Balancing gate and runner systems for a family mold using CAE tools

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Abstract

Various problems have been found in the plastic injection industry recently. One of the major obstacles is a balancing of gates and runners in a family mold due to lack of clear understanding of the flow behavior of plastic in the mold resulting in overpacking, short shot or any other defects on the parts. The objective of this research is to investigate the effects of gate size and a runner balance system for a family mold. In this work, the simulation from the Computer Aided Engineering (CAE) technique was performed. Different sizes of simple geometric parts were selected as a case study for a family mold with three cavities. Moldex3D was employed to analyze the plastic feeding system i.e. sprues, runners and gates. The simulation results were obtained as a useful guideline for balancing of gate and runner system for a family mold. Consequently, a numerical tool simulating plastic injection processes can assist mold designers to design molds and to optimize the injection processes in order to avoid any defects such as warp, weld lines and air traps before manufacturing the molds.

Introduction

The mold and part design of plastic parts for injection molding is a complicated and time-consuming process. Some commercial software packages are able to simulate and optimize the injection process. The computer-aided engineering (CAE) tools have been widely used to optimize the injection process variables such as the shrinkage prediction, the minimum pressure or the determination of the weld lines [1-5]. In addition, the results from CAE tools can thus reinforce the ones from the rules that have been established by experts throughout decades of work.

In this work, Moldex3D was employed to analyze and balance the feeding system for a family mold with three cavities of simple geometric parts. The effects of runner size, gate size, and type of material on balancing the feeding system were studied.

Computer modeling details

The rectangular plates of 40x40 mm, 50x50 mm, and 60x60 mm with the same thickness of 5 mm have been chosen for the analysis and defined as *part I*, *part II* and *part III*, respectively. The gates of the runner are edge gates attaching to the part along its perimeter. Three-node triangular elements with 1 mm sides were used to generate the mesh of the parts and tetra and prism elements for the runners. The quality of the mesh for parts and feeding system was shown in terms of the aspect ratio in **Table 1**. All the mesh in the geometry model has been improved until the average value of aspect ratio for all elements approached 1.0. **Fig. 1** shows the geometric model and the runner system for three cavities family mold at the initial stage with runners of 6.5 mm in diameter and gates of 3 mm in diameter.

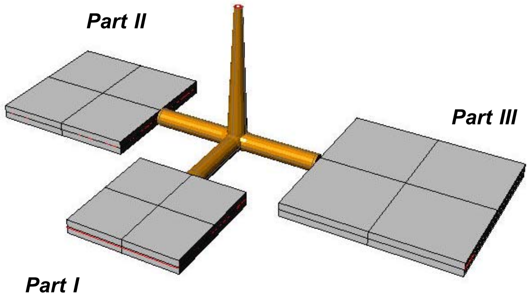

Fig. 1. Analyzed geometric model and the runner system.

Mesh geometry of the three parts with 9098 nodes and 63,728 elements is illustrated in **Fig. 2**.

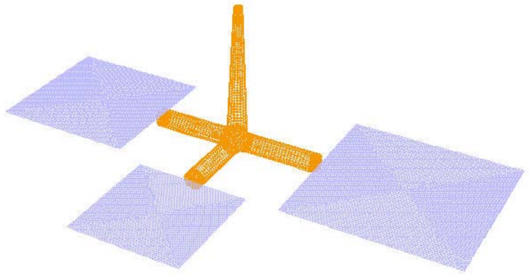

Fig. 2. Mesh geometry of the parts and the runner system.

Table 1: Aspect ratio of feeding system in solid mesh

Category	Solid mesh for feeding system	Surface mesh for cavity parts
Average Value	0.88	1.00
Total Element Count	10354	17590
Total Node Count	5687	9098

The material used was CAE-313, a polycarbonate for the process of balancing gate and runner system. Material properties of PC (CAE-313) and process conditions for the analysis were listed in **Table 2**. Five more materials which were ABS (AF-303), PC (Makrolon2458), and PS (STYRON666D), PMMA (LUCITE-140), and PE (GUR-4120) have also been used in order to examine the influence of material properties in the process of balancing gate and runner system. The Battenfeld TM500/210 with a maximum injection pressure of 204.2 MPa and a clamp force of 50 ton was used for the simulation.

Table 2: Material properties and process conditions.

Description	Values
Material (genetic name)	Polycarbonate
Manufacturer's name	CAE-313
Melt temperature (°C)	305
Mold temperature (°C)	70
Maximum injection pressure (MPa)	204.2
Injection Volume (cc)	47.43
Injection time (s)	2
Packing time (s)	1
Maximum Packing pressure (MPa)	204.2
Clamp force (ton)	50

Results and discussion

Gate and runner sizes are the main variables in this study in order to balance the feeding system and achieve the identical delivery of melt to each cavity. In this analysis, lengths of runners from the sprue to each cavity were fixed at 30 mm and no cooling channels were introduced. Diameter of gates (ϕ_g) and diameter of runners (ϕ_r) to each cavity have been varied. The subscript *1*, *2*, and *3* were defined for *part I*, *part II*, and *part III*, respectively.

The effects of gate and runner sizes to the fill time differences, maximum (T_{max}) and minimum (T_{min}) fill time between the cavities at the end of the filling processes are shown in **Table 3**and **4**. It is desirable that the delivery of melt to each cavity is identical in a multicavity mold, thus, the fill time differences at the end of the filling processes, should approach zero in order to avoid incomplete cavity filling or premature freezing during the packing, or compensation stage. It is obviously shown that gate and runner sizes vary proportionally to the size of cavity. Varying only runner sizes may not overcome the unbalanced system as can be seen from the results in **Table 3** compare with the ones in **Table 4** that the feeding systems were balanced by varying both gate and runner sizes simultaneously. The diameter of gates and runners to each cavity for the balanced feeding system of analyzed three cavities mold are ϕ_{g1} = 2.8, ϕ_{g2} = 3.4, ϕ_{g3} = 3.9, ϕ_{r1} = 6.5, ϕ_{r2} = 7.0, and ϕ_{r3} = 7.5 using PC (CAE-313). **Fig. 5** and **6** show the melt front time for the unbalanced (initial stage) and balanced system, respectively.

Type of materials also affected the gate and runner balancing for a family mold as can be seen from **Table 5**. Different types of materials were used with the balanced feeding system for PC (CAE-313) and it is shown that the balanced feeding system analyzed with one material may not be used with other materials.

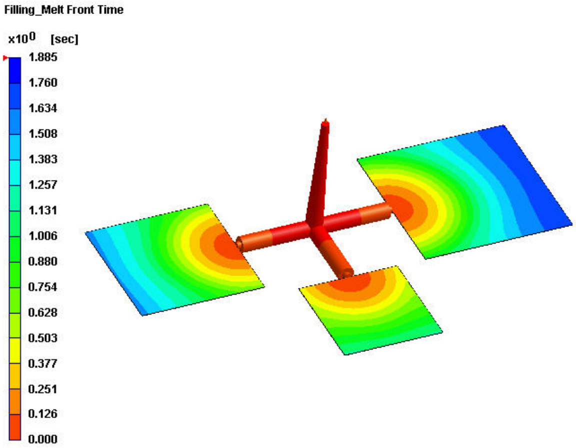

Fig. 3. Melt front time in each cavity for the unbalanced system at the initial stage.

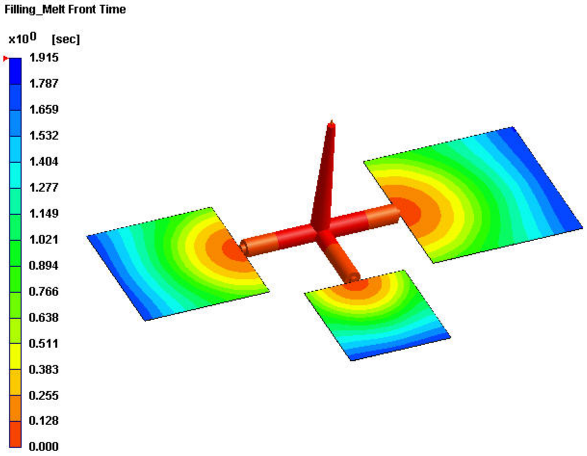

Fig. 4. Result of filling melt front time in the three cavities mold after balancing.

Table 3: The diameter of runners to each cavity and fill time differences between the cavities with fixed gate diameters of 3 mm.

$\phi_{r1}, \phi_{r2}, \phi_{r3}$	T_{max}-T_{min} (s)
6.5, 6.5, 6.5	*0.3292*
6.5, 7.0, 7.5	*0.2025*
6.5, 7.2, 7.5	*0.1919*
6.3, 7.3, 7.5	*0.1356*
6.2, 7.3, 7.5	*0.1098*
6.1, 7.3, 7.5	*0.0967*
6.0, 7.2, 7.5	*0.0875*
6.0, 7.2, 7.4	*0.0963*
6.0, 7.0, 7.5	*0.0879*

Table 4: The diameter of runners (ϕ_{r1}, ϕ_{r2}, ϕ_{r3}), gates (ϕ_{g1}, ϕ_{g2}, ϕ_{g3}) and fill time differences between the cavities at the end of the filling processes.

$\phi_{r1}, \phi_{r2}, \phi_{r3}$	$\phi_{g1}, \phi_{g2}, \phi_{g3}$	T_{max}-T_{min} (s)
6.5, 6.5, 6.5	3.0, 3.0, 3.0	*0.3292*
6.5, 6.5, 7.0	3.0, 3.0, 3.0	*0.2848*
6.5, 6.5, 7.5	3.0, 3.0, 3.0	*0.2484*
6.5, 6.5, 7.5	3.0, 3.0, 3.5	*0.1795*
6.5, 6.5, 7.5	3.0, 3.0, 4.0	*0.1333*
6.5, 6.5, 7.5	3.0, 3.0, 4.5	*0.1584*
6.5, 7.0, 7.5	3.0, 3.0, 4.5	*0.0877*
6.5, 7.0, 7.5	3.0, 3.5, 4.5	*0.0405*
6.5, 7.0, 7.5	3.0, 3.0, 4.0	*0.0167*
6.5, 7.0, 7.5	2.8, 3.5, 4.0	*0.0214*
6.5, 7.0, 7.5	2.8, 3.4, 3.9	*0.0161*

Table 5: Fill time differences between three cavities with balanced gate and runner systems for different types of materials.

Type of materials	**MFI**	T_{max}-T_{min} (s)
PMMA (LUCITE-140)	*1.55*	*0.1083*
PE (GUR-4120)	*2.62*	*0.2026*
PS (Styron-666D)	*12.24*	*0.0433*
PC (Makrolon-2458)	*22.80*	*0.1346*
ABS (AF-303)	*68.74*	*0.1109*

Conclusion

Computer-aided engineering (CAE) tools are very useful for designing the molds and optimizing the process conditions. The variations of the melt front time, the pressure, and the temperature at the end of the filling process have been observed as the parameter for the balancing of feeding system. However, only the melt front time was focused in this analysis in order to achieve the complete cavity filling at the same time for each cavity.

Gate and runner balancing for multicavity mold can be achieved by using CAE tools. There are no exact equations describing the relationship between gate and runner sizes for the balanced system. It depends on many factors such as shape and size of the plastic part, used materials, or the limitation of mold design. Thus, these factors must be taken into account for the analysis of balancing system.

Future Work

The effects of temperature, pressure, runner layout and shape of the plastic parts on the process of balancing the feeding system for multicavity mold will be studied further. Also, defects causing from unbalanced feeding system will be focused.

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