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Publication date:
2016

Document Version
Peer reviewed version

Technical University of Denmark
DTU Mechanical Engineering
Department of Mechanical Engineering
Micro/Nano and Precision Manufacturing

Polymer Replication on Nanoscale – 3rd International Conference
19-20 May 2016
FHNW University of Applied Sciences and Arts Northwestern Switzerland

Metrology of sub-micron structured polymer surfaces

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Introduction

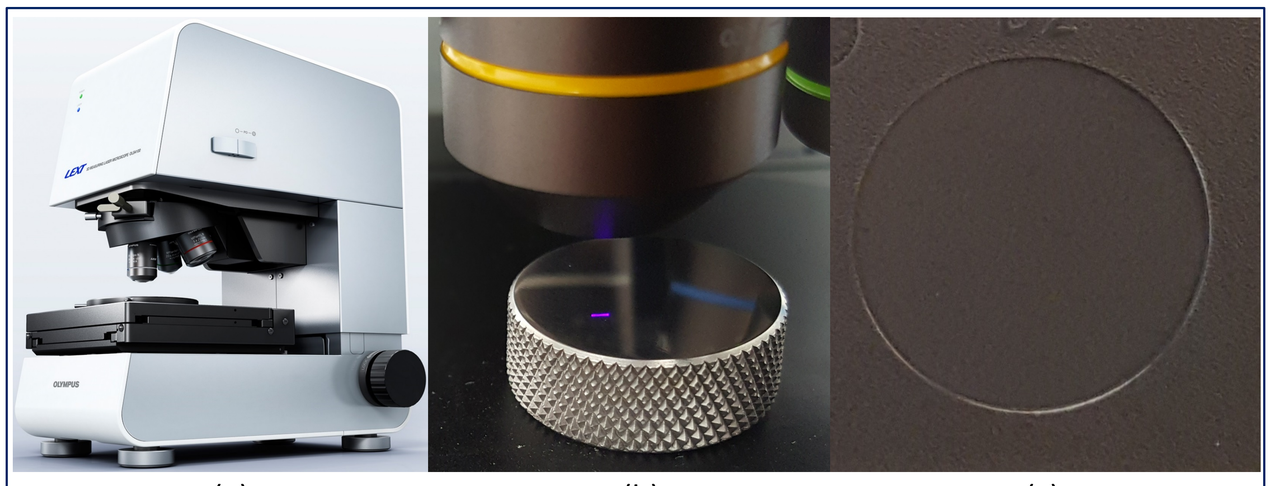
Precision moulding is an essential technology for the miniaturisation of moulded parts and it is continuously needing for specially developed solutions to face new challenges in injection moulding processes.

One of the key challenges in advanced injection moulding technology is the achievement of a full surface replication of the tool insert component when moulding the polymer melt [1]. This aspect is particularly critical when dealing with increasingly small dimensional scales in micro- and nano-structured surfaces [2, 3].

In this context, a metrological investigation (see Fig. 1) of polymer replicated surfaces using metal masters with different types of finish was carried out.

Four types of surface finish were considered (see Fig. 2): a) Diamond buff polishing. b) Grit paper polishing. c) Stone polishing. d) Dry blast polishing.

Both master and replicated surfaces were measured using a laser scanning confocal microscope. Hence, the replication fidelity was evaluated comparing the measurements of the polymer surfaces against the ones of the masters. The amplitude and the slope replications were considered calculating respectively *Sq* and *Sdq* areal surface texture parameters.



(a) (b) (c)

Figure 1. Metrological investigation: (a) Confocal microscope Olympus Lext. (b) Metal master polished by diamond buff. (c) Polymer replica of dry blast polished master.

Uncertainty evaluation

The uncertainty model was inspired to ISO 15530-3:2011 and adapted to optical measurements.

Calibrated standards

- **Calibration certificate** $u_c = \frac{U_c}{k}$
- **Measuring procedure** $u_p = h \cdot \frac{STD}{\sqrt{n}}$
- **Systematic behaviour** (CTE of gauges material) $u_b = (\bar{T} - 20°C) \cdot u_\alpha \cdot \bar{d}$

Specimens

- **Manufacturing process** $u_{wp} = \frac{d_{x,Max} - d_{x,Min}}{2\sqrt{3}}$
- **Specimens material** (CTE of specimens material) $u_{wt} = (\bar{T} - 20°C) \cdot u_\alpha \cdot \bar{d}$

$\sum$ Uncertainty contributions

Expanded Uncertainty

$$U = k \cdot \sqrt{u_c^2 + u_p^2 + u_b^2 + {u_{wp}}^2 + {u_{wt}}^2}$$

The uncertainty was successively propagated to the replication fidelity ($f_r = {Sx_{replica}}/{Sx_{master}}$) according to the formula

$$U(f_r) = 2\sqrt{\sum_j \left(\frac{\partial f_r}{\partial Sx_j}\right)^2 u_{Sx_j}^2}$$

Results

A good amplitude replication was achieved for the stone polished surface. The worst amplitude replication was achieved for both diamond buff and grit paper polished surfaces.

The tendency is almost the same for slope replication but the replication fidelity values were lower (see Table 1, Table 2 and Figure 3).

Table 1. Replication fidelity.

	Sq /%	Sdq /%
Diamond buff	47	33
Grit paper	56	51
Stone	95	67
Dry blast	70	50

Table 2. Replication fidelity uncertainty.

	U_{Sq} /%	U_{sdq} /%
Diamond buff	13	16
Grit paper	7	18
Stone	11	21
Dry blast	3	7

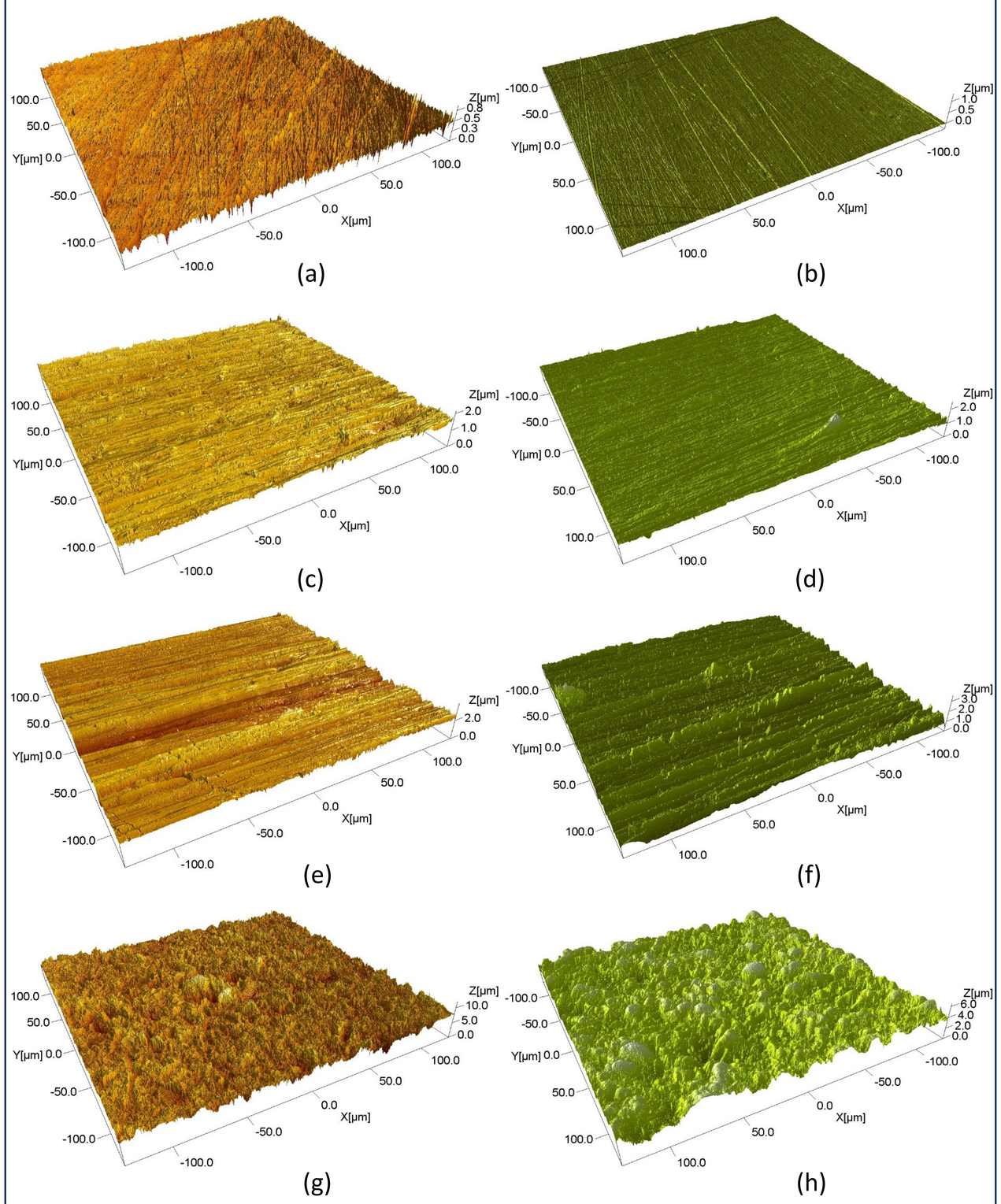


Figure 2. Examples of acquired surfaces. (a) Diamond buff polished master. (b) Replica of diamond buff polished master. (c) Grit paper polished master. (d) Replica of grit paper polished master. (e) Stone polished master. (f) Replica of stone polished master. (g) Dry blast polished master. (h) Replica of dry blast polished master.

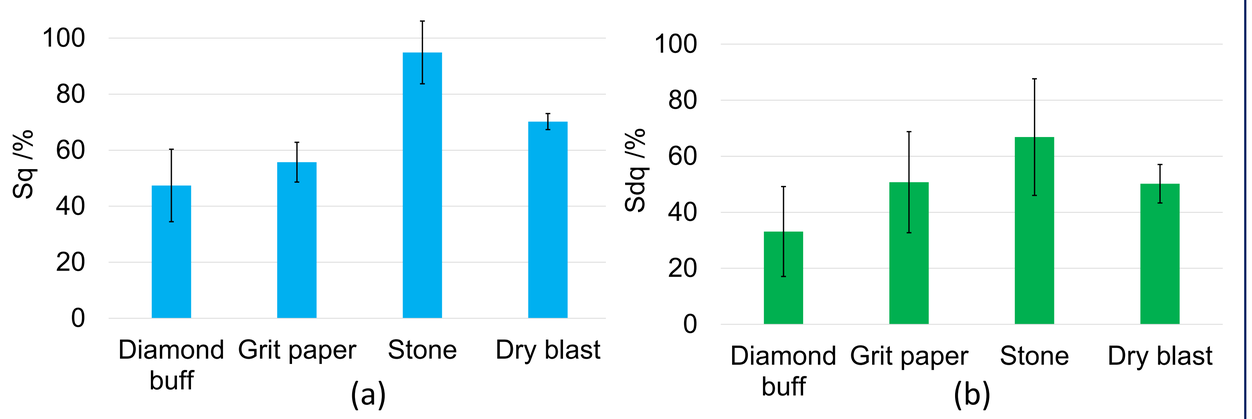


Figure 3. Replication fidelity of amplitude (a) and slope (b) for the different considered surfaces.

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