FIBER REINFORCEMENT INDUCED WARPAGE ON INJECTION MOLDED THERMOPLASTICS

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1 Abstract

The warpage characterizations of injection molded plastic parts are not standardized and very challenging due to its complex process. This paper presents a novel examination method of the deformation of injection molded plastic parts especially for fiber reinforced materials. A special, but simple part was introduced for the description of the effect of different technological parameters and different fiber reinforcements on warpage.

2 Introduction

The quality of injection molded thermoplastic parts is considerably determined by the material, the process parameters and the mold design. One of the main problems is caused by shrinkage resulting warpage with its unevenness. This deformation is strongly influenced by non-uniform cooling, differential shrinkage and orientation effect [1].

2.1 Geometry influence on warpage

Several researchers dealt with the formation and characteristics of warpage using different methods especially different types of specimens.

Tang et al [2] introduced a mold producing ABS plates for warpage testing while Fahy [3] investigated the warpage of reinforced thermoplastics on a regular circular disk. Kikuchi and Koyama [4] analyzed disk specimens and plates too and introduced a warpage index for the characteristics of injection molded parts. They pointed out that plate-like specimens are not capable to measure because of their simple geometry. So they suggested using a more complex shape.

2.2 Material influence on warpage

Mlekusch [5] analyzed the warpage on a special part with various kinds of corners. The effect of short-fiber-reinforcement on the deformation was studied, and it was attributed to the anisotropy of the material. Multi-layer model predictions were compared with the experimental measurements showing that the additional warpage observed for short-fiber-reinforced materials could be attributed to the anisotropy of the material. Ammar et al. [6] used a specimen with four corners with different radii. They concluded that two phenomena caused warpage: the first was the asymmetrical cooling and the second was the spring forward effect. The spring forward effect was generated in fiber reinforced materials to the higher thermal expansion coefficient in the thickness direction. The deformation around the corner and the deformation of the initially flat surfaces were distinguished.

3 New methodology and measuring technique

In order to characterize the warpage at corners of injection molded parts a special part was designed. The main goal was to enable the measurement of the effect on warpage of different technological parameters, mold design or material properties.

The length of the V-top specimen is 75 mm, the width of it is 46 mm. The two plates of it close an angle of 90°, and the wall thickness can be chosen either as 1 mm or 2 mm (Fig 1).

The orientation of the material and this way the positioning of the injection location has a significant effect on the deformation. Therefore three different

gate types – standard middle, standard front, and film – can be used by changing the gate inserts in the mold (Fig 1).

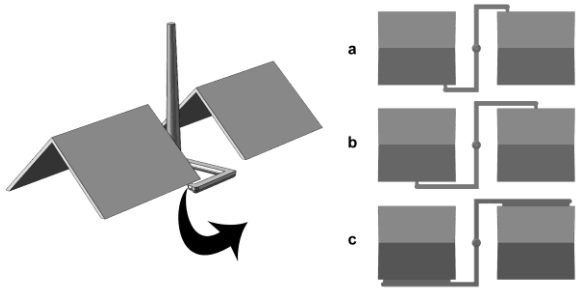

Fig.1.Specimen for the warpage measurements

Warpage is highly influenced by cooling and it is really significant at corners. The core of the mold has to dissipate the heat faster than the cavity otherwise the internal area of the part's corner solidifies later and shrinks more sharpening the corner itself. To meet the high requirements of the warpage tests an efficient cooling system was required.

To evaluate the warpage of the V-top specimen special developed image analysis software was used. The deformation is determined by fitting curves on the part edges and calculating their derivatives along the edge length. As a result the closing angle of the tangents is determined in 5% steps (Fig.2.).

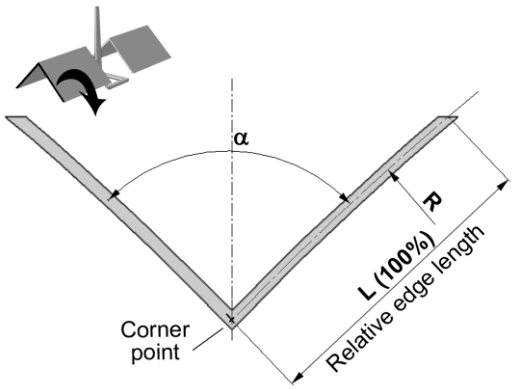

Fig.2. Functional background of the measurements

4 Measurements

Neat polypropylene and polypropylene reinforced with glass fiber of different weight content (10, 20, 30 wt%) were examined to evaluate the new method comprehensively in a wide range of deformed parts.

On Fig.3. a typical result of the experiments, the closing angle in the function of relative edge length is shown.

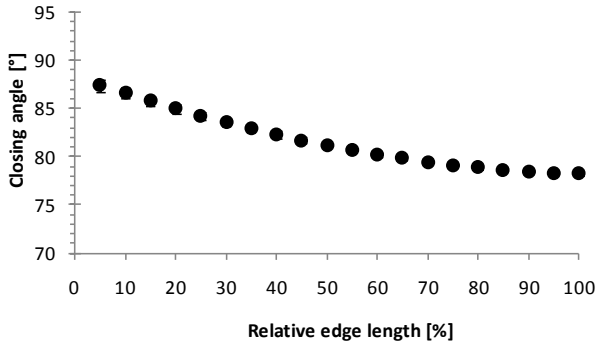

Fig.3. Typical results from the measurements

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References

[1] J.M. Fischer: *"Handbook of molded part shrinkage and warpage"*. 1st edition, Plastics Design Library/William Andrew Inc., Norwich. 2003

[2] S.H. Tang, Y.J. Tan, S.M. Sapuan, S. Sulaiman, N. Ismail and R. Samin. "The use of Taguchi method in the design of plastic injection mould for reducing warpage". *Journal of Materials Processing Technology*, Vol. 182, pp 418-426, 2007

[3] E.J. Fahy "Modeling warpage in reinforced polymer disks". *Polymer Engineering and Science, Vol.* 38, No.77, pp 1072-1084, 1998

[4] H. Kikuchi and K. Koyama "Generalized warpage parameter". *Polymer Engineering and Science, Vol.* 36, No.10, pp 1309-1316 ,1996

[5] B. Mlekusch "The warpage of corners in the injection moulding of short-fibre-reinforced thermoplastics". *Composites Science and Technology*, Vol. 59, No. 12, pp. 1923-1931, 1999

[6] A. Ammar, V. Leo and G. Régnier "Corner deformation of injected thermoplastic parts". *International Journal of Forming Processes*, Vol. 6, No. 3, pp 53-70, 2003