

An approach for predicting the correct geometry and parameters of the sprue system of an optical disc mould by use a computer aided design and simulation

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Abstract

3D CAD models of different variants of the sprue system design of an experimental optical disc mould are developed. The main purpose of the present work is to be predicted the correct geometry shape and parameters of the sprue system before these elements to be produced. The 3D CAD models are built as a combination of the polymer substrate and the sprue system, considered as one object. This approach allows achieving a precise design of the sprue system, before to import the 3D CAD model in the computer simulation program. Different variants of the sprue system design are defined and three parameters are chosen as variables: the gate length and depth and the sprue draft. By means of iterative steps in the frame of the mould filling simulation software, correct variants of the gate geometry and parameters and the processing conditions are achieved. The best results are obtained using the new proposed sprue system with symmetrical melt distribution area.

Keywords: optical disc substrates, computer simulation, optical disc mould, 3D CAD model

1. Introduction

1.1. Optical disc moulding

Optical data discs have become increasingly used for information storage in recent years. The disc is composed of an optically transparent substrate, with injection moulding as the primary manufacturing process.

The experience gained up to now in injection moulding of substrates for optical discs has shown that the mould occupies a central place and is the most significant part in the production process. The obtaining of the geometrically simple substrate, being a circular washer with width of 1,2 mm, diameter of the central hole 15 mm and external diameter varying from 120 mm up to 300 mm, together with the necessity for precise copying of the information structure with the help of a stamper set in the mould, the accuracy of the geometric dimensions and the low level of birefringence, imply high requirements towards the mould connected with precise construction and tolerances of the order of microns [1,2].

1.2. Definition of the technical problem in the optical disc moulding

In the process of injection moulding of optical disc substrates, a hot polymer melt is injected in the thin cooled mould cavity under high speed and pressure with the help of a circle gate located in the cavity centre. This practically means that substrate indicators such as birefringence, residual tensions and copying of the information structure are highly dependent on the behaviour of the melt flow, filling the mould cavity. It becomes clear that great internal tensions are available in the final product as a result of improper location, form and dimensions of the circle gate, which result at the end in high level of the main indicator for substrate quality - the birefringence. It follows from this, that the construction solution and the scheme of the circle gate location play a significant role in the quality of the final product [3,4].

A "statement of the problem" for optical disc

moulding starts with the fundamental difficulty of filling and packing a mould cavity of much greater length than depth, without incurring high levels of moulded-in stress and orientation. For instance, a 120 mm diameter erasable media disc, which is 50 times longer melt flow path than part thickness [5,6,7,8]

In spite of the progress in this area, the approach applied up to now by different manufacturers in solving the problem of cavity filling and formation of the central hole substrate has not declined from the basic method - filling through a thin film circle gate located at the place where the central hole is to be formed. This requires the use of a complex and precise cropping punch system, removing the circle gate, in order to form the central hole. On the other hand, the necessity to shape the central hole by punching, calls for minimal depth of the circle gate enabling its easy removal. This approach influences badly the level of the product internal tensions and the orientation phenomena, accompanying the process of filling [9,10].

1.2. Computer simulation in the optical disc moulding

Mould-filling computer programs have had success in predicting filling behaviour in extremely complicated geometries, assisting in gate placement, runner sizing, clamp-force requirements [11,12].

Computer simulation is occupying a significant role in the most of the recent papers, which consider the optical disc moulding, but they concern mainly the advantages of the program or the creation of nonlinear viscoelastic models without an analysis of the influence of the concrete sprue system geometry on the mould filling process. Probably, the reason of this is that the sprue system is the key for useful optical disc moulding and its design represents Know-How of the companies, working in this area.

In the present work 3D CAD models of an experimental optical disc mould and different variants of the sprue system are developed in respect to be used for predicting the correct variants of the sprue system design before these elements to be produced. Another purpose of our work is to give a possibility for future investigations

of the influence of the sprue system geometry and dimensions on the mould cavity filling by use computer simulation techniques.

2. 3D CAD models of the optical disc mould and the sprue system

The 3D CAD model of an object is the first stage, when computer simulation techniques are used. A flow chart of the stages, necessary for the purpose of the present work is developed (see Fig. 1).

The mould design concept is based on the special design features of the really used at the moment optical disc moulds, in which the central hole of the polymer substrate is formed by direct punch of the circle gate. On the base of the existing authors punch system, which allows to the central hole of the polymer substrate with a greater gate depth to be formed, the sprue system design concept with different values of gate depth is proposed [3].

As a first step, a 3D CAD model of the experimental optical disc mould is developed (see Fig. 2). For all of the 3D CAD models SolidWorks 2006 software is used. The injection mould consists of moving left and fixed right halves. A single mould cavity between them is formed, representing an accurate copy of the polymer substrate.

On the base of the 3D CAD model of the mould, 3D CAD models of the sprue system and the polymer substrate are developed (see Fig. 3 and Fig. 4). Usually, a 3D CAD model of the object is developed and then the sprue system is built in the frame of the computer simulation program. In this way it is impossible the sprue system design to be precisely formed. For that reason an integrated 3D CAD model of the sprue system and the polymer substrate, considered as one object is obtained. The sprue system consists of a central sprue, melt distribution area and a circle gate (see Fig. 3).

Two main variants of the sprue system design are developed which differ by the geometry shape of the melt distribution area. The first variant presents the typical sprue system with a conventional shape of the melt distribution area (see Fig. 3). As a special feature of our work the second variant of a sprue system with symmetrical shape of the melt distribution area is proposed (see Fig. 4 and Fig.7).

For the purpose of our analysis the following parameters of the sprue system are chosen as variables: D1 (gate length), D2 (gate depth), D3 (sprue length), D4 (sprue draft) and D7 (see Fig. 3, Fig. 4).

3. Mould filling simulation and results

For a primary verification and investigation of the advantages of the 3D CAD models, a mould filling simulation program MoldflowXpress (integrated with SolidWorks) is used. The program is an entry-level mould filling simulation tool, which can predict whether the injection moulding will be successful. The algorithm is based on the gate geometry, the plastic injection location, the type of plastic material and the processing conditions (melt temperature, mould temperature and injection time). A correct analysis of the results allows to predict the effectiveness of the mould filling using different geometry parameters of the sprue system.

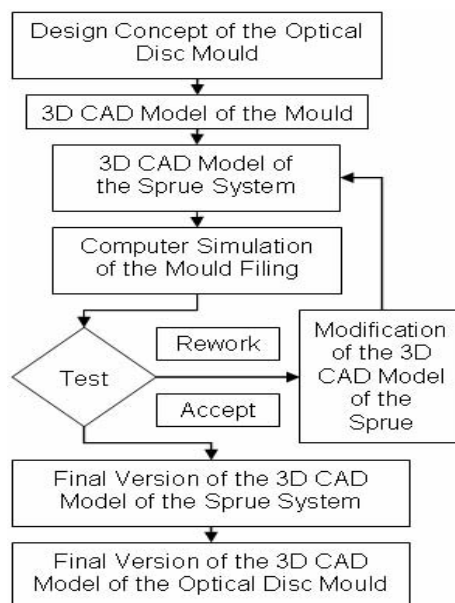


Fig. 1. Flow chart of the investigation scheme.

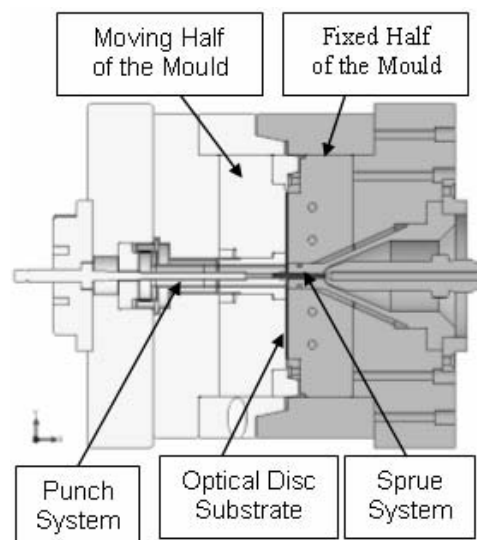


Fig. 2. 3D CAD model of an experimental optical disc mould.

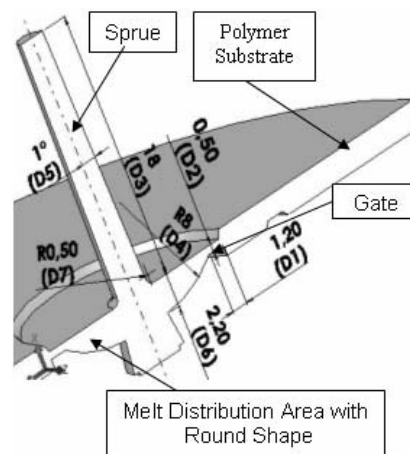


Fig. 3. 3D CAD model of the sprue system with conventional round distribution area.

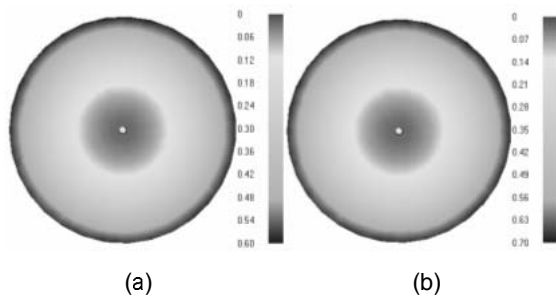


Fig. 10. Mould filling simulation: D1 (gate length) = 0.6 mm; D2 (gate depth) = 0.4 mm; D3 (sprue length) = 26 mm; D4 (sprue draft) = 2° (see Fig.7); a) $T_{melt} = 280^\circ\text{C}$, $T_{mould} = 80^\circ\text{C}$; b) $T_{melt} = 300^\circ\text{C}$, $T_{mould} = 100^\circ\text{C}$.

The results show that the mould cavity can be easily filled with uniform and complete mould filling for all of the selected variants of processing conditions (T_{melt} ; T_{mould}) when the sprue system with symmetrical melt distribution area and the sprue geometry parameters D1 (gate length) = 0.6 mm, D2 (gate depth) = 0.4 mm, D3 (sprue length) = 26 mm and D4 (sprue draft) = 2° are used (see Fig. 10).

4. Conclusions

3D CAD models of an experimental optical disc mould and the sprue system are developed in order to select the correct variants of the sprue system design. Possibilities for easy change of the geometry shape and dimensions of the sprue system are achieved.

A special feature of our study is that the 3D CAD model of the sprue system is designed as a combination of the polymer substrate and the sprue system, considered as one object. This allows a precise design of the sprue system to be obtained before to import the 3D CAD model in SolidWorks. The proposed 3D models are verified with the simulation software MoldflowXpress. Two main variants of the sprue system design with two different geometry shape of the melt distribution area are proposed. The following parameters of the sprue system are chosen as variables: the gate length and depth and the sprue length and draft.

The results of the investigations show that small changes of the sprue system parameters provoke essential influence on the possibility to fill the mould cavity. The suitable combination of the gate and the sprue length to assure easy mould cavity filling is achieved. The results show that the existing sprue systems do not allow achieving a complete, uniform and easy filling of the mould cavity, especially at low values of the melt and mould temperatures.

By means of iterative steps during the simulation procedure, the correct variants of the sprue system geometry and dimensions and the processing parameters are obtained. The best results are achieved by use the new proposed sprue system with symmetrical melt distribution area.

The presented approach and the 3D CAD models of the sprue system can be used as a base for future development of the mould filling simulation, oriented to determine more precisely the resulting injection pressure and the temperature distribution.

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