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Publication date:
2018

Document Version
Publisher's PDF, also known as Version of record

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Citation (APA):
Davoudinejad, A., Charalambis, A., Zhang, Y., Calaon, M., Pedersen, D. B., Tosello, G., & Hansen, H. N. (2018). *Assessment of sub-mm features replication capability in injection moulding using a multi-cavity tool produced by additive manufacturing*. Poster session presented at 18th International Conference of the european Society for Precision Engineering and Nanotechnology (euspen 18), Venice, Italy.

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18th International Conference & Exhibition
4th – 8th June 2018, Venice, Italy

Assessment of sub-mm features replication capability in injection moulding using a multi-cavity tool produced by additive manufacturing

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Abstract

This research investigates the effect of injection moulding process parameters on photopolymer mould inserts produced with the Digital Light Processing (DLP) additive manufacturing (AM) method. The main motivation of applying AM to produce mould inserts, is the potential of reducing lead time and manufacturing cost, as well as achieving a more flexible manufacturing method in case of non-mass produced products such as prototypes. In this research moulds inserts of 20 x 20 x 2.7 mm with mould cavities as small as 5 x 4 mm in dimensions are tested. The parts are analyzed and evaluated by the measurements of different features and the influence of the IM process.

Experimental procedure

Soft Tooling

The mould inserts were produced in the photopolymer by vat photopolymerization method in which liquid photopolymer in a vat is selectively cured by light activated polymerization layer by layer. A high precision industrial 3D-printing system Digital Light Processing DLP-LED Stereolithography was used with a 50 µm pixel detail in X and Y directions and the precision of ± 50 µm in X, Y, and Z directions.

Injection Moulding (IM)

The IM was carried out on an Arburg (370A 600-70), 60 tonne moulding machine. Injection moulding material with a higher melting point was used. Acrylonitrile butadiene styrene (ABS) was used at 220-260°C. The material was dried for 4 hours at 80°C in a HELIOS WINsystem Micro D dryer. The IM is carried out with standard settings for the ABS. The 200 bar packing pressure and 4 s packing time were kept constant in different conditions. In order to collect the exact manufactured parts in the initial of the moulding process for each insert only one cavity with AM insert was used for each moulding out of four cavities. Table 1 shows the IM parameters applied for each insert.

Measurements and Analysis

Heights of both the heart and the brick cavities are considered by measuring from the mould surface to the bottom of the cavities. The bricks are measured according to, two heights, both from the mould insert surface to mid plane of the brick and to the knob surface. The investigation was carried out with a focus variation microscope (Alicona Infinite Focus), using a 5× magnification lens for visual inspection and a 20× magnification lens (pixel width 883 nm × 883 nm) for the measurements. In order to analyse the measurements data a scanning probe image-processing software was employed for the purpose (SPIP). Figure 2 shows the acquisition of the lower part of the heart in the SPIP for angle measurement.

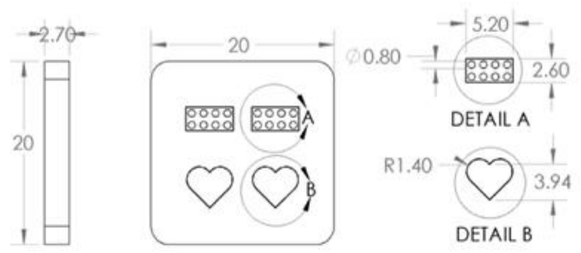

Fig. 1 (**a**) Drawing of insert and details (dimensions in mm)

TABLE 1 IM experimental parameters

Insert	T melt (°C)	Injection speed (mm/s)	T mold (°C)
A	220	80	25
B	260	40	50
C	220	80	50
D	220	40	25

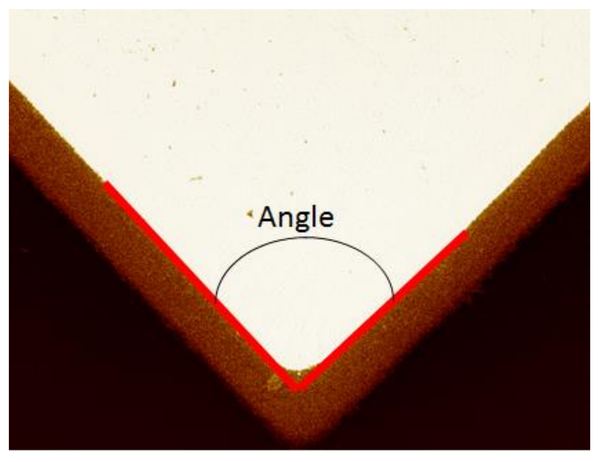

Fig. 2 *The acquisition of lower angle shape of the heart in SPIP for the IM part*

Results

In order to evaluate the manufactured parts with soft tooling insert, the measurement results of the first five parts for each batch is presented in following graphs. Figure 4 shows the angle measurement of the hearts in both sides of the parts and Figure 5 illustrates the average diameter of the pillars. The results reveals variation between the right and left side of the parts mainly for the angle measurements. Batch A had minimum variation on the left and right side of the part in comparison to other setting. Regarding the diameter of the pillars in all conditions smaller size observed in comparison to the nominal geometry. The variation of the dimensional features of parts are mainly due to the IM setting parameters and also might be due to the shrinkage of ABS material, and the crack of the insert that affect the feeding of the mould.

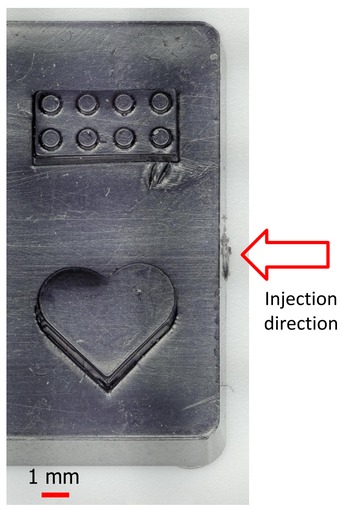

Fig. 3 *IM part one side*

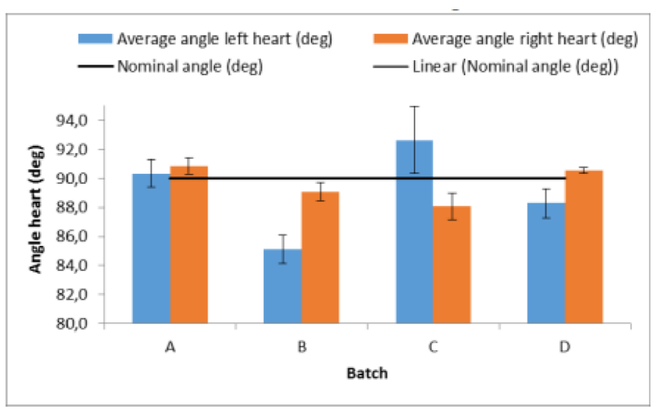

Fig. 4 *The lower angle shape variation of the hearts in IM parts*

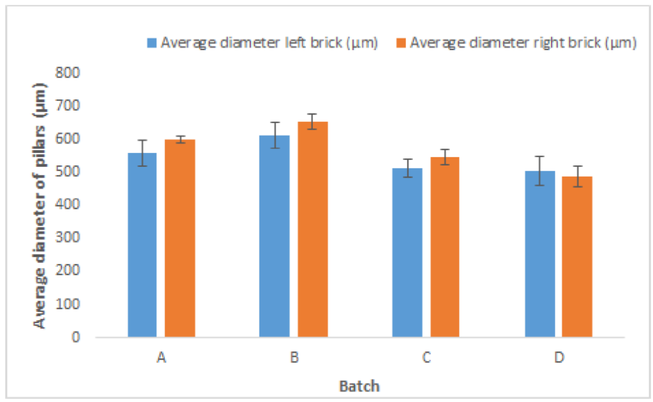

Fig. 5 The average diameter of the pillars

Conclusion

This work presented the capability of the soft tooling insert manufactured by digital light processing AM method for injection moulding. Inserts of 20 x 20 x 2.7 mm with mould cavities as small as 5 x 4 mm in dimensions were tested. Different feature of size was designed and evaluated for this experiments with various IM parameters setting. The measurements carried out for different features to evaluate the effect of the IM parameters. The five initial parts were investigated to eliminate the other effects. The influence of the IM parameters were observed in different batches of parts.

Acknowledgment

The research leading to these results has received funding from the People Programme (Marie Curie Actions) of the European Union's Seventh Framework Programme (FP7/2007-2013) under REA grant agreement no. 609405 (COFUNDPostdocDTU).