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Review

Surface quality of PVC fittings based on the design of the sprue

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ABSTRACT

The prediction of the surface quality of injection parts supposes a great advantage, because it can avoid the optimization of the product by trial-and-error methods, i.e., by the modification of the mould and the process parameters, both expensive and time-consuming. In the injection of polyvinyl chloride (PVC) fittings, a blush around the gate appears; this defect is produced by the design of the feeding system as much as the injection conditions. To improve the overall quality of PVC injection moulded components, the influence of the feeding system is analyzed through the design of two different sprues. Since it is important to analytically predict the blush produced by each sprue, computer-aided engineering (CAE) simulation and experimental injection tests have been performed. The correlation between the variables obtained by both methods, such as flow temperature and shear stress, allows to determine which factors are responsible for the surface defect and to choose the right sprue. The procedure followed can be applied to analytically check the suitability of other gate injection designs.

Contents

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1. Introduction

Injection moulding is the most commonly used process to produce parts with high product rates and good control of the product dimensions, but it must be taken into account that the aesthetics of a plastic part are often as important as its dimensional quality. The achievement of a proper surface quality can avoid extra manufacturing tasks to improve part appearance, implying a cost reduction, but the process of filling a cavity mould with a plastic melt is complex owing to the many variables that exist and their interdependence. Nowadays, CAE techniques are used to simulate the injection of plastic parts and a good agreement is obtained between experimental and analytical results, in the prediction of process conditions such as injection pressure, clamp force, location of injection points, and weld lines. For instance, Dairanieh et al. (1996) correlated Moldflow's computed viscosities with the experimentally measured reduction in the strength in the weld-line area of a poly(methyl methacrylate). Moldflow and Cflow were used by Chun (1999) to check several designs of a polystyrene flask in order to eliminate the bubbles and a long visible weld line, often occurring during the injection of the part. To reduce product development time and to improve product quality, Lam and Seow (2000) developed an automated cavity balancing routine that was implemented in a computer program running as an external loop to the Moldflow software. In addition, mould-filling software can help to optimize part wall thicknesses, gate locations, materials, or part geometry. To understand the flow behaviour of the plastic melt in the mould cavity, Özdemir et al. (2004) designed an injection mould to record the real flow behaviour of PP and HDPE during the injection of a part. They found that the experimental melt front profiles were similar to the ones calculated by Moldflow. Koszkul and Nabialek (2004) analyzed different rheological models to determine the proper viscosity model that provided the most reliable results of the injection of a part, and Shen et al. (2002) found the optimal process conditions and material for the injection of a thin shell by means of Moldflow. However, it is a challenge to foresee the surface quality of a part that depends on the injection parameters as much as on the design of the gate.

One surface defect that appears in some materials, for example, acrylonitrile butadiene styrene (ABS), polycarbonate (PC), or PVC, is a blush around the injection point of the part, and if this flaw is in a visible place, it can make the part useless. In consequence, research in this field has been performed by several authors. Serrano (1994) studied the stress around the gate of injected ABS plates and found that the surface quality of that zone improves with low injection rate and high melt temperature. Regarding the use of additives, Price et al. (1992) found that the addition of an organophosphorous additive to an impact-modified polycarbonate reduces the white mark by about 25%; further, as investigated by Stevenson and Einhorn (1993) the use of acrylic aids in rigid PVC of molecular weight higher than the PVC improves the cohesion of the material and this property is believed to be in connection with the reduction of the white mark around the injection point, because in this case the material can better bear the high stress at that zone. Finally, Weir (1994) studied the prediction of surface defects in injected PVC components by means of the commercial simulation software C-Mold, and the checking of the theoretical results with experimental tests establishes a correlation between the white mark and the limit shear stress.

The aim of this paper is to know, for PVC fittings, the relation that exists between the design of the sprue and the surface quality around the injection point. To completely understand the PVC moulding process and achieve the maximum degree of injection control that has a positive effect on the aesthetics of the finished product being moulded, it is important to be able to properly simulate the injection process. This will be carried out by the injection analysis of a prototype part representative of a PVC fitting. Injection moulding software packages will be used to simulate the filling and packing phases, and this study will be complemented with experimental injection tests, where the flow temperature inside the mould is controlled. The correlation of the theoretical and experimental results will let us check the numerical method, establish the cause of the blush, and determine which sprue design is more suitable to improve the cosmetics of a PVC part.

2. Experiments and simulation

2.1. *Material specifications*

The polymer considered in this study is a rigid PVC of Solvay Benvic IR705, which is a standard material used for the injection of PVC fittings. The following are some of the properties used for the simulation:

- Density = 1320 kg/m^3,
- Conductivity = 0.13 W/(m °C),
- Glass transition temperature = 79–80 °C,
- Specific heat = 1767 J/(kg °C).

Table 1 also lists the rheological characteristics. The critical shear rate and the degradation temperature are about 0.2 MPa and 215 °C, respectively.

2.2. *Part geometry*

The prototype part used was a semi-cylinder with a central sprue (see Fig. 1). This geometry has been chosen because it represents the shape of the fittings and the way the flow enters into the cavity, besides the mould being easier to manufacture and the location for a temperature sensor being more accessi-