Maintenance, repair and overhaul (MRO)-process for galvanic retroreflector moulds

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Abstract
During the injection moulding processes, galvanic retroreflector moulds suffer from considerable wear. To remove defects from the mould's optical surfaces without tedious manual labour, a partially automated process chain is being developed combining surface metrology and machining technology. The work here suggests the use of a vibration polishing process. The challenge hereby is given by the areal limitation of the structured surfaces, therefore conventional rotatory polishing processes cannot be applied: Instead, vibration polishing is applied to remove critical surface errors and to enhance surface roughness to a value of Sa ≤ 50 nm.

1. Introduction

For the manufacturing of transmissive and reflective plastic parts, which are used for lighting and safety purposes in the automotive industry, sophisticated, structured injection mould inserts are needed [1, 2]. The mould consists of several millimeter-sized hexagonal pins, each of which exhibits three orthogonal facet surfaces, as shown in Figure 1.

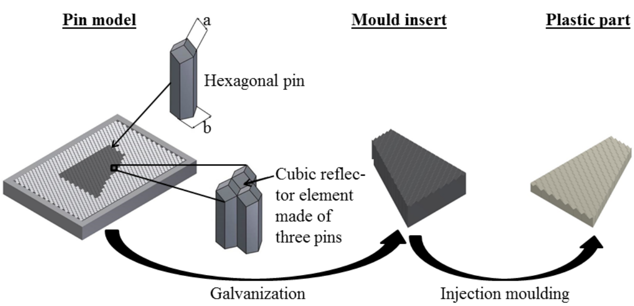


Figure 1: Process chain technology and hexagonal pin geometry (NiCo mould material)

Each arrangement of three pins provides a single cubic reflector element, whereas “a” is the characteristic length (here a = 1.27 mm) and “b” is the pin diameter (here b = 2.38 mm). The resulting galvanic replica of the mould insert, which is later on used in the injection moulding process, can only be used for a limited number of cycles due to surface wear. Metrological assessment of the surface as well as the possibility to examine important features like uniform appearance, functionality, angle accuracy and contour accuracy are crucial to estimate and finally guarantee the required quality. Up to now galvanic moulds are visually inspected and manually polished by qualified personnel, which is a highly undeterministic and tedious process always depending on the qualification and experience of the personnel. The collective work aims to connect metrology and machining technology to develop a partially automated process chain using a 6-axis robot for vibration polishing. Within this paper, the machining technology part, meaning the polishing process including the developed tool design, is presented.

2. Tool development and kinematic

The small sized structures of the galvanic moulds require a specially adapted tool geometry. Due to the areal limitation of the structured surfaces, conventional rotatory polishing processes cannot be applied. Therefore vibration polishing is applied instead to remove critical surface errors [2, 3]. To prevent collision of the tool head with the optical surfaces, only one of the three retroreflector surfaces is polished at a time and the tool edges are chamfered. Figure 2 shows the final vibration tool geometry. As edge rounding could be a serious issue, the tool is oscillating uniaxially and the width “w” is kept the same as the length “a” of the edge of one retroreflector surface.

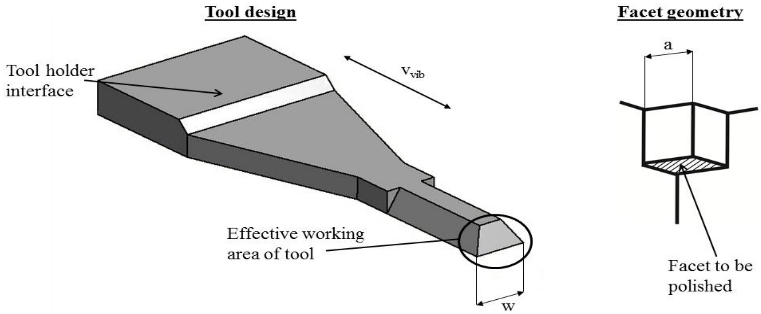
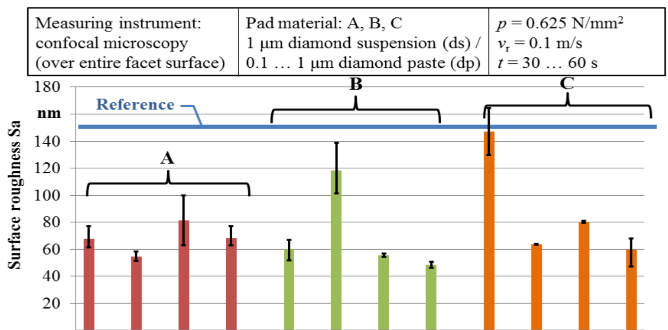


Figure 2: Tool concept and geometry

The tool itself is clamped into a voice coil actuator, with an adjustable vibration frequency (range: 0…250 Hz). Preliminary experiments showed, that reasonable results regarding material removal rate and surface roughness were achieved at a frequency of f = 133 Hz, which was kept constant for the following investigations.

3. Vibration polishing: results and discussion

Based on previous investigations, different polishing pad materials were used (cloths and foams) as well as different polishing media (diamond suspension (ds) and diamond paste (dp)). Figure 3 gives an overview for the parameters applied.



polishing media	dp	dp	ds	ds	dp	dp	ds	ds	dp	dp	ds	ds
particle size [µm]	0.1	0.1	1	1	0.1	1	1	1	0.1	0.1	1	1
time [s]	30	60	30	60	30	30	30	60	30	60	30	60

Figure 3: Surface roughness Sa achieved by vibration polishing

The main criterion for the evaluation of the polishing process was the surface roughness Sa. The roughness of the unpolished surfaces averaged at Sa = 150 nm and is given as reference in Figure 3. It was possible to reduce surface roughness by a factor of three to a minimum of Sa = 48 nm. This is a sufficient quality for the intended application, as a uniform appearance of the mould, which can be achieved by the developed process, is more important than a high quality optical surface. A better surface finish can be achieved by using diamond suspension instead of diamond paste. Also a longer polishing time yields a lower surface roughness. Considering the particle size, there is no coherent trend for polishing with the diamond paste. The most suitable polishing medium carrier is type B, which is a short-pile polishing cloth. Investigation of the polished surfaces showed regular polishing marks when using a diamond paste, which is an indicator of two-body-abrasion [1]. The use of suspension instead showed short micro indentions typically achieved by three-body-abrasion. In addition to polishing marks, an irregular material removal could be detected on some facet surfaces, see Figure 4.

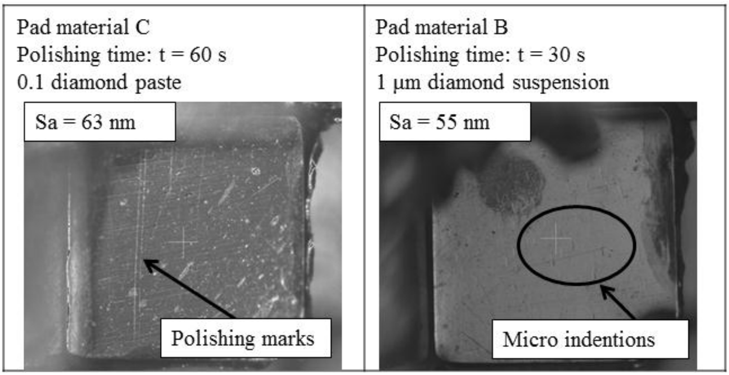


Figure 4: Polishing marks (left) and micro indentions (right) on the facet surfaces as prove for abrasion-mechanisms

4. Summary and conclusion

A tool design for the polishing of millimeter-sized retroreflector facets was developed and proven suitable for galvanized NiCo alloy facets. For this purpose, different parameters as well as polishing media and pad materials were taken into account. The operability of the chosen design and process was verified by a reduction of the surface roughness from Sa = 150 nm down to Sa ≈ 50 nm. Recommendations regarding polishing media and medium carriers could be derived. It was found that inherently stable pad materials have a better tendency to contribute to lower surface roughness.

Future investigations will aim to further enhance the surface quality. By using tools made of copper and brass, without any additional pad material, a two-body-abrasion can almost be excluded and a more regular material removal is provided. In combination with a finer grain size of the diamond suspension, a further reduction of surface roughness is expected. It is also considered to superpose a second vibration direction, therefore being able to create an even more nondirectional polishing pattern. A difficulty that would have to be confronted in this case is the increased edge rounding.

Acknowledgement

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References

[1] Evans C J and Bryan J B 1999 *Annals of the CIRP 48* No. 2 pp 541-55

[2] Brinksmeier E, Riemer O and Krause M 2011 *wt Werkstattstechnik online Jahrgang 101* pp 758-64

[3] Brinksmeier E, Riemer O and Gessenharter A 2006 *Journal of the International Societies for Precision Engineering and Nanotechnology 30* pp 325-36