Deflectometry for surface inspection and shape fidelity analysis for manufacturing and polishing of safety spectacle molds

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A non-contact deflectrometric measurement technique for injection molding tools is being proposed. Global shape deviations and local surface quality is derived from target surface comparisons and curvature measurements. Deflectometry is a suitable tool for quality control of safety spectacles before and during the injection process.

Introduction

Work with possible chemical, thermic or mechanical hazards requires protection with safety spectacles [1]. Most of the spectacles are plastic optics, produced by injection molding techniques. Optical testing of the molds is difficult before or during the injection process, despite the high importance of optical quality [2]. Poor optical quality caused by deficient steel molds can only be detected by optical testing of the molded parts. Outworn mold shapes and surfaces are the main reason for poor optical quality and rejection in optical testing. The purpose of this study was to implement 3D phase measuring deflectometry (PMD) for shape fidelity tests of (bi)spherical and full form mold surfaces. The scope of this work is to present the ability of PMD to detect mold defects and mold outwear for personal protective eyewear.

Material and Methods

The setup is based on a phase measuring deflectometer (3D-Shape GmbH, Erlangen, Germany), equipped with 3 cameras. Two cameras (f' = 16 mm) are used for absolute position measurement in space (standardized PMD – Sensor) with a field of view (FoV) of 80 x 80 mm² [2]. The third camera (f' = 8.5 mm) was used for full form molds with a FoV of 150 x 150 mm². Analysis of the objects surface was reviewed by GOM Inspect (GOM mbH, Braunschweig, Germany) and SoftPMD (Max Planck Research Group, OSMIN, Friedrich-Alexander-University of Erlangen-Nuremberg, Germany). The analysis is based on target surface comparison by substraction of a predefined- or best-fit sphere and inspection of the mean radii of curvature. Especially, global shape differences and local surface quality were presented. Eight injection molds of a bispherical safety spectacle were measured. The injection molding tool is separated into concave nozzles sides (1-4 NS) and convex ejector sides (1-4 ES) of two cavities for two polycarbonate shields respectively (Figure 1). We designed a predefined sphere, consisting of a best-fit sphere with target radii constraint to point out global differences from the target shape. Additionally, two spherical full form molds were measured and evaluated by curvature maps. A classical best–fit analysis was used for detection of local deviations for both sides of the cavity.

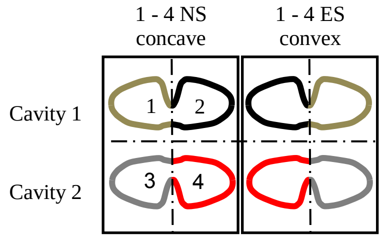


***Fig. 1** Tool layout of the measured bispherical samples. The same-color molds form together a spectacle side.*

Results

The statistical evaluation included deviation from the target shape (distance) by descriptive statistics (range, mean, standard deviation). Characteristic variables for the global and local fits are the integrated values (integrated absolute distance). Figure 2 and 3 show the results of the full form best-fit evaluation.

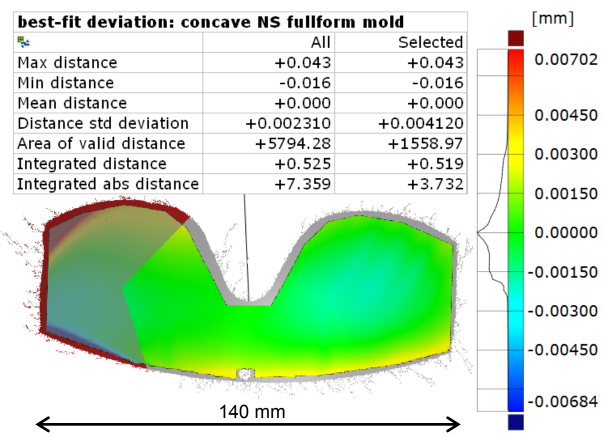
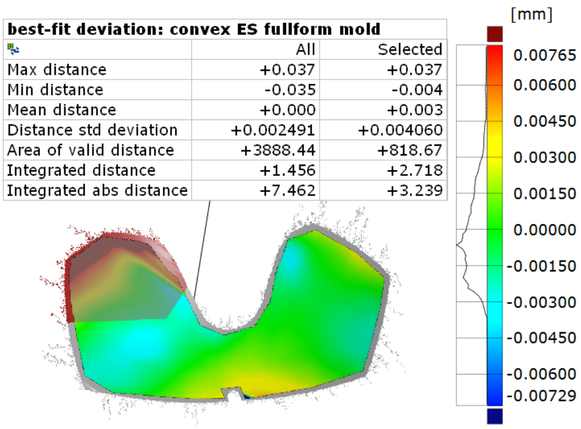


***Fig. 2** Deviation plot of the full form concave NS mold.*



best-fit deviation: convex ES fullform mold	All	Selected
Max distance	+0.037	+0.037
Min distance	-0.035	-0.004
Mean distance	+0.000	+0.003
Distance std deviation	+0.002491	+0.004060
Area of valid distance	+3888.44	+818.67
Integrated distance	+1.456	+2.718
Integrated abs distance	+7.462	+3.239

Fig. 3 *Deviation plot of the full form convex ES mold.*

Both left sides had uniform elevated deviations on the edge, especially the ejector side. The mean curvature map of the NS full form mold illustrates visible elevations caused by expansion of mounting bores of about 200 nm (Figure 4).

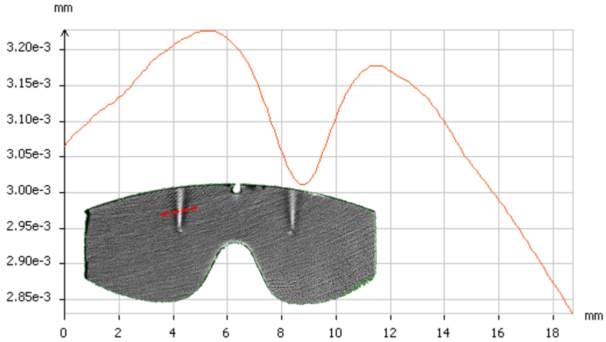


Fig. 4 *Concave full form mold with visible mounting bores directly under the relevant injection molding surface. Mean curvature measurement and cross section through the fixation point: about 200 nm difference.*

Figure 5 and 6 show the extracted distance parameters for shape fidelity analysis of the bispherical mold series. Three nozzles sides had bumps and local surface errors, except 2 NS, due to a higher integrated absolute distance. They were additional tested by best-fits, e.g. Figure 7a. Two of four ejector sides had max/min deviation under 3 µm. For example, the false color plot of 1 ES mold conducts good shape fidelity with insignificant local errors (Figure 7b).

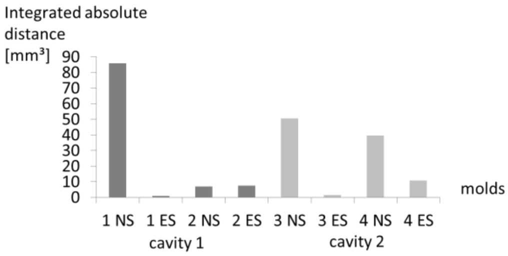


Fig. 5 *Deviations from the target surface of the defined fit analysis - Integrated absolute distance.*

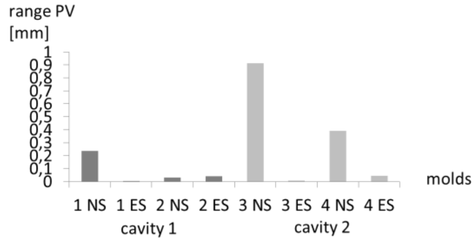


Fig. 6 *Deviations from the target surface of the defined fit analysis – PV range.*

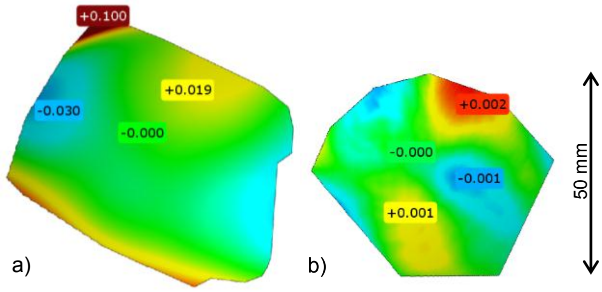


Fig. 7 *False color deviation plots of the bispherical mold series. a) Best - fit difference of the 1 NS mold (concave nozzles side). b) Target difference of the 1 ES mold (convex ejector side).*

Discussion

We applied a deflectometric setup for developing and analysis of injection molding tools for occupational safety eyewear. With this system, we were able to measure deviations of the mold shape and surface from the theoretical design. We measured 8 molds of an injection molding tool for bispherical safety spactacles and additional one cavity of a full form model. Target surface comparisons showed abrasive effects like local bumps, peaks and global shape deviations on outworn molds. In general, wear and tear could be detected and clearly distinguished from intact mold surfaces.

In conclusion, the setup is an appropriate tool for shape fidelity tests of full form and (bi)spherical safety spectacle molds. It allows shape and surface characterization for development and re-engineering of molds.

Acknowledgements

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