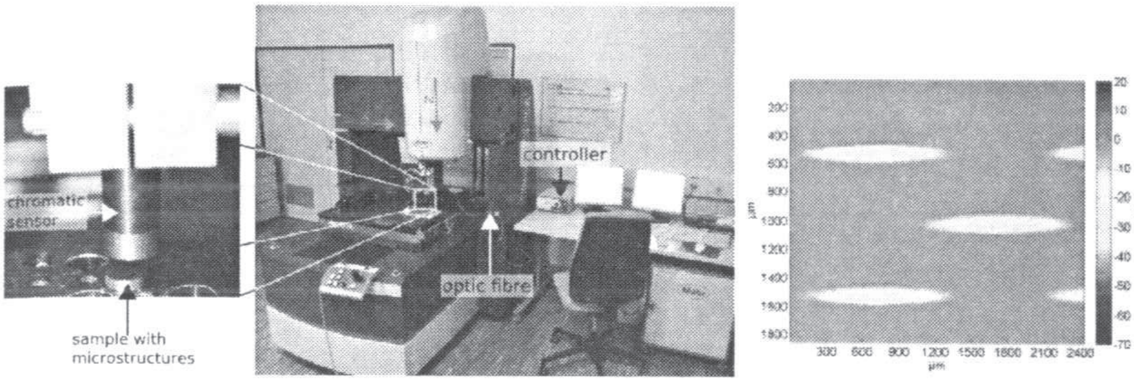

Figure 1: Coordinate measuring machine and measured microstructures

3 Segmentation and Characteristics

For further analysis of the microstructures, they have to be identified and separated from the other non-structured parts of the surface. Several segmentation methods can be used for this purpose. A common method is the watershed transformation [4] that floods the measured data with virtual water and raises the level of this virtual water sequentially. Thus, the structures with the largest depth are filled with this virtual water first. While the water level increases the structures with a smaller depth are being filled. If the level reaches a specific value, the water floods the whole surface and not only the structures. On this value watersheds are constructed on the edges of the microstructures that keep the water in the structures and avoid the flooding of the whole surface.

The watershed transformation is only useful for pores, but the created microstructures also have flashes near the structures as shown in the lateral cut in figure 2. The virtual water would rise up to the flashes and thus would segment parts that are not structures but parts between flashes and thus falsify the results. Due to this fact, a segmentation based on the threshold method is used. The requirement for this method is a precise form elimination based on a plane fit. The fitting of a plane into the measurement data is based on the measured data with the height which has the most occurrences in the histogram. So, the data points of the structure and the flashes are not being used. All the data points above the fitted plane belong to the flashes and the data below to the actually produced microstructures. A region finding algorithm assigns the flashes to its nearest microstructure.

Several characteristics like depth, length, width, volume, area, area in length and cross direction and percentage contact area are computed.

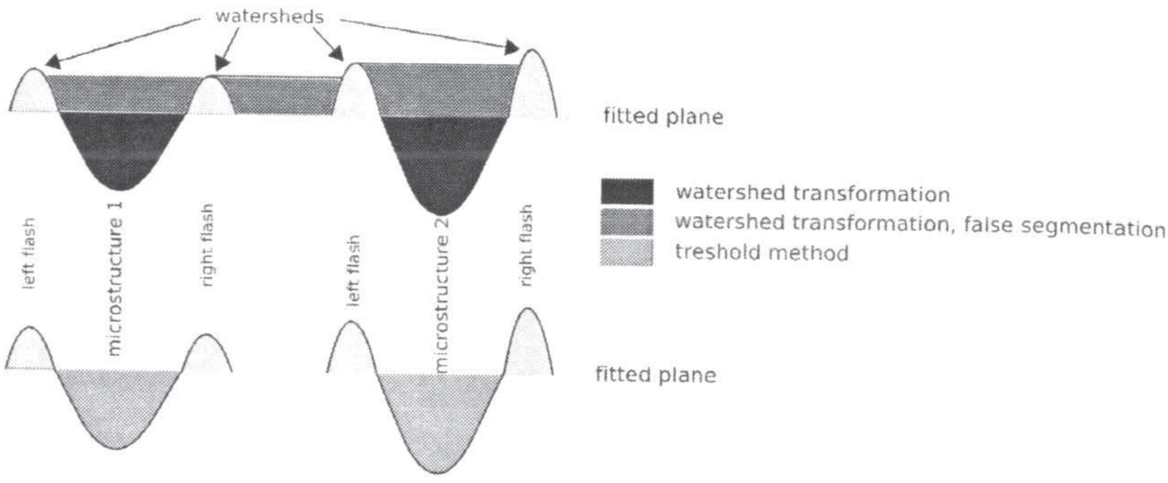

Figure 2: Lateral cut of deterministic microstructures and two segmentation methods

4 Tribological Experiments

Tribological experiments on surfaces with several microstructures show an influence of the microstructures to the friction coefficient. Several variations of parameters of the microstructures are tested in combination with different loads with p = 1.25 MPa – 5 MPa and relative velocities of v = 1 – 8 m/s in a tribometer.

In one of theses experiments microstructures of the same shape with different depths have been tested. In figure 3 the developing of the friction coefficient with a load of p = 1.25 MPa is shown. The depth of the microstructures is the mean value of about 30 microstructures that have been produced with the same parameters and that have been used in the experiments. The general run of the curve follows the Stribeck curve: At very low velocities there is boundary lubrication with a decreasing developing of the friction coefficient. In a minimum (0.2 m/s in figure 3) of the friction coefficient mixed lubrication takes places between the friction partners. On higher velocities hydrodynamic lubrication occurs between the surfaces and the coefficient increases with increasing velocity. Comparing graphs with different depths of microstructures, a positive correlation between the depth and a lower friction coefficient at higher velocity is evident. The greater depth of the microstructures also causes a higher volume and area of the structures. These larger microstructures thus improve the hydrodynamic lubrication, since they improve the pressure buildup between the friction partners.

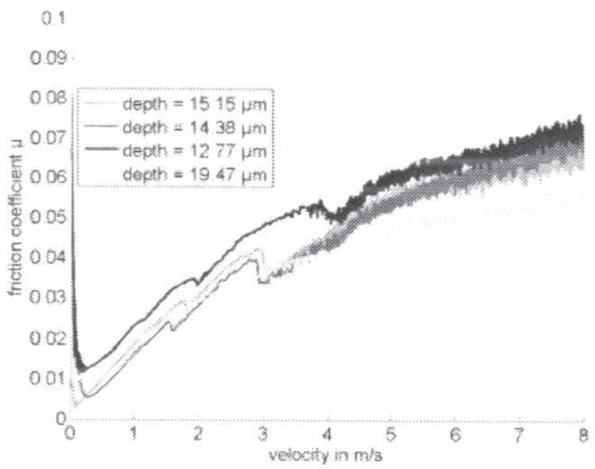

Figure 3: Friction coefficient of deterministic microstructures with different depths

5 Conclusion

A punctual sensor mounted into a coordinate measuring machine measures the microstructures. For segmentation, a modified threshold method provides correct results in contrast to a method based on the watershed transformation. Several characteristics are computed from the measurement data and compared with tribological experiments that show a positive effect of the microstructures on the friction coefficient.

6 Acknowledgement

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References:

[1] Denkena B.; Knoll, G.; Bach, F.; Reithmeier, E.; Kästner, J.; Brandt, S.; Drößler, B.; Bretschneider, M.: Mikrostrukturierung funktionaler Oberflächen, wt Werkstatttechnik online Jahrgang , Heft 6, 2008.

[2] Denkena, B.; Reichstein, M.; Kästner, J.: Micro Structuring of Functional Surfaces via Cutting Processes, 7th euspen conference in Bremen, 2007, S. 123-126.

[3] Bretschneider, M., Püschmann, D.; Fahlbusch, T, Reithmeier, E.: Chromatische Punktsensoren in der Kontur- und Oberflächenmesstechnik, Tagung der Deutschen Gesellschaft für angewandte Optik, Esslingen am Neckar, 2008.

[4] Vincent, L.; Soille, P.: Watersheds in digital spaces: an efficient algorithm based on immersion simulations, IEEE Transactions on Pattern Analysis and Machine Intelligence 13, Nr. 6, S. 583–598, 1991.