INFLUENCE OF GATE POSITION DURING THE INJECTION MOULDING PROCESS

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Abstract

This article deals with the influence of the gate position on the final properties of a plastic product after the injection moulding process. Parameters such as temperature, fibre orientation and filling velocity are evaluated. The importance of the internal fibre orientation on the mechanical properties is also described. Advanced virtual mould-flow analysis is used for this research. A simple brick from Polybutylene Terephthalate (PBT) with 30% of short glass fibres is chosen as the reference part. A virtual model of PBT is described in depth in this article. An injection process with the same initial parameters was used for three different locations of the pin gate. This type of gate is considered because it is one of the most frequently used in the plastics industry. Different kinds of gates and their influence on filling are also briefly described. This paper shows the importance of the gate location and it also helps to understand the flow of short fibre reinforced thermoplastics inside the mould cavity. The article presents an in-depth and complex view of the issue of mould filling.

Keywords: injection moulding; gate; filling; fibre orientation

1. Introduction

The injection moulding process is the process that produces plastic parts through the injection and cooling of molten polymers in a mould cavity. In this process, the material is driven by a screw and enters the cavity through a system of gates and channels where it is shaped. It is well known that the configuration of the gates and channels can directly affect the final properties of the parts.

Short fibre reinforced thermoplastic composites are one of the most widely used materials. They are commonly used in the automotive and aerospace industries. The improvement in mechanical properties by using fibres is dependent on the particle orientation through the whole part. [1], [2], [3] The mechanical properties of an injection moulded product depend strongly on how the fibres are orientated in relation to the applied load. The best performance occurs when both the fibres and the applied load are oriented in the same direction, while the worst performance occurs when the fibre orientation is perpendicular to the direction of the applied load. This research is mainly focused on acquiring fundamental knowledge about cavity filling and melt flow inside the mould cavity. It also deals with different types of gates and gate locations.

Results, such as times, pressures, temperatures, deformations and velocities are used for evaluating the mechanical properties and filling behaviour. The work is primarily done using virtual simulation. It is a commonly known fact in the plastic industry that the positions of the gates and channels affect the melt flow inside the cavity, therefore different gate configurations will result in parts with different mechanical properties under the same load conditions.

2. Methodology

A brick with dimensions 80 x 80 x 40 cm was used for this study. The main goal of the study is to analyse the melt flow behaviour and its properties during the filling of the cavity. The dimensions of the brick were chosen in order to allow the observation of the melt flow behaviour in a non-steady state; in other words, a brick was chosen in order to give the melted material space to flow freely. [4], [5], [6]

The model of the brick was created using NX10 Siemens PLM computational design software. The inputs of the gates, different gate locations, runner cross-sections and runner angles, mould and cooling channels, were made using the software Moldex 3D Designer. The whole design is shown in Fig. 1.

Fig. 1. Mould with product, gate and cooling channels

Parameters in the following table were used for mould-flow analysis (all simulations were done with the same inputs).

Melt Temperature	260°C	Cooling time	30.00sec
Mould Temperature	80°C	Mould Opening Time	5.00 sec
Maximum Injection Pressure	155°C	Maximum Packing Pressure	155.00 MPa
Packing time	20.10 sec	Air temperature	25°C

Table 1. Parameters for injection moulding

2.1. Material description

The material was a short fibre reinforced thermoplastic polymer called Celanex 3300, produced by Celanese. The polymer is Polybutylene Terephthalate (PBT) filled with 30% of short glass fibres and its properties are shown in Table 2. [7], [8], [9]

Melting Temperature (10°C/min)	225	°C	ISO 11357-1,-2,-3
Glass Transition temperature (10°C/min)	60	°C	ISO 11357-1,-2,-3
Test Specimen Production	Value	Unit	Test standard
Processing conditions acc. ISO	7792-2	-	-
Injection moulding melt temperature	260	°C	ISO 294
Injection moulding mould temperature	82	°C	ISO 294
Injection moulding flow front velocity	300	mm/s	ISO 294
Injection moulding hold pressure	48	MPa	ISO 294

Table 2. Material properties of Celanex 3000

Viscosity is an important parameter for mould-flow analysis. It is described in the following figure for Celanex 3300. It can be seen (Fig. 2) that better flow occurs at higher temperatures.

Fig. 2. Dependency between viscosity, shear rate and temperature for Celanex 3000

3. Gate Design

The main influence of gate design is on flow behaviour, especially near to the gate. The use of automatic trimmed gates is the reason why pin or tunnel gates are often used (Fig. 3). The difference between these two types is not so big from a simulation point of view (if the same cross-sections are considered). The geometry of the pin gate was used in the simulation. [10], [11]

Fig. 3. Pin (left) and tunnel (right) gate

3.1. Pin gate

This kind of gate is common for a three-plate mould design, where the runner system is in one half of the mould. Reverse taper runners drop through the middle (third) plate, parallel to the direction of the mould opening. As the mould cavity parting line is opened, the small-diameter pin gate is torn from the part. A secondary opening of the runner parting line ejects the runners. An auxiliary, top-half ejector system extracts the runners from the reverse taper drops and it tears the runners from the parts. [12], [13]

3.2. Tunnel gate

A tunnel gate is used in two-plate mould construction. As the parts and runners are ejected, the gate is trimmed from the part. [14] If a large diameter pin is added to a non-functional area of the part, the tunnel gate can be built into the pin, avoiding the need of a vertical surface for the gate. If the pin is on a surface that is hidden, it does not have to be removed. [15], [16]

4. Gate Location

To analyse the influence of the gate location, the pin gate design was chosen with three positions as shown in the following figure. [17]

Fig. 4. Pin gates and their positions used in the analysis

4.1. Time and temperature results

In regard to total filling time, no significant changes were noticed. Although the melt front is influenced by the cavity walls, the filling time results are very similar. The filling behaviour for each design can be clearly seen in Fig. 5.

Fig. 5. Filling behaviour for various gate positions

The influence of the corner geometry is obvious in Fig. 6. It shows the melted volume (in blue) during filling. It is obvious that near the corner the temperature is lower and it leads to freezing of the plastic material. This is why gates should not be placed close to the corners.

Fig. 6. The influence of corner geometry

4.2. Velocity results

By analysing the velocity, it is clear the influence that the walls have over the melt behaviour flow. The contact with the wall causes loss of heat by conduction, which further results in reduction of the melt temperature and thus also a slowing of the filling velocity.

Fig. 7. Filling velocity and filling vectors

Fibre orientation is directly connected with the velocity vectors which are shown in Fig. 7. An important parameter for filling is the position of the gate and contact with the walls. The walls can be considered as a boundary condition for material flow.

5. Conclusion

The influence of the gate position is described in depth in this paper. This position influences the final properties of the product. Gates should be placed in areas where all the points of the product are filled at a comparable velocity. Analysis of the filling velocity shows the influence of the walls, which decrease the velocity of the flowing material. The walls also decrease the temperature of the material, which leads to freezing of the material near to the corners.

Mechanical properties are also influenced by filling, because short fibres and macromolecules in the final product are formed in the direction of the filling velocity. The filling of a simple brick was used as an example. Pin gates and tunnel gates are often used and are briefly described in this article. The main aim is to show the importance of gate location. It is easier and cheaper to simulate a mould-flow analysis with different locations of gates than to make changes in a real steel mould. Future work will continue with real testing of this brick in terms of its mechanical properties.

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7. References

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