

A System for Computer-Aided Gating Design for Single and Multi-Cavity Injection Moulds

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Abstract - Design of injection moulding dies (called moulds) is a time consuming and complex activity that requires domain knowledge and vast experience of the die-designer besides information about manufacturing resources, part geometry, number of cavities, etc. The gating design is of great importance for reducing lead time and cost of part produced and to achieve first-piece-right. The gating design encompasses several steps, involves complex computational work, and requires a number of iterations. In the present research work an attempt has been made to develop a computer-aided system, which facilitates gating design of an injection mould taking part CAD file as input. The gating parameters are calculated by taking part geometry, material and number of cavities as input. The proposed system is divided into three modules, namely Gate design, Runner design and Sprue design. To demonstrate the capabilities of proposed system, it was tried for a number of parts and the results for two industrial case study parts are presented. Proposed system is a step forward to design-manufacturing integration for injection moulding process.

Keywords: Injection Moulding, Mould Design, Multi-Cavity, Gating Design, Computer-Aided Design.

I. INTRODUCTION

Injection moulding is one of the most widely used production processes for producing plastic parts with high production rate and little or no finishing required on plastic products. In this process, molten polymer is injected under high velocity into the mould, where it is solidified and cooled to get desired shape component. The injection moulding machine with mould cavity and mould is shown in Figure 1. Injection moulding process is used to produce many household appliances, automotive and industrial parts.

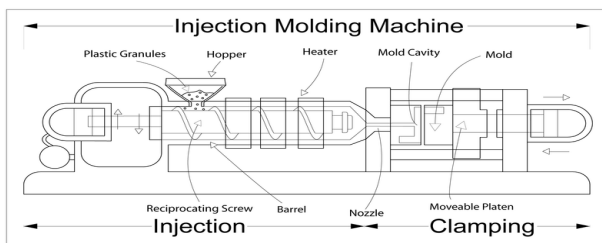


Fig. 1 Injection moulding machine

The main function of the gating system is to deliver molten polymer to all mould cavities at equal pressure and temperature. Poor gating designs can lead to defects such as gas porosity, shrinkage porosity, flow line cold shut, and poor surface quality.

The gating system design refers to the design of its various elements, such as gate, runner, and sprue, which are discussed in next section. The design of a gating system is crucial because not only it affects manufacturing of the mould but quality and cost of the part produced also.

Previous research works [1-6] on computer-aided gating design for injection moulding process provide good insight on determination of gating parameters and optimization of gating elements. Less attention was given by previous researches on determination of gating parameters for multi-cavity moulds.

This paper presents a new system, which helps the mould designer to design gating system of single and multi-cavity moulds for injection moulding process. The system takes part geometry and material information from part CAD file and display gate, runner and sprue type with dimensions.

Rest of the paper is divided into the following sections. Section 2 discusses the elements of gating system. Section 3 deals with the determination of gating system parameters. Section 4 discusses the system implementation and industrial case studies. Lastly, Section 5 discusses conclusions drawn from this research work.

II. ELEMENTS OF GATING SYSTEM

Figure 2 shows various elements of gating system of an injection mould, which are briefly explained in the following paragraphs.

Gate: It is the entry point for the molten polymer to the cavity. It is the smallest opening in the molten polymer flow path. Several types of gates are used in injection moulds according to their shape, size and application preferences.

Runner: To connect the sprue with the entrance of gate to impression, the runner is a channel machined into the mould plate. A runner can be divided into two sections:

- **Main-runner:** The main runner is the passage, which connects the sprue to the branch-runners
- **Branch-runner:** The portion of the runner which connects main-runner to the gate is known as a branch-runner. A branch-runner leads the polymer into the die cavity through the gate.

Sprue: Sprue is described as a channel from where molten polymer enters and flows into runner.

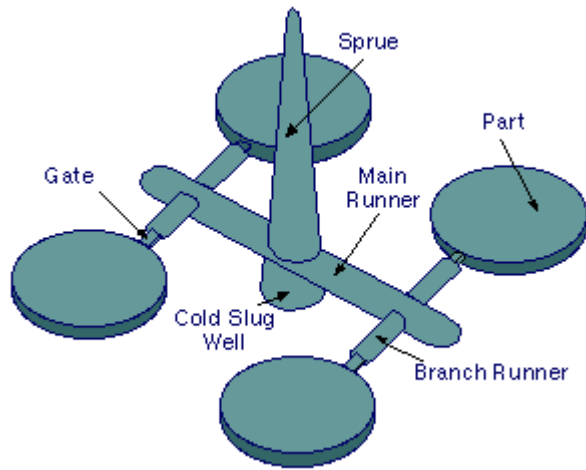


Fig. 2 Elements of the gating system of an injection mould

III. DETERMINATION OF GATING SYSTEM PARAMETERS

While designing a gating system for an injection mould a number of guidelines need to be taken care of, most of which are based on the physics of the process and industry best practices. To take care of this aspect a number of guidelines have been compiled based on the information available from the published literature and understanding industry best practices.

- Always try to gate into that part which has the greatest wall thickness.
- Round parts, should be gated centrally such as gears.
- Use a diaphragm gate or three-plate mould. This will ensure that the parts are balanced and round.
- Multiple cavities always place the gates symmetrically in relation to the sprue. This is critical for injection molding plastic parts.
- Parts that are cup-shaped, such as capacitors, should be gated near the base. This will help avoid gas build-up and burning.

The determination of parameters of the gating system elements, namely gate, runner and sprue is discussed here.

A. Gating parameters

In this section the procedure to calculate parameters of the gate, runner, and sprue are discussed. The system uses the bottom-up approach to determine the gating system parameters, in which parameters of the gate are determined first, followed by determination of parameters of other gating system elements, namely runner and sprue.

1. Gate parameters

The determination of gate parameters, namely gate area, gate thickness, and gate width, which are critical for the injection speed of the molten metal are using Equation 1, 2 and 3.

$$\text{Gate Area} = \frac{\text{Total volume of cavity}}{\text{Gate velocity}} \quad (1)$$

$$\text{Width of gate} = \frac{n \times \sqrt{\text{Gate Area}}}{30} \quad (2)$$

$$\text{Gate Thickness} = \frac{\text{Gate area}}{\text{Gate width}} \quad (3)$$

TABLE I SELECTION OF MATERIAL CONSTANT (N)

Group No.	Name of Polymer	Density (gm/cm ³)	Constant (n)
1	Polythene, Polystyrene	1.05	0.6
2	Polyacetal, Polycarbonate	1.21	0.7
3	Cellulose, Acetate, Nylon	0.941	0.8
4	PVC	1.38	0.9

TABLE II DECISION CRITERION FOR SELECTION OF GATE TYPE

Cavity Type	Single Cavity		Multiple Cavity						
	Manual	Automatic	Manual	Automatic					
Gate Thickness	0.2 ~ 1.49	< 1.5	0.1 ~ 1 mm	0.1 ~ 0.59	0.6 ~ 0.99	< 1	0.1 ~ 0.99	1 ~ 1.59	< 1.6
Gate Type	Diaphragm Gate	Tab Gate	Pin Gate	Film Gate	Fan Gate	Star / Edge gate	Flash Gate	Submarine Gate	Ring Gate

The total volume of cavity is taken from CAD file of the part, gate velocity is chosen by user considering various factors and material constant (n) is taken from material database shown in Table 1. Selection of gate type is based on gate thickness. System automatically displays the name of gate type for a given part based on decision criterion shown in Table 2.

2. Runner parameters

The function of a runner is to deliver the metal to the gate and to generate the desired flow pattern within the cavity. The ratio of the runner area to gate area varies with the part design, which usually ranges between 1.1 and 1.4. However, a larger ratio of 1.6 is used in the case of small parts. The system takes runner area as 1.4 times of gate area by default.

Various types of runner used in injection moulds are listed in Table 3 as per their efficiency. Selection of type of runner is done by designer based on his experience. Diameter of runner is calculated by using Equation 4.

TABLE III RUNNER TYPES AND THEIR EFFICIENCY

S. No.	Runner Type	Priority (As per Efficiency.)
1	Modified Trapezoidal (R=D/2)	1st
2	Trapezoidal (D=W)	2nd
3	Round (D)	3rd
4	Hexagonal	4th

$$\text{Diameter of Runner} = \frac{\sqrt[3]{\text{weight of moulding}}}{3.7} \times \sqrt[3]{\text{length of runner}} \quad (4)$$

3. Sprue parameters

Sprue is a taper channel that is connected with main runner at one end, and another end is used to receive the molten polymer. In the present system, standard sprue is selected by the designer and polymer receiving hole diameter is calculated as per the Equation 5.

$$\text{Diameter of polymer receiving hole} = \text{Runner diameter} + 2 \times L \times \tan A \quad (5)$$

Where, L = length of sprue selected by the designer; A = tapered angle (2° to 5°)

IV. SYSTEM IMPLEMENTATION AND INDUSTRIAL CASE STUDIES

The development platform for the system for gating system design for single and multi-cavity injection mould is Windows 7 with programming in Microsoft Visual Basic 6. The system has been successfully tested on number of parts. Results of two parts taken from industries are presented to show its capabilities.

A. Case Study 1

The plastic part taken in this case study is a household appliance part which is shown in Figure 3. The characteristics of the part are: PVC material, having volume of 129552.27 mm^3 and surface area of 45628.18 mm^2 . Number of cavity for this part is single.

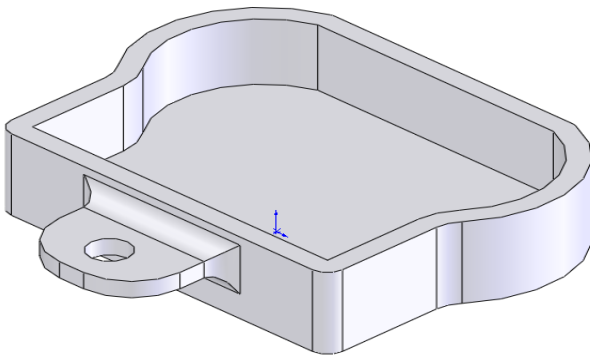


Fig. 3 Case study part model 1

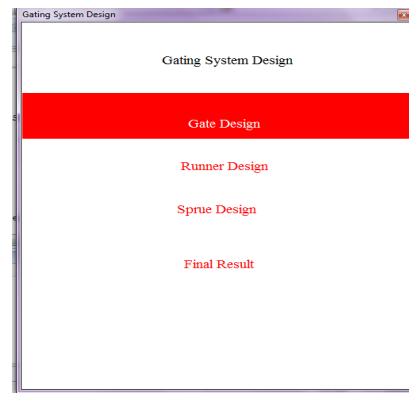


Fig. 4 GUI of developed system

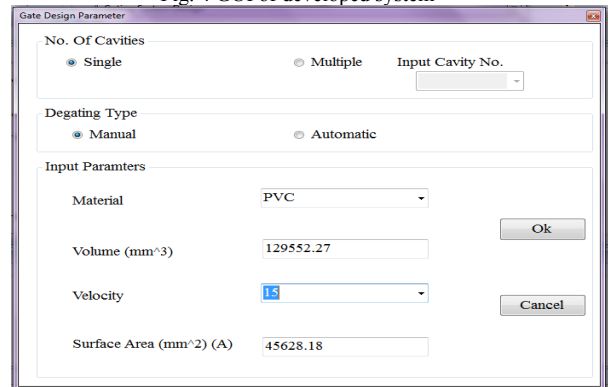


Fig. 5 Input process data window

Figure 4 shows the graphics user interface (GUI) for the developed system and Figure 5 shows the input process data window. User need to select number of cavities, degating type, surface area and volume of part model. Figure 6 and 7 shows the runner and sprue design window respectively. Figure 8 shows the final results of gating parameters for Case study part model 2.

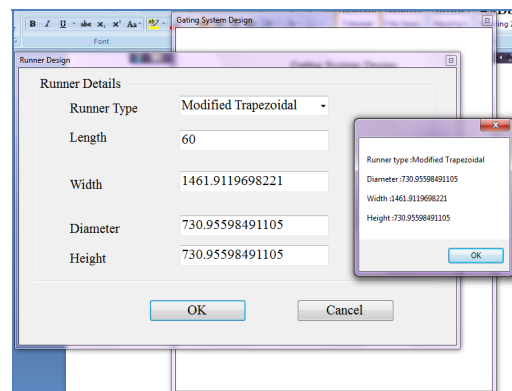


Fig. 6 Runner design window

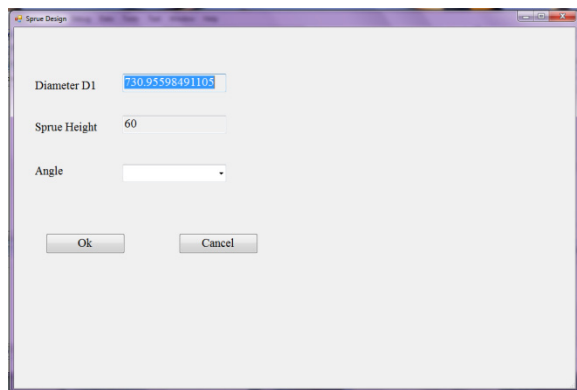


Fig. 7 Sprue design window

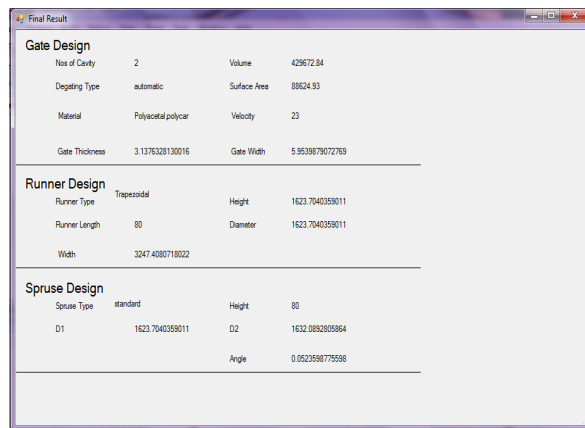


Fig. 10: Final results of gating parameters for case study part model 2

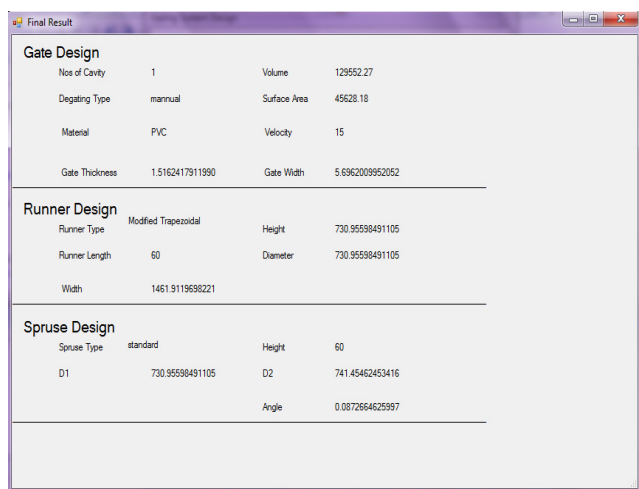


Fig. 8 Final results of gating parameters for case study part model 1

A. Case Study 2

The plastic part taken in this case study is an automotive part which is shown in Figure 9. The characteristics of the part are: Polycarbonate material, having volume of 214836.42 mm³ and surface area of 88624.93 mm². Number of cavity for this part is two. Figure 10 shows the final results of gating parameters for Case study part model 2.

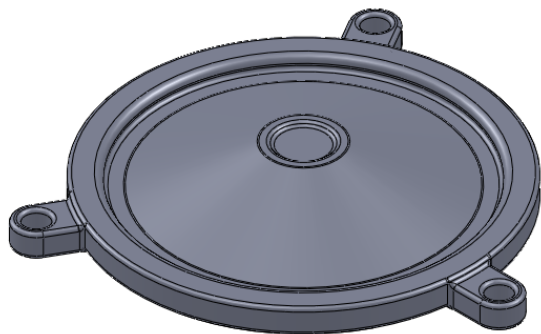


Fig. 9 Example Part Model 2

V. CONCLUSIONS

A system for the gating system design for single and multi-cavity injection moulds has been developed. The gating system design guidelines and the determination of gating system parameters in a selected cavity layout are discussed in detail. The developed system uses CAD part file along-with the user interaction to determine parameters of the gating system for a multi-cavity injection moulds using a gating library. The developed system is tested for industrial parts and results of two case study part are demonstrated. The developed system proves to be an effective tool in the hands of a die-designer. Development of 3-D gating design system is highly desirable in injection moulding industries better visualization and accuracy. Improvements in the system are being attempted in this direction to make it more useful.

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