Automated Measurement Data Analysis for Micro Structured Surfaces

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Abstract

Microstructures applied to the surface of a friction bearing are able to improve the behavior of the part. Due to the challenges regarding the production processes of microstructured surfaces an automated and user-independent in-line quality assurance can make a contribution to improve the production processes significantly. Therefore a three stage measurment filter was developed in order to automatically detect microstructures on the surface even under the restriction of a bad signal-noise ratio.

1 Introduction

Microtechnology nowadays can be found in many industrial applications as well as in consumer products, whether as microparts or microstructured workpieces. Though there are many challenges regarding the production processes of microstructured surfaces, an automated and user-independent in-line quality assurance can make a contribution to improve the production processes until they reach a stable and repeatable level.

2 Automated Quality Assurance of Microstructured Workpieces

The main difficulty in obtaining a complete user-independent in-line quality assurance is frequently a low signal-to-noise ratio when it comes to the detection of microstructures on a preliminary grinded technical surface.

2.1 Signal-to Noise Ratio

In general, the signal-to-noise ratio (SNR) ist defined as the quotient of the signal amplitude A and the noise standard deviation σ. In the case of an automated analysis of a three-dimensional microstructured surface measurement, the SNR can be defined in the following two ways (Figure 1):

$SNR_{\mu} = z_{st}/R_{max}$ or $SNR_{\mu} = z_{st}/R_{z}$

with z_{st} = depth of the produced microstructure, R_{max} = maximum surface roughness and R_z = average surface roughness.

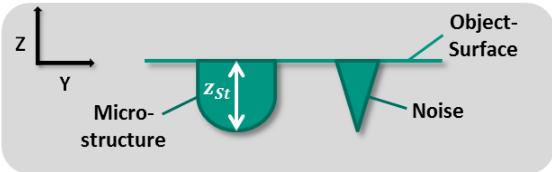

Figure 1: The values for calculating the SNR (noise is given e.g. by a grinding grove).

If the SNR ≤ 1, the applied microstructure cannot be detected by a simple filtering of the measurement point values in z-direction caused by noise on the surface (other structures with the same depth as the microstructure).

2.2. Example of Microstructures

With the aim to reduce friction losses in automotive applications, small microstructures are applied onto the surface of friction bearings to increase fuel economy by max. 12 % [1]. Depending on the operation itself, the tribologically affected surface area can vary. This means that the dimensions of the microstructure have to be scaled down when the affected surface gets smaller. When regarding the laserablation as the most flexible process to produce microstructures it can be seen that the scalability of focus diameter is limited.. When using a laser system with a wavelength of 1064 nm (Nd:YAG), the smallest structure size is up to ten times bigger than the dimensions applied with comparable system parameters and a wavelenth of 355 nm. A structure size in this area of limitation (~3 µm) is almost drowned among the original roughness (noise).

2.3 Reduction of Noise by a Three-Stage Measurement Filter

For the automated recognition of microstructures by confocal measurement and a following calculation of surface characterizing values, the reduction of noise caused by e.g. grinding groves on the surface is necessary. Therefore a three-stage methodology for measurement analysis of a microstructured surface with a low signal-to-noise ratio was developed.

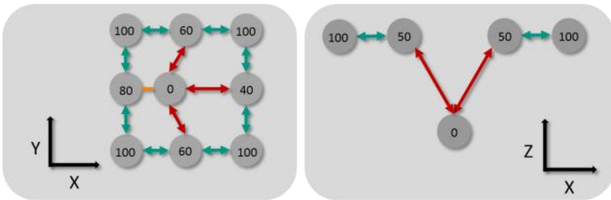

Figure 2: Principle of the single-point analysis in the x-y- and the x-z-plane (referred to [2]).

The first stage consists of a single-point analysis: the regular shaped measurement point-cloud is processed to a quality rating for all measurement points from zero to 100 by observing the three dimensional distances between each point and its direct neighbors (Figure 2). Within this stage, the regions of interest (ROI), i.e. the areas with a remarkable offset in z-direction, are marked by the algorithm by plotting the quality rating to a corresponding color scale [3]. This is an essential step in order to generate a two-dimensional digital picture, which can be processed subsequently, out of a xyz-data table.

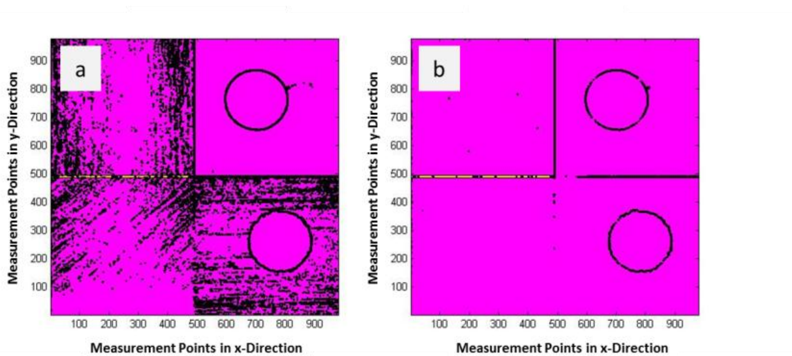

Figure 3: Results of the Sobel edge-detection algorithm. The grinding groves in horizontal, vertical and diagonal directions (a) are filtered out and the microstructure can still be detected (b).

The second stage of the methodology consists of the Sobel edge-detection algorithm. Beside the edge detection, the adjustability of the Sobel algorithm is used as a filter function in z-direction where flat grinding grooves are eliminated (Figure 3).
The remaining noise in the processed measurement data after the first two stages are grinding groves or other surface artifacts with the same depth as the applied microstructure, which cannot be removed by a single filtering in z-direction. This directly leads to the requirement of a third stage: the two or three dimensional object recognition. Based on the results of the object recognition, the surface values for the characterization of the microstructured surfaces can be automatically evaluated.

3 Summary

With the approach presented, the surface structure of microstructured workpieces can be analyzed automatically even under the restriction of a bad signal-noise ratio. The developed three-stage methodology consists of the single-point analysis, the sobel algorithm and a three dimensional object recognition.

4 Acknowledgements

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