Investigation of inserts surface structures on injection moulded parts

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Abstract. Nowadays, the surface quality of injection moulded products is becoming increasingly important to users. Due to increasing demands, engineers (especially in the automotive industry) creates structures on the surface of the parts that are close to the appearance of natural materials (e.g. leather, wood, etc.). These aspirations are not only aesthetically but functionally important. In order to create quality product, besides processing parameters, it is also crucial how to design the mould. However, it is important to know how the processing parameters affect the mould surface mapping. The preliminary objective is to investigate the effect of different macro-geometric structures created by cutting technology on the flow of polymer melt.

1. Introduction

The production of a quality finished part requires perfect knowledge of the filling and compression phase. One of the main tasks of this research is to study the relationship between polymer melt and the manufactured surface structure. The preliminary objective is to investigate the effect of different macro-geometric structures created by cutting technology on the flow of polymer melt. The backbone of the research is provided by a special, experimental injection molding tool, consisting of two symmetrically positioned cavities which used for producing bending specimens (Figure 1.).

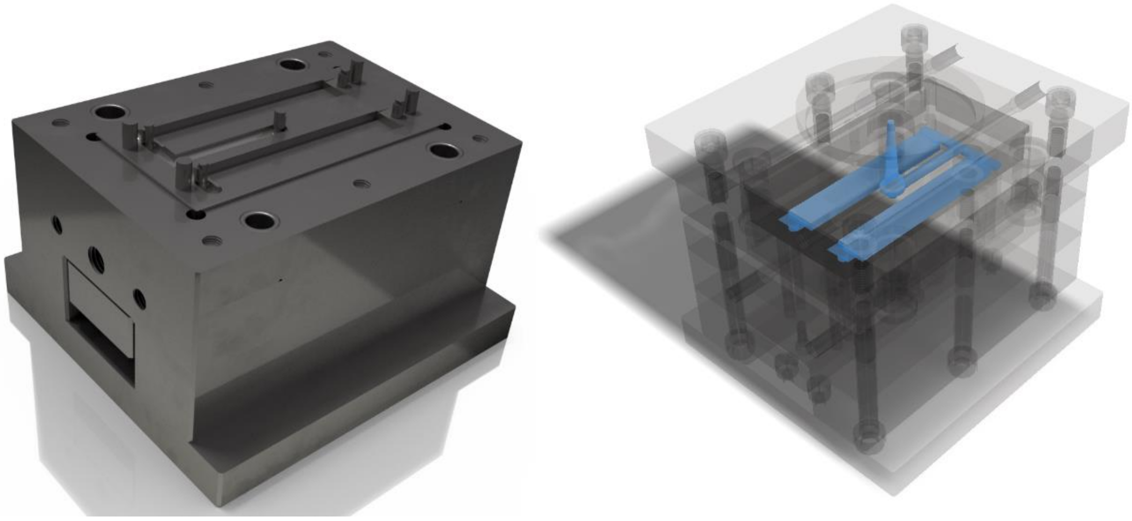

Figure 1. Experimental injection molding tool

2. Description of the research and experimental conditions

The premise was to create two paths on the insert's surface that result significantly different orientation during injection molding. We designed a special mold insert, kept the dimensions of the former active insert, and then created grooves on its surface as shown on Figure 2.

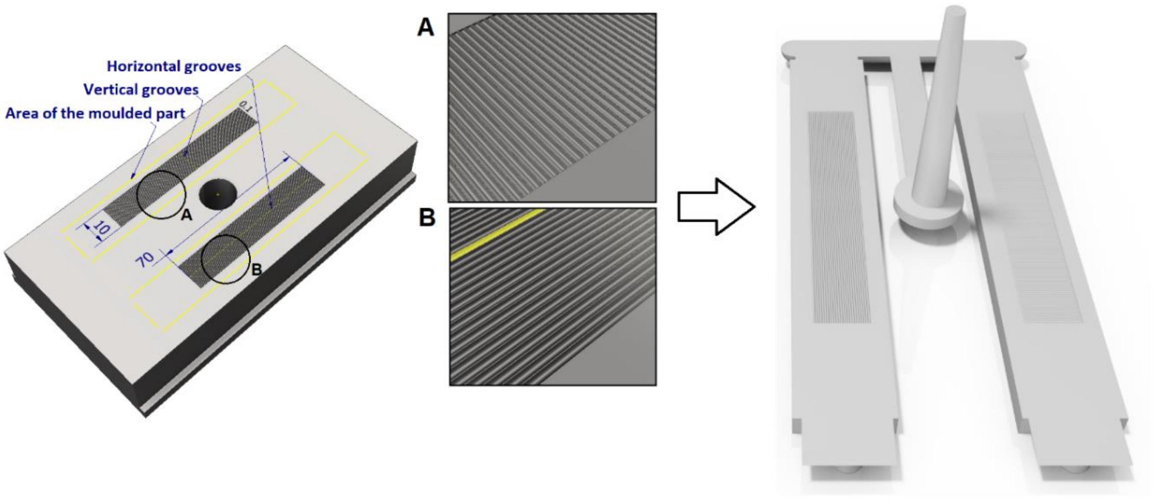

Figure 2. The designed insert and the moulded part.

In terms of flow direction, we designed perpendicular and parallel grooves which depths were 0.1 mm. As for the manufacturing technology, the selected tool was a TiN coated, carbide engrave tool, with 30° tip angle and 0.2 mm corner radius. It is shown in the Figure 3.

Figure 3. TiN coated, carbide engrave tool

After the geometrical boundary conditions have been recorded, material selection has taken place. Our aim was to use an amorphous and semi-crystalline polymer. In the semi-crystalline polymers, the melting of the crystalline phase has a higher heat demand during heating and, when cooled, the crystallization need a higher heat dissipation compared to the amorphous polymers. During the phase transition, the density also varies: the crystalline phase is of greater density than the amorphous phase or the melt, so the shrinkage of the semi-crystalline polymers is greater:

- The shrinkage of crystalline polymers is 1.5-2.5%.
- Shrinkage of amorphous polymers: 0.4-0.8%.

In crystalline polymers, a further approx. 1% post-shrinkage, which is completely absent in amorphous polymers. The properties of the two selected materials are shown in the Table 1.

1. Lexan Resin 141R – Polycarbonate (amorphous)
2. Dowlex 2027G – LLDPE (semi-crystalline)

Table 1. Examined polymers and its properties

Properties	**Lexan 141R**	**Dowlex 2027G**	unit
Recommended processing temperatures			
Tool surface temperature	100	16	°C
Melt temperature	320	230	°C
pvT properties			
Density (melt)	1,0534	0,72883	g/cm^3
Density (solid)	1,1983	0,92819	g/cm^3
MFI (Melt flow index)	11	4	g/10 min

3. Experimental results

3.1 Microscopic recordings

The Figure 4 shows the engrave tool, captured with a Dino-Lite Pro HR AM7000 microscope. That more or less confirmed the properties of the tool's datasheet. The tip angle was close to the description, however the corner radius was not 0.2 mm, but rather a parallel edge to the surface. The tools were exposed to increased wear due to the long tool path. Since the horizontal and vertical grooves were made with different engraving tools, the quality was less affected by the tool wear.

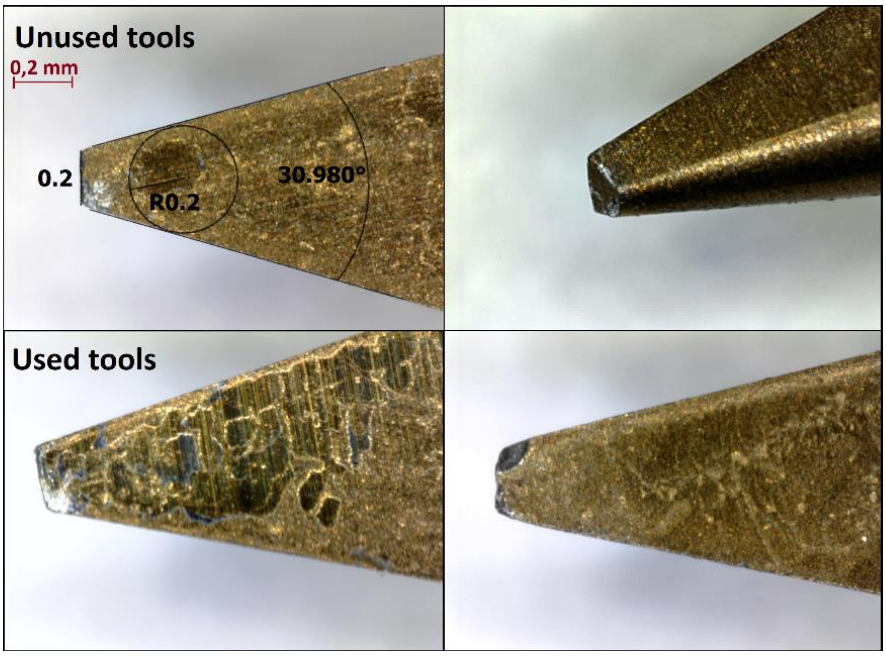

Figure 4. Microscopic recordings about the TiN coated, carbide engrave tool

To check the quality of the engraved grooves a Mitutoyo QuickVision Elf Pro microscope was used. The macro and micro-geometric characteristics of the grooves are well visible on the Figure 5.

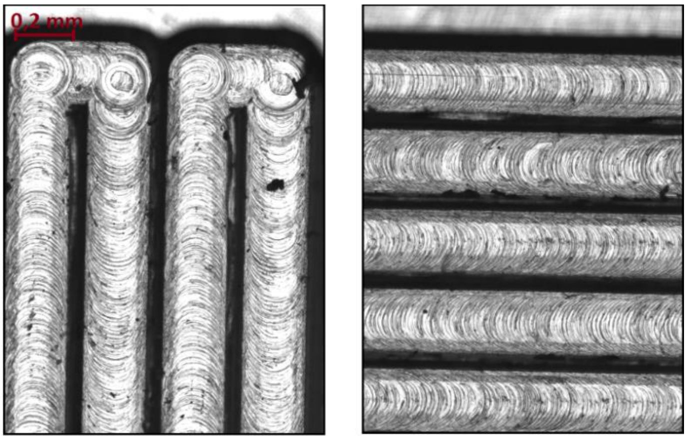

Figure 5. The vertical (left) and the horizontal (right) paths recorded with Mitutoyo Quick Vision microscope.

3.2 Examination in contour measuring instrument

The cavity filling quality was measured using a Mitutoyo Formtracer Sv-C3000 contour measuring instrument. The primary purposes of contour measurement were:

- Find the differences between the actually created and the planned geometries.
- Investigating the filling of injection products
  - → in case of Dowlex 2027G LLDPE
    - ▪ with back pressure (500 bar)
    - ▪ without back pressure
  - → in case of Lexan 141R polycarbonate
    - ▪ with back pressure (500 bar)
    - ▪ without back pressure

3.2.1 Contour measuring of the insert

Both the horizontal and the vertical paths were divided into 3 to 3 sections. In these areas we measured the surface contour on a 3.5 mm long distance. The sections were recorded at the beginning, middle and end of the path. The difference in height due to tool wear was also investigated (Figure 6).

Figure 6. The marked measuring sections on the insert and the process of the measurement.

IOP Conf. Series: Materials Science and Engineering **448** (2018) 012052   doi:10.1088/1757-899X/448/1/012052

The differences between the engraved grooves and the planned geometries were clearly visible in the microscopic images. After the contour measurement, the facts found there are proved. However, there is a regular arrangement between the engraved grooves, which is shown in Figure 7. The geometric differences of the engraving tool and wear after manufacturing were also noticeable on the paths. The differences between the depths of the grooves in the measuring sections were not significant, so it can be stated that the tool suffered a most part of the wear during the plunge. The wear was 0.02 mm on average. The figure also shows that the distance between the tool paths was in accordance with the programmed value (0.346 mm)

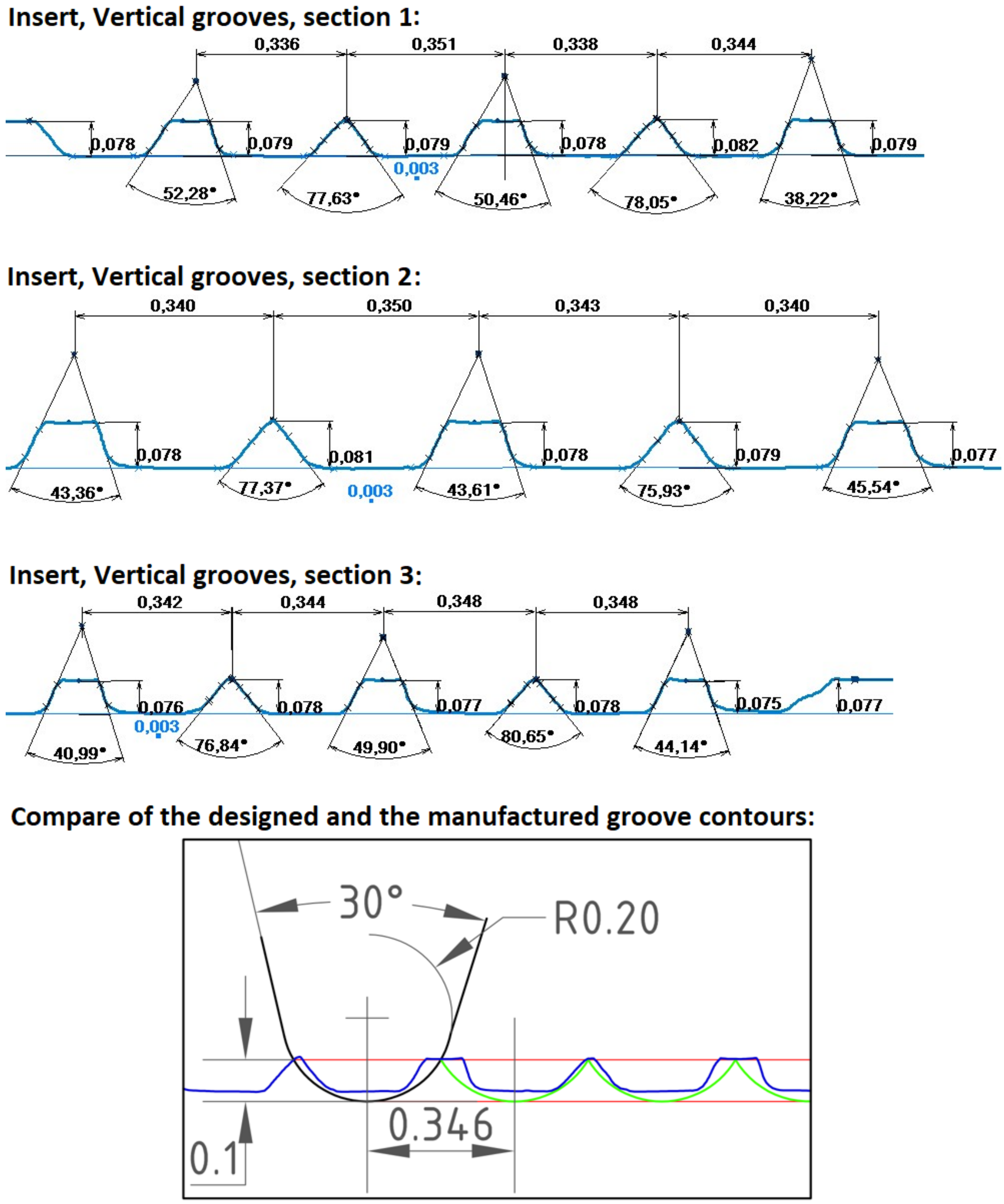

Figure 7. Measured geometries on the insert's surface.

IOP Conf. Series: Materials Science and Engineering **448** (2018) 012052 doi:10.1088/1757-899X/448/1/012052

3.2.2 Contour measuring of the moulded parts

The comparative examination of the structures on the moulded products was carried out similar to the insert (Figure 8). We compared products with backpressure, and without backpressure, which had a value of 500 bar. The examined section of the moulded product was combined with the same contour section of the insert. The objective was to analyze the geometric mapping.

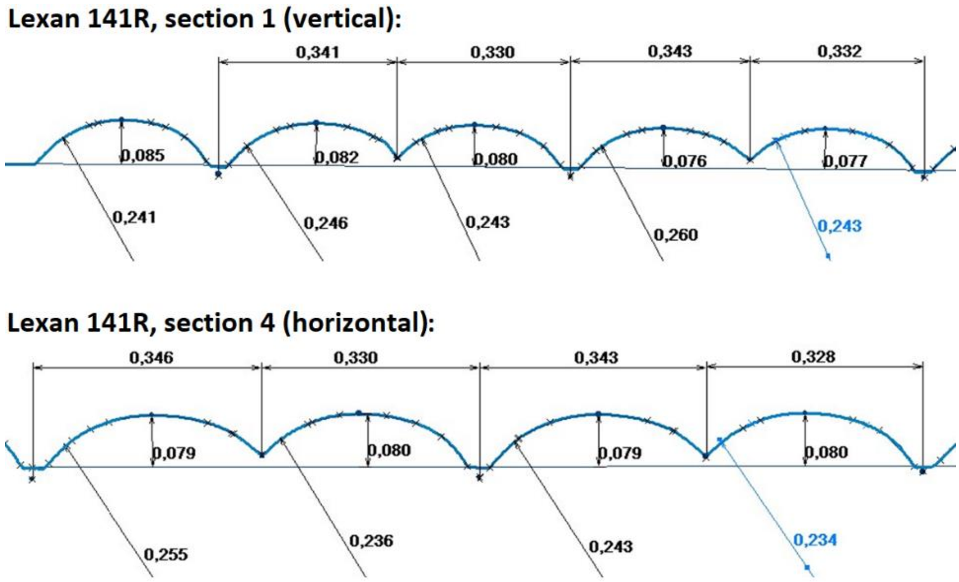

Figure 8. Measured geometries on the insert's surface.

The figure shows that, the contours of Lexan 141R horizontal and vertical paths did not show significant differences in the moulded products. In the case of the Dowlex 2027G, it also got similar results, so I did not differentiate the structures that were engraved. The following sections have been studied on vertical paths. The points measured by the contour measuring instrument can be saved in ".dxf" format. The software can automatically align these points with polynomials. The number of the points were a magnitude greater than the desired limit of measurement, so the approximation was sufficient. The comparison was done in AutoCAD using the ".dxf" files. In the case of height, the flat surfaces were used, while in the direction of the length the first groove served as a reference. With this technique, the geometries could be fitted with the accuracy of <0.01 mm.

The examination was started with the semi-crystalline Dowlex 2027G (Figure 9). It can be seen that the structure of the insert is not nearly covered by the product. The shrinkage was significant in longitudinal parts and sharp corners. In addition to its depth, the differences between the products with backpressure and without backpressure were clearly visible. This often resulted two-fold differences.

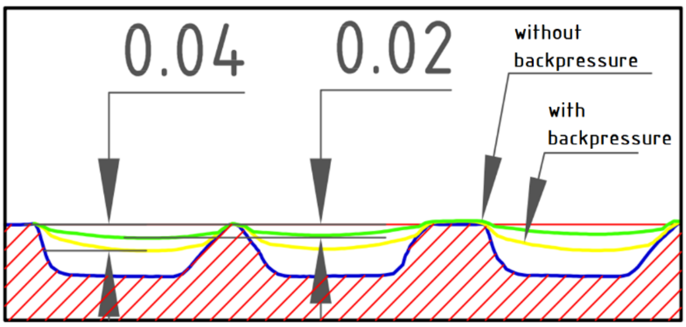

Figure 9. The measured contours of the semi-crystalline Dowlex 2027G with and without backpressure.

Then we examined the products made from Lexan 141R (Figure 10.). Since it is an amorphous material, the expected shrinkage was less. The grooves were better filled, and its depths were far better than on the LLDPE parts. The sharp corners and contour lines were better returned by product geometry. In this case the presence of the backpressure was not significant.

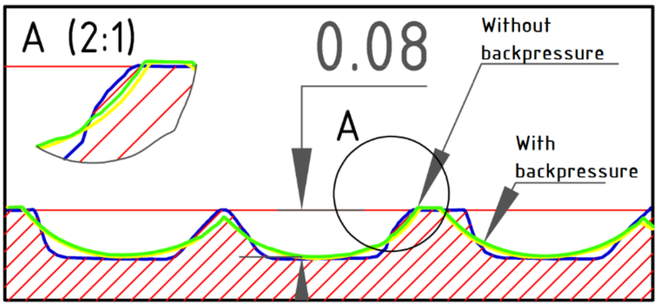

Figure 10. The measured contours of the amorphous Lexan 141R polycarbonate, with and without backpressure.

4. Results and discussion

The moulded contours did not show significant differences in the horizontal and vertical paths. The orientation of the paths less influenced the inserts filling. The filling of the structures were not perfect either. The moulded parts had a positive effect on shrinkage after backpressure. The Lexan 141R polycarbonate (amorphous and higher MFI) had a significant shrinkage and its surface contour did not followed well the insert's geometry. In spite of all these, it had a better mapping ability with the applied technologies compared to the LLDPE.

5. Conclusions

Examination of geometric mapping with contour measurements gave clear results. In order to have the designed insert surface structure on the manufactured parts, it is appropriate to have a careful geometric design and further experiments. The thickness of the moulded parts and the depth of the grooves can also be definitive perspectives and steps forward in the near future. As a long-term goal, it is possible to design a surface structure that guides the molecule orientation of the melt to different needs. However, the structure of the surface which affecting the molecular orientation on boundary layer, and the influence it has on the mechanical properties requires a series of further research and experiments. The measurements in this article made may serve as a basis for these investigations.

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