Characterisation of Microstructures

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Abstract
The project "structure oriented surface characterisation based on optical measurement techniques" is a subproject of the DFG research group 576 "microstructuring of thermomechanically high stressed surfaces". The aim of the research group is to improve tribologic properties of surfaces that are used in cylinders of piston engines. Several methods of simulation, production and analysing the microstructures are developed. This subproject deals with the measurement and characterisation of microstructures.

Keywords:
Optical roughness measurement, chromatic sensor, segmentation, characterisation

1 INTRODUCTION

The subproject "structure oriented surface characterisation based on optical measurement techniques" uses two different methods to measure and characterise two kinds of microstructures produced by two other subprojects: deterministic and stochastic microstructures. The purpose is to find correlations between characteristics of the microstructures and their tribologic performance.

1.1 Measurement of stochastic microstructures

Microstructures that have a stochastic shape and allocation on the surface are produced by the Institute of Materials Science (IW) of the Leibniz Universität Hannover. The used process is thermal spraying with different production parameters. The pores that are generated have small lateral and vertical dimensions of few micrometers. Thus, a normal white light interferometer can be used to measure the surface that contains enough structures that are later analyzed.

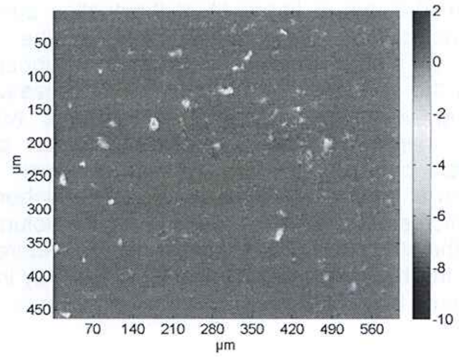

Figure 1 Stochastic microstructures, © IMR

1.2 Measurement of lateral large scale deterministic microstructures

Deterministic microstructures are produced by the Institute of Production Engineering and Machine Tools (IFW) of the Leibniz Universität Hannover. A variable cutting process is used to produce the structures. Depending on the production parameters structures with a different shape and depth are produced. During the process material is transformed into flash at the edge of the cutting edge.

Due to the fact that the lateral dimensions of each microstructure can be greater than 1 mm and there are several microstructures placed side by side, normal areal roughness measurement devices cannot be used since the possible measured area contains only very few squaremillimeters.

Because of this reason a punctual chromatic roughness sensor has been integrated into a coordinate-measuring machine. This coordinates-measuring machine positions the sensor and so measure surfaces up to several square centimetres [1].

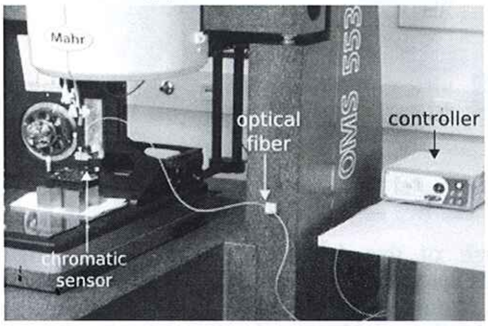

Figure 2: Coordinate-measuring machine with the integrated chromatic sensor, © IMR

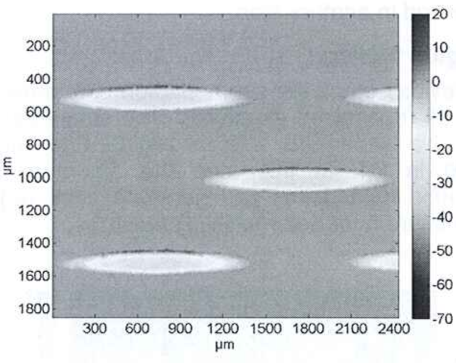

Figure 3: Deterministic microstructures, © IMR

2 SEGMENTATION OF STRUCTURES

The measured data has to be processed in order to identify and characterize each microstructure. Therefore two segmentation processes are used.

2.1 Segmentation of stochastic microstructures

The stochastic microstructures are segmented by the watershed transformation [3]. This segmentation method floods the measured data with virtual water and rises the level of this virtual water sequentially. Thus, the structures with the largest depth are filled with this virtual water firstly and 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 are watersheds are constructed on the edge of the microstructures that keep the water in the structures and avoid the flooding of the whole surface.

2.2 Segmentation of deterministic microstructures

The topography of the deterministic microstructure not only consists of the microstructures but also of the unwanted flashes nearby the structures (see figure 4). This topography cannot be segmented by the watershed transformation as described in the above paragraph. The part between flashes would be segmented and generate additional but false regions or larger regions above existing microstructures as shown in figure 4.

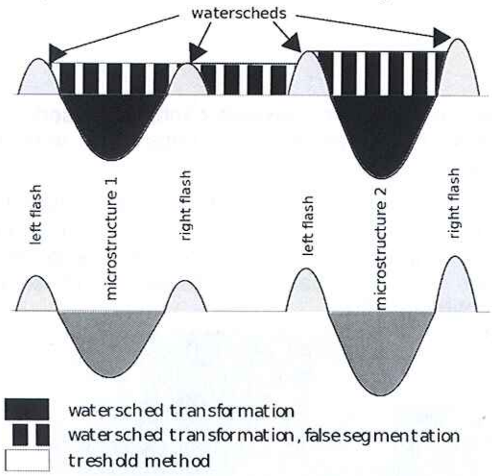

Figure 4: Lateral cut of deterministic microstructures and two segmentation methods, © IMR

Because of this false segmentation a segmentation process based on the threshold method is used: Data, which is less than an empiric value, is assigned to microstructures. Measured data that is greater than another empiric value is assigned to the flashes. The flashes are related to its microstructures in dependence to the distance to microstructures and are also characterized in another step.

2.3 Region finding

In the previous steps the segmentation only provided an entity of all recognized structures. The single structures have to be separated with a region find algorithm described in [3]. In this step the algorithm search neighbouring data points and generate each region as shown in figure 5 for deterministic structures.

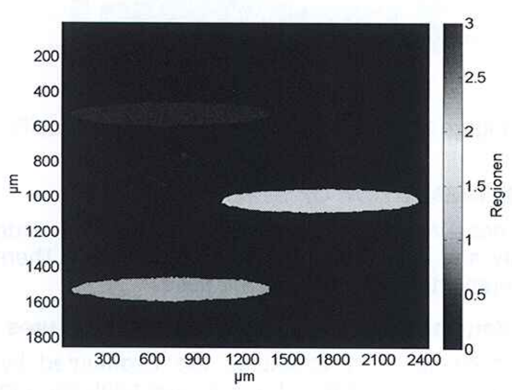

Figure 5: Segmented microstructures, © IMR

3 CHARACTERISATION OF STRUCTURES

Several characteristics have been developed to describe each structure, for example:

- depth
- length
- width
- volume
- area
- area in length and cross direction
- percentage contact area

These characteristics are being calculated from the measurement data of each segmented region.

The one-dimensional characteristics like depth are calculated by using the minimum value of the values of each recognized region. If there is wrong measurement information within this minimum value the characteristic is notable influenced by this false information. Because of this, a histogram based characteristic is also calculated.

4 TRIBILOGICAL EXPERIMENTS

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

In one of theses experiments microstructures of the same shape with a different depth have been tested. In figure 6 is the developing of the friction coefficient at one load of p = 1.25 MPa 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 developing of the graph is the developing of the Stribeck curve [2]: At very low speeds there is boundary lubrication with a decreasing developing of the friction coefficient. In a minimum (0.2 m/s in figure 6) of the friction coefficient mixed lubrication takes places between the friction partners. On higher velocities hydrodynamic lubrication is between the surfaces and the coefficient increases with increasing velocity. Comparing the graphs with the different depth of the microstructures a positive correlation between the depth and a lower friction coefficient at higher velocity is evident. The higher depth of the microstructures also cause 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.

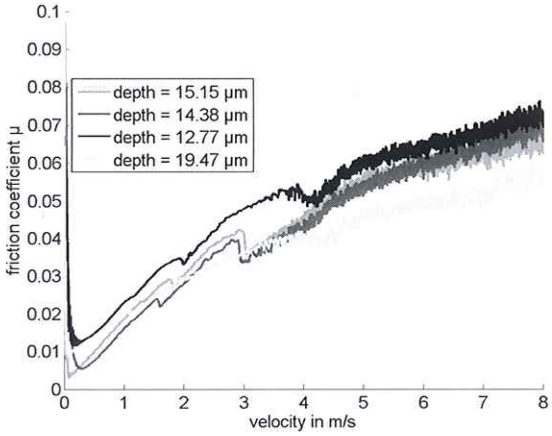

Figure 6: Friction coefficient of deterministic microstructures with different depth, © IMR

5 SUMMARY

Two different methods have been shown to measure and segment the different kinds of microstructures: The watershed transformation is used for stochastic microstructures and the threshold segmentation for deterministic structures. Several characteristics are computed from the measurement and compared with tribologic experiments that show a positive effect of the characteristics.

6 ACKNOWLEDGMENT

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