Investigation of elastic grinding pins

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In order to develop a grinding tool for shape adaptive grinding, elastic grinding pins are used as an example to investigate the behaviour of those tools. In the following, we describe the results for test tubes machined with elastic grinding pins. Therefore, the surface profile of the test tubes is analysed for different parameter sets. The varied parameters are the size of the grinding particles and the stiffness of the base material.

The interdependencies between the parameters are as expected: larger particles and stiffer material lead to a rougher surface. This is the case for both acrylic glass and steel tubes. However, irregularities in the uniformity of the specimens surface indicate that the manufacturing process has still to be improved at different points.

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Proceedings in Applied Mathematics & Mechanics published by Wiley-VCH Verlag GmbH & Co. KGaA Weinheim

1 Introduction

Recently a new machining process with an elastic tool is developed to overcome the problems of finishing complex surfaces [1]. As a feasibility study, we aim to microstructure tubes with elastic grinding pins. These pins consist of a shaft and a head of silicon with silicon carbide (SiC) particles mounted on its surface (Figure 1).

The grinding result is influenced by different parameters. In this feasibility study we vary the grinding particle size, the tube material and the stiffness of the base material. It is expected that the larger the particles are and the stiffer the base material is the rougher the surface will get. A softer tube material also leads to a rougher surface.

In the first step, two different SiC-particle sizes F60 (260 µm) and F180 (69 µm) [2] are fixed at silicon grinding pins of three stiffnesses (ADDV-10, ADDV-25, ADDV-42, where the number indicates the Shore hardness) and tested on acrylic glass tubes. After comparing the results, the interdependencies are verified on steel tubes.

2 Desired surface and roughness indicators

The desired surface of the test tubes is a smooth surface with a pattern of deeper grooves in axial direction like shown in Figure 2. This is forced by the idea of reducing friction by lubrication pockets. Those pockets are common, for example at pistons of combustion engines or journal bearings [3, 4]. In the following the surface of the specimen is described by the characteristic values Rz (DIN EN ISO 4287), Rk and Rvk (DIN EN ISO 13565-2).

Rz is a measure for the mean roughness depth. A determined path gets divided into five sections. Rz is defined as the average value between the highest peak and lowest valley of each of these sections. According to the recommendation of the standard, the length of each path is equal to the cut-off wavelength of the filter used to suppress the waviness. As the tube profile is larger than the determined paths, we determine several Rz values, which indicate the uniformity of the surface.

Rk and Rvk are determined by the Abbott curve, which shows the material share per height. Rk is an indicator for the core roughness, whereas Rvk is an indicator for the valleys depth. At the example of the desired surface, we aim for deep valleys (high Rvk) combined with a low core roughness (low Rk).

3 Experimental setup and results

As this is a feasibility study, the investigated grinding pins are handmade. This leads to inaccuracies one has to be aware of when interpreting the results. To reduce the influence of these inaccuracies, nine grinding pins of every parameter set were manufactured.

The test bench consists of a jigsaw and a jaw chuck. The tubes are fixed in the jaw chuck, whereas the grinding pins are moved by the jigsaw. The motion follows the axial direction of the tubes.

The surface of the tubes is measured with a Hommel-Etamic Nanoscan 855, which has a resolution of 0.6 nm. To suppress the waviness the profile is filtered according to the standard DIN EN ISO 3724:1998.

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Figure 3 shows one exemplary surface profile of an acrylic glass tube for grinding pins of each stiffness and SiC particles F60. The surfaces have a very uniform profile with some variations due to inaccuracies of the grinding pins. This is the case for most of the specimen.

In general, the amount of removed material increases with the stiffness of the silicon. With the exception of silicon ADDV-42, $R_{vk}$ increases significantly with the stiffness of the silicon, while $R_k$ remains almost the same. This is the desired behaviour. A comparison of ADDV-25 and ADDV-42 shows that $R_k$ and $R_{vk}$ increase equally. This is a sign that ADDV-42 is to stiff in combination with F60 particles, which leads to an extremely rough surface instead of a patterned profile.

Additional tests with steel tubes lead to the same results as described. Due to the harder material, the difference between the silicon types is not as significant as with acrylic glass tubes.

The results for F180 particles (Figure 4) are not as clear as those for F60 particles. Although the surface of the shown examples is very uniform, it is not for most of the tubes. In addition, there is a high spread between the roughness measures. Those grinding pins with silicon ADDV-42 removed less material than expected, which is caused by too less oversize of the pins. However, a dependency between silicon stiffness and material removal is still visible. Due to the small effect on the surface, tests with steel tubes were not performed.

## 4 Conclusion

We aimed to show that the grinding particle size, the tube material and the stiffness of the base material have a significant influence on the surface of test tubes machined with elastic grinding pins. The impact of the parameters is as expected if they match to the tube material.

For example, grinding acrylic glass tubes with larger particles leads to good results with ADDV-10 and ADDV-25, while ADDV-42 is already too stiff. For smaller particles, ADDV-10 and ADDV-25 are not stiff enough to lead to a significant influence of the silicon type. However, in any case an increase in $R_{vk}$ is possible and a patterned surface is achieved.

By improving the manufacturing processes for future investigations in terms of a consistent oversize and the mounting of the particles a positive impact on the uniformity of the tube surfaces and a reduced spread of the results is expected.

### Acknowledgements

This research was supported by the measuring system Nanoscan 855 of the company Jenoptik.

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