Analysis of residual errors during computer controlled polishing

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Abstract. In computer controlled subapertur polishing the formation of mid spatial frequency errors (MSFE) needs special attention. In this work the formation of MSFE in feed direction is investigated using the ADAPT tool from Satisloh.

1 Introduction

In previous projects computer controlled polishing (CCP) was found to be a suitable method for correcting form errors in precision optics. However, CCP methods tend to produce mid spatial frequency errors (MSFE) on the surface, which is especially critical when the polished optics are used for high power laser applications [1, 2]. Using the ADAPT tool from Satisloh the formation of MSFE in feed direction is in depth investigated by polishing a complete surface. This also extends the work from [3] where the shape of the removal function is analyzed using one path.

2 Experiment setup

The ADAPT tool consists of two parts: A polyurethane (PU) polishing foil and a PU pin. The pin is brought to a specific radius and the polishing foil is bent over this pin. The tool is then dressed in a MCP 250 machine from OptoTech.

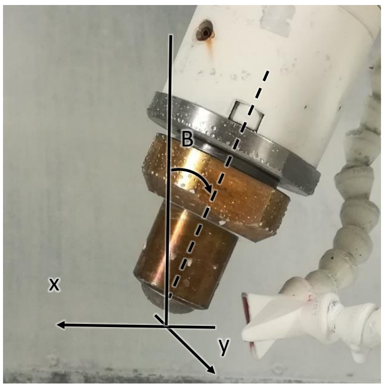

Figure 1. The Satisloh ADAPT tool as mounted in the OptoTech MCP 250 [4]

As seen in Figure 1 the tool rotates around its axis of symmetry and is tilted by the angle of precession B. The tilted tool is then moved across the workpiece in a meander pattern. The meander pattern consists of a reciprocating movement in x direction and a path distance between each path in y direction.
The resulting surface is afterwards interferometrically measured using a VeriFire XP/D by Zygo and the Zygo MetroPro 8.3.4 software for evaluation. To get the resulting spatial frequencies, four randomly positioned profiles are placed on the measured surface in feed direction using MetroPro. From these profiles the amplitude of the main frequency is noted and the mean is calculated.

3 Experiment results

The experiment shows, there is a correlation between the resulting spatial frequency error f in feed direction and the ratio between the feed speed v_F and the rotational frequency n as shown in Equation 1.

$$f = \frac{n}{v_F} \tag{1}$$

Concluding from these results, the irregularities of the polishing tool depict on the surface after each rotation. By varying the parameters path distance, compression and precession angle the amplitude of the resulting main frequency can be lowered or raised. Whereas by adjusting the ratio from Equation 1 above a certain threshold the amplitude of the resulting frequency falls to an almost non measurable value. With the used parameters this threshold ranges at about five tool rotations per 1 mm feed length. This coherence is surveyed in [4] and this coherence can also be seen in grinding as described in [5].

4 Simulation

In order to recreate the observed pattern a simulation is carried out using Python. The simulation is based on the assumption that the MSFE results from irregularities on the surface of the polishing foil which imprints on the substrate surface when spiraling across the surface with the feed and rotational frequency of the tool. Hence these

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irregularities are approximated as a virtual TIF spiraling across the surface as seen in Figure 2.

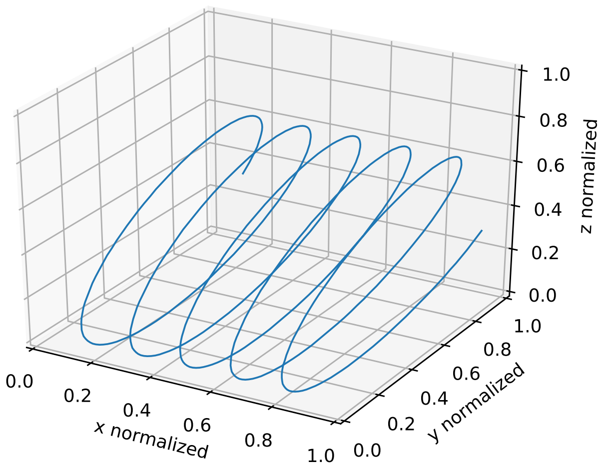

Figure 2. Normalized depiction of the spiraling movement of the irregularities on the ADAPT tool surface cf.[4]

The resulting tool path for the virtual TIF across the surface is shown in Figure 3. The tool path is generated by shifting the spiral from Figure 2 by the compression of the tool in z direction. The positive part of the spiral is then cut off. The remaining part of the spiral defines the tool path on which the virtual TIF removes material from the substrate in one path. In the respective path distance in y direction further paths are lain. These paths are also shifted by a small arbitrary offset dx in x direction. This arbitrary offset ensures that the spiral sections do not completely align. Thus the reality is emulated where the fast rotation over the slower feed speed randomizes the position of the respective irregularities on the tool surface.

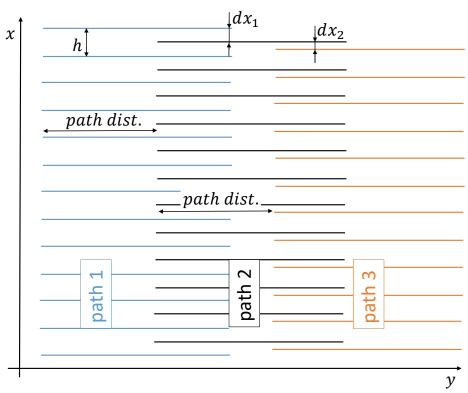

Figure 3. Normalized depiction of the spiraling movement of the irregularities on the ADAPT tool surface

The removal in CCP can be calculated as the convolution of a TIF with a dwell time and since the dwell time remains constant the tool path can be used. Hence the virtual TIF is convoluted with the beforehand generated tool path. The result is shown in Figure 4. This so simulated removal can be imported in MetroPro to measure the amplitude of the resulting main frequency in the same way as it was done for the experiments.

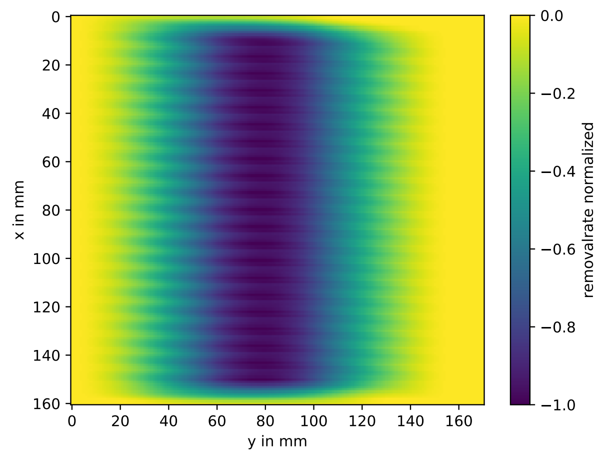

Figure 4. Simulated removal generated by the virtual TIF on the calculated tool path

5 Simulation results

By varying the virtual TIF the results from the experiment can be approximated hence the effect from Equation 1 may be predictable. Also the threshold as seen in the experiment can be replicated. This threshold may result from the formation of a plateau when the rotations per mm reach a certain value. The arbitrary offset in x direction also has an impact on the amplitude of the resulting spatial frequency.

References

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