

Robot assisted steel polishing and surface characterisation

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Abstract

Steel moulds for polymer optics are normally produced in several process steps; the last step before moulding is manual polishing. This step requires skilled experts and is very time-consuming. The focus of this paper is on robot polishing of steel moulds for polymer injection moulding of optics. The goal of this work is to replace manual polishing and other process steps with robot polishing. Therefore a new process has been developed to minimize the number of required process steps.

This project was started by Aalen University and UVEX Safety Group together with the Experimental Ophthalmology Group Homburg/Saar.

1 Introduction

Manual polishing is a common used process for mould manufacturing. Depending on the field of application of the polymer parts the demands on the mould vary strongly. One field of application is polymer optics. There are several applications with polymer optics from low level, cheap polymer optics in mass-produced goods up to high precision polymer optics in much specialised applications. The latter have very high demands on the steel mould concerning both shape accuracy and roughness. Usually the moulds are supposed to have no visible defects like scratches, holes or colour changes on the surface. It is not really known which size defects are reproduced on the polymer surface [1].

To achieve the demanded results on the steel mould, not only the manufacturing processes but also the measurement technology is of essential importance. Different measurement equipment was used to test the polished surfaces concerning shape accuracy and micro roughness.

To use an automated process it is however very important to have fixed parameters to qualify the surface and the shape. The measurement machines use different

parameters for roughness values like Ra, Sa or rms values and for shape accuracy they plot the results in μm or something comparable. But it is important to make this knowledge also available to the customers, because they have to generate the specifications for the polished part.

2 Process development

The goal for the new process chain is, to minimize the number of necessary process steps. Moreover the new process chain should be feasible for small and medium enterprises. Therefore it is necessary to achieve good results on the moulds with stable and easy to handle processes.

Expensive, difficult and hard to handle processes like diamond turning, nickel plating and manual polishing are superseded with robot polishing. The new fully automated robot polishing process was recently developed [2].

Different kinds of diamond powders have been tested with different polishing tools on plane samples of hardened steel; the steel samples have been hardened to approx. 59 HRC to be comparable to the materials of real moulds. Different polishing agents proved insufficient for working on hardened steel samples. But different grain sizes of synthetic diamond powder lead to good results.

There are several robot steps necessary when starting with ground samples and various tool materials lead to the requested surface qualities. Figure 1 shows an industrial robot that moves the ZOT polishing head on the surface.

First robot steps were used to remove a lot of material in a short time. Grinding marks can be removed very well with hard tool materials and rough grain sizes. This was followed by choosing a softer tool material and smaller polishing grain sizes.

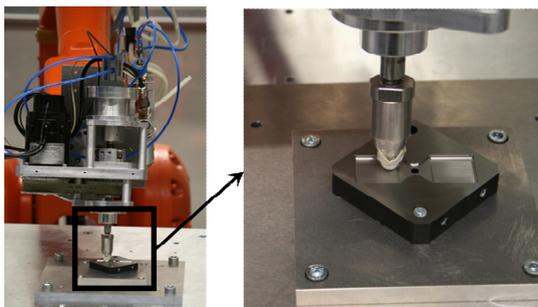


Figure 1 left: industrial robot with polishing head, right: tool with soft cloth

3 Metrology

To develop this new process two commercial measurement machines have been used; a white light interferometer for roughness measurements of the surface with different magnifications and a tactile measurement machine for measurements of the shape accuracy. The following Figure 2 shows the progress in micro roughness after several robot lapping and polishing steps. These results were measured on a commercial white light interferometer at Aalen University.

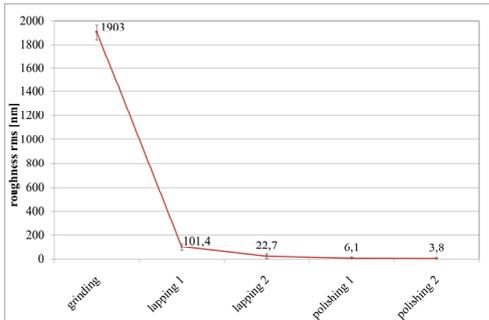


Figure 2: Surface roughness after different process steps

In addition to these commercial measurement machines new interferometer setups were developed in Halmstad, in order to achieve comparable measurement results in a shorter time with more robust equipment. Detailed information will be published in [3].

Figure 3 shows the results of a measurement with the newly developed white light interferometer on a polished surface. The field of view is approx. $763 \times 911 \mu\text{m}$. This measurement equipment is far more robust than commercial interferometers. So one can imagine the possibility to attach the interferometer to the polishing head of the robot.

A robust measurement system can be used in the manufacturing process, to help position the sample more exactly, for example to enable possibilities, such as direct defect correction. The position of the work piece is really important both in manufacturing and in measurement processes. If some areas on the surface have to be reworked it is necessary to know where the relevant areas are situated.

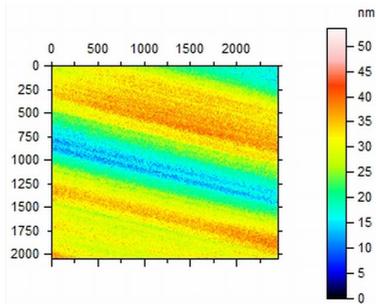


Figure 3: White light interferometer measurement results (roughness Sa 5.87 nm)

4 Results and Outlook

First tests showed that mould manufacturing with an automated robot process is possible, although there is a lot of work to be done. New tools will be developed for the robot polishing process with different tool materials. However, the first injection moulding tests with robot polished moulds will show if the achieved surface quality is sufficient for injection moulding, especially for polymer optics.

Another important aspect is the creation of something like an internal standard. Therefore several parameters like Ra, Sa or rms can be used to specify the required roughness values and shape accuracy, usually specified in μm .

Future polishing setups for industrial robots will probably contain measurement equipment to enable in situ measurement of surface roughness and shape accuracy.

Acknowledgments

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