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DTU MADE Manufacturing Academy of Denmark

PRN 2017 Polymer Replication on Nanoscale

A preliminary study on replication and quality correlation of on-part and on-runner polymer injection moulded micro features

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Abstract

Injection molding is increasingly gaining place in manufacturing of polymer components as is can ensure a cost efficient production with short cycle times. To ensure the quality of the produced parts and the stability of the process it is essential to perform frequent metrological inspections. In contrast to injection moulding's short cycle time, a metrological quality control can require a significant amount of time. The late detection of the problem can result to high losses and scrap rate. This work presents an alternative approach to process monitoring and part quality control with fast off/in-line metrology of physical part quality indicators ("Product Fingerprint").

The proposed approach is based on the concept of metrology applied to dedicated micro pillar features, positioned on the runners, similar or equal to those in the part in order to access the quality of the produced plastic parts. A designed experiment was employed to map the experimental space and quantify the pillars replication depending on position and processing parameter combinations. The pillars were assessed and the main effects of the processing parameters, were calculated to reveal that the effects of process parameter changes were similar in all measurement positions.

Objectives and geometry

- Objective ⇒ To study the replication and quality correlation of on-part and on-runner polymer injection moulded micro pillar features
  - Increase quality of pillars ⇔ better products and process stability
  - Correlate quality on part and runner ⇔ Fast QA , reduction of metrological effort

- Tablet biochip 20×20×2mm^3 geometry
- Key injection molding parameters
  - ⇒ Melt temperature
  - ⇒ Mould temperature
  - ⇒ Injection speed
  - ⇒ Packing Pressure
- Key geometry parameters
  - ⇒ Pillar position

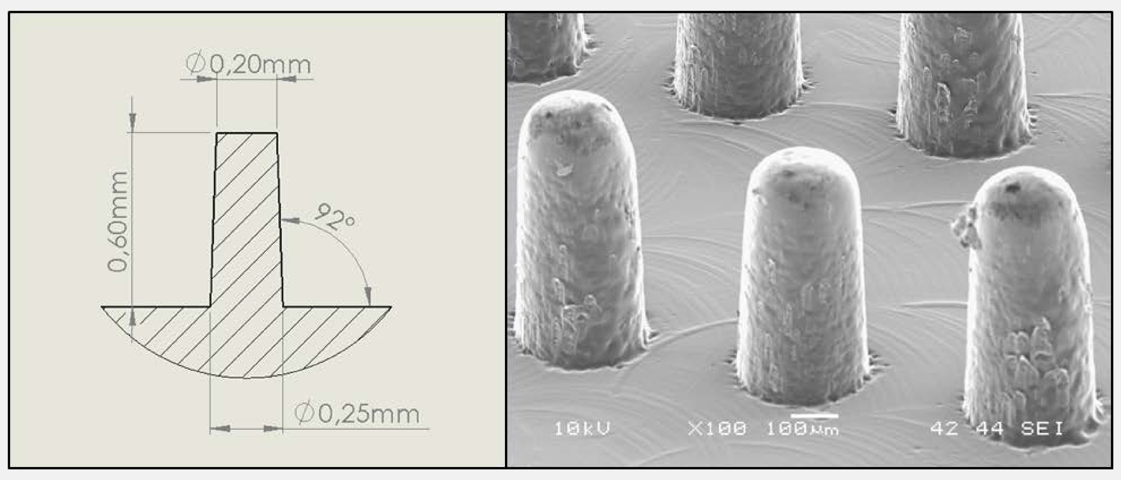

Fig. 1: Pillar micro features shape and dimension

Experimental set-up

- Design of Experiments (DOE) technique was employed
- 2^4 full factorial design (Table 1) in ABS material
  - Melt temperature ⇒ 220˚C, 260 ˚C
  - Mould temperature ⇒ 40˚C, 60 ˚C
  - Injection speed ⇒ 100 mm/s, 140 mm/s
  - Packing pressure ⇒ 440 bar, 540 bar
- 4 measurement positions for each part
  - 3 pillars per position- 4 profiles per pillar

- Alicona (infinite focus): focus variation microscope ⇔
  - Constant scanning settings:
    - Objective x20
    - Scanning area of 714×542 µm^2
      - Centered on pillar center
    - Vertical resolution of 299 nm
    - Lateral resolution of 2,93 µm

Experimental Run No#																
Run	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Tmelt [°C]	220	260	220	260	220	260	220	260	220	260	220	260	220	260	220	260
Tmould [°C]	40	40	60	60	40	40	60	60	40	40	60	60	40	40	60	60
Inj.Speed [mm/s]	100	100	100	100	140	140	140	140	100	100	100	100	140	140	140	140
Pack.Pressure [bar]	440	440	440	440	440	440	440	440	540	540	540	540	540	540	540	540

Table 1: 2^4 full factorial design

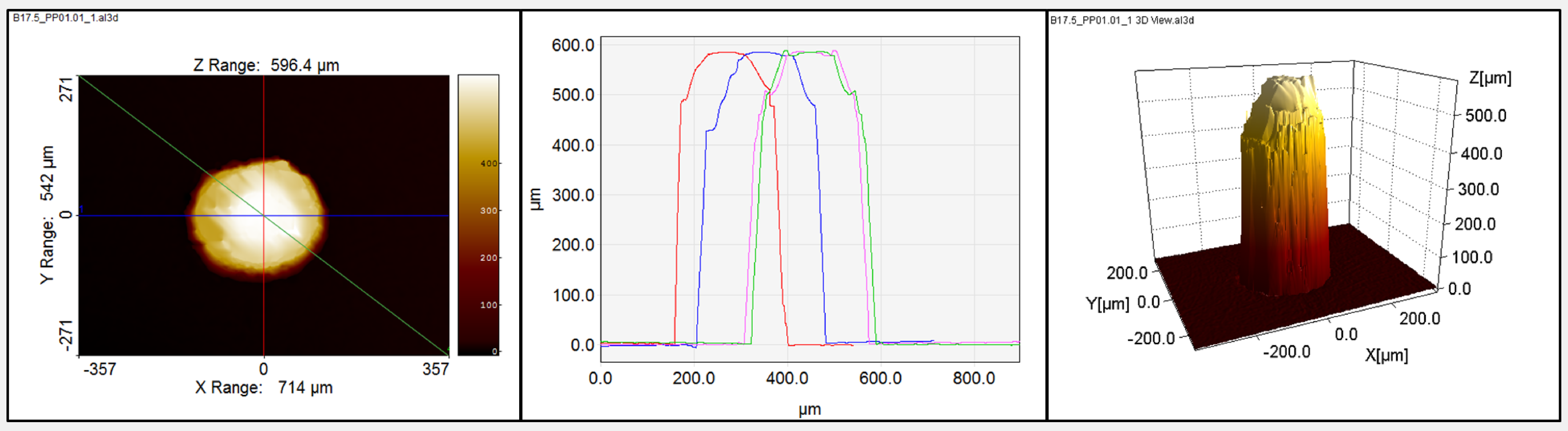

Fig. 2: Pillar height assessment with SPIP: Averaging of the maximum values from 4 profiles

Effects of process conditions and position on pillar height replication

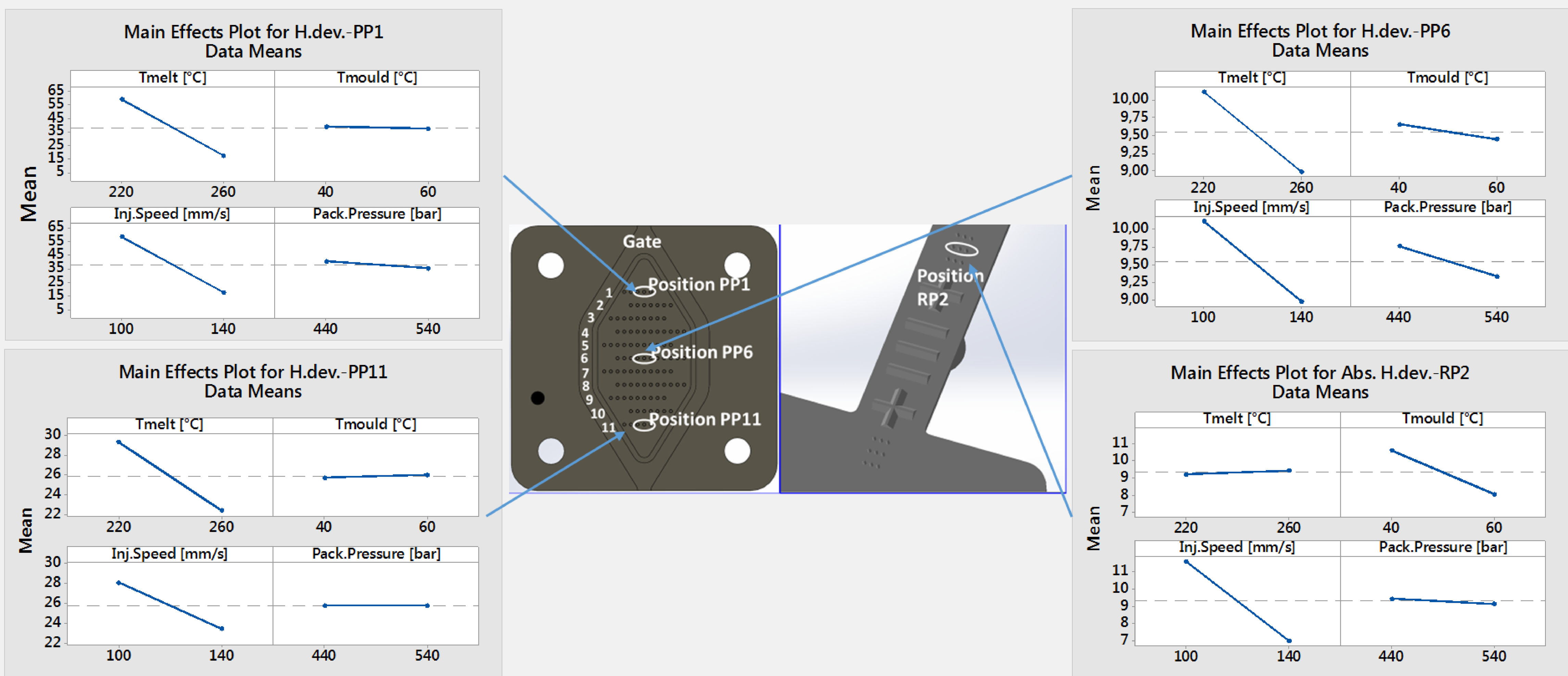

Fig. 3: Influence of injection speed, packing pressure, melt (Tmelt) and mould (Tmould) temperature on pillar heights depending on measurement positions. High melt temperature results to better pillar replication, beside position RP2 (runner) were the parameter causes opposite effects, though in smaller magnitude. Injection speed has the next biggest effect with the same effect behaviour to be present in all positions, producing better replicated features.

Conclusions

A designed experiment was employed to map the process window and quantify the pillars replication depending on position and process conditions in each run. The replication of the pillars was evaluated and the effects of the processing parameters were calculated to reveal that the effects of process parameter changes were similar in all measurement positions; It is indicated that the proposed approach can be used to assess part quality based on off-part/on-runner micro features.

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