Laser triangulation in harsh industrial conditions

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Laser triangulation is a well-established technique for three-dimensional measurement of surface topographies. Impurities such as cooling agents or dust from abrasive machining during component manufacturing can easily manipulate the measurement result. In this article, a measurement system is introduced which can be used in harsh operating conditions.

1 Introduction

High precision manufacturing, e.g. milling and grinding, which have manufacturing tolerances in the range of <10 µm require microscopic measurement techniques for the inspection of the manufactured components. These measurement techniques are very sensitive to cooling liquids and lubricants which are essential for many manufacturing processes. Therefore, the measurement of the components is usually conducted in separate and clean laboratories and not directly in the manufacturing machine. This approach has some major drawbacks, e.g. high time consumption and no possibility for online process monitoring. In this article, a novel concept for the integration of high precision optical topography measurement systems into the manufacturing machine is introduced and compared to other concepts. Detailed information about measurement system integration concepts for manufacturing machines can be found in [1].

2 Microscopic inspection in manufacturing machines

Many manufacturing processes, e.g. milling and grinding, require the use of cooling liquids and lubricants, microscopic topography measurement can usually not be performed inside the manufacturing machine. Splashing liquids and lubricants can damage or destroy high precision microscopes and even when the microscope is installed in a protective housing, the measurement process is disturbed by cooling liquids and lubricants. Figure 1 shows the comparison of an undisturbed microscopic measurement and Figure 2 shows a measurement when there is a thin oil film between the microscope and the measurement object. The thickness of the oil film is < 100 µm, however, it prevents the microscope from obtaining sharp images of the measurement object. This means that even very thin depositions of cooling liquids and lubricants on the viewing windows of the microscope's protective housing prevent the microscope from measuring the surface topography with accuracy in the micrometer range. Therefore, microscopic inspection is usually performed off-line in a separate and clean laboratory and not inside the manufacturing machine.

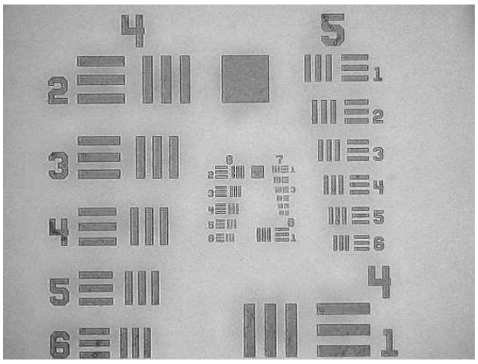

Figure 1: *Measurement of a USAF1951 test target with a microscope. The measurement was conducted in standard operating conditions.*

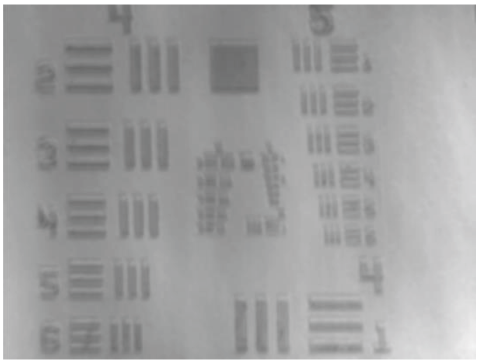

Figure 2: *Measurement of the USAF 1951 test target with a thin oil film between the microscope and test target.*

3 Basic setup of the measurement system

The developed measurement system for the integration into the manufacturing machine uses laser triangulation to measure the micro-topography of components in the manufacturing machine. In the presented application, the measurement object is a grinding wheel. The setup is shown in Figure 3.

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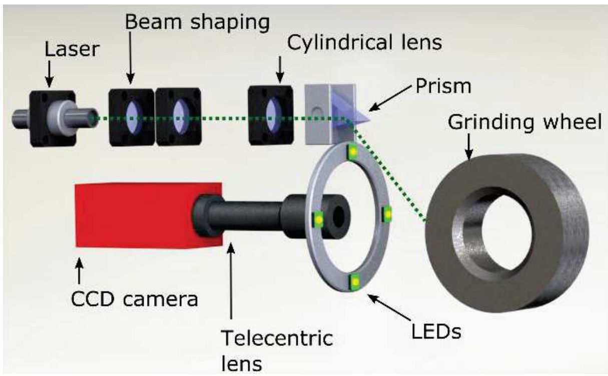

Figure 3: *Basic components of the measurement system.*

The measurement system includes a laser whose output light is focused on the surface of the grinding wheel by beam shaping optics. By the use of a cylindrical lens, the measurement object is illuminated with a laser line and not only with a laser spot. The laser line on the component's surface is imaged by a telecentric lens with an adaptable magnification in the range of 2x to 10x. Therefore, the surface topography can be calculated form the laser line position in the camera image. Detailed information on laser triangulation can be found in [1], [2], [3] and [4].

4 Integration into the manufacturing machine

For the integration of the basic measurement setup, which is shown in Figure 3, into the manufacturing machine, the setup needs to be in a protective housing. Viewing windows in the house are required for the camera and the laser line generator. During the manufacturing process, the cooling liquid will cover the viewing windows and the measurement object, which leads to disturbed measurements (see Figure 2). In order to avoid the optical aberrations which are induced by the liquid films on the viewing windows and the measurement object, different strategies were examined and introduced in [1]. In summary, the following concepts were evaluated:

- Concept A: Permanent removal of the cooling liquids, lubricants or other pollutants from the viewing window and from the measurement object using high pressured air.
- Concept B: Similar to concept A, but no removal of liquids from the viewing window of the camera. Therefore, the setup is compacter and uses less compressed air. The effects of the liquids on the camera images are reduced using blind deconvolution image processing algorithms.
- Concept C: No removal of the cooling liquid. For the execution of a measurement, the measurement object is immersed in a liquid reservoir which is mounted on the viewing window of the camera and laser line projector.

In the conducted experiments, concept C had the highest reliability for performing measurements in the manufacturing machine. Due to the permanent coverage of the viewing windows and the measurement object by the cooling liquid, the measurement conditions remain constant at all times. Since the calibration of the measurement system can be performed with covered windows and calibration target, it is possible to use concept C for the measurement of the micro-topography of the grinding wheel. Since concept C had the highest reliability and also the concept does not require compressed air supply, we chose concept C for the integration of the measurement system into the manufacturing machine. The principle of concept C is shown in Figure 4.

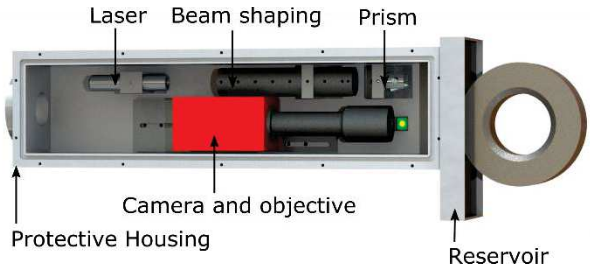

Figure 4: *Assembly of concept C. For better visualization in the figure, the measurement system is rotated 90° compared to the installation position in the manufacturing machine.*

5 Outlook

In this article, we introduced an integration concept for microscopic inspection in harsh operating conditions. During the measurement, the grinding wheel is immersed into a cooling liquid reservoir. This concept can also be applied for different manufacturing objects and processes such as milling or turning.

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References

[1] T. Mueller, A. Poesch and E. Reithmeier: *"Topography Measurement for Monitoring Manufacturing Processes in Harsh Conditions"* in Engineering, **8**, 292-300 (2016)

[2] Z. Ji and M.C. Leu: "*Design of optical triangulation devices"*, Opt. Laser Technol., **21**(5), 339-341 (1989)

[3] A. Donges and R. Noll: *"Laser Measurement Technology: Fundamentals and Applications, Springer"*, Heidelberg (2015)

[4] R. G. Dorsch, G. Häusler and J. M. Herrmann *"Laser triangulation: fundamental uncertainty in distance measurement"*, Applied Optics, **33**(7), 1306-1314, (1994)