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A Study of High Viscosity Melt Front Advancement at the Filling Process of Injection-Compression Mold

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Injection-compression molding parts are many cases with complicated boundary condition which is difficult to analysis of mold characteristics precisely. In this study, the effects of various process parameters such as multi-point gate location, initial charge volume, injection time and pressure have been investigated using finite element method to fomulate the melt front advancement during the mold filling process. A general governing equation for tracking the filling process during injection-compression molding is applied to volume of fluid method. To verify the results of present analysis, they are compared with those of the other paper. The results show a strong effect of processing conditions as a result of variations in the three-dimensional complex geometry model.

Keywords : Injection-Compression, Filling Process, Melt Front, Finite Element Method

1. INTRODUCTION

Conventional injection molding is unable to meet product design requirements in precision parts that require low residual stresses, such as optical discs, vehicle bumper, the interior things of a door and high-precision moldings. Because injection molding can produce net-shape products with good dimensional accuracy in a very short cycle time, it has become one of the most important polymer-processing operations in the plastics industry today. An alternative processing method is injection- compression molding, which is often referred to as coining, stamping, compressive-fill, or hybrid molding. In injection-compression molding (as shown in Figure 1), the molding cavity initially has an enlarged cross section; this allows flow to proceed readily to the extremities of the cavity under relatively low pressure and stress. At some time during or after filling, the mold cavity thickness is reduced by a compressive force, forcing the resin into the unfilled portions of the cavity and producing a more uniform packing pressure across the cavity. This results in more homogeneous physical properties and less molded-in stresses compared to conventional injection molding.

For the previous studies of injection- compression molding, Siver-Nieto etc[1] and Lee etc[2] studied injection- compression molding flow characteristics. Tucker and Folgar[3] analyzed the compression molding filling process for isothermal Newtonian fluids based on the Hele Shaw's approximation using the finite element method. Many researches have been performed for the injection-compression molding by experimentally and numerically.

However, many researches have been performed for the injection-compression molding, It is not easy to get injection-compression molding parts with anisotropy of materials and complicated boundary condition which is difficult to analysis of mold characteristics precisely.

In this study, we investigated the molding characteristics for injection-compression molding using previous studies. A numerical analysis was performed high viscoelastic flow through a cavity effectively with minimum cost and efforts before making experimental scale models.

2. NUMERICAL ANAYSIS

For the high viscoelastic flow through a cavity in the mold, Most of numerical analyses have been on the Hele Shaw's approximation.[10] The injection-compression mold filling is modeled by a generalized Hele-Shaw flow for an inelastic, non-Newtonian fluid under non-isothermal conditions in similar way.

The incompressible governing equation for the high viscoelastic fluid of flow behavior in general rectangular coordinates is expressed as

$$\frac{\partial h v_x}{\partial x} + \frac{\partial h v_y}{\partial y} = 0 \qquad (1)$$

$$\frac{\partial p}{\partial x} = \frac{\partial}{\partial z}\left(\eta \frac{\partial v_x}{\partial z}\right) \qquad (2)$$

$$\frac{\partial p}{\partial y} = \frac{\partial}{\partial z}\left(\eta \frac{\partial v_y}{\partial z}\right) \qquad (3)$$

3. MELT-FRONT ADVANCEMENT

After a pre-set amount of polymer melt is fed into an open cavity, it is compressed. During the compression, the melt front is advanced. The free surface of the melt-front is obtained from the time variation. For a representation of the melt-front, it is applied the FAN which is used to compute the filled area. For the convenience of computation, the nodes which are shown in fig. 2 can be categorized into three groups in general.

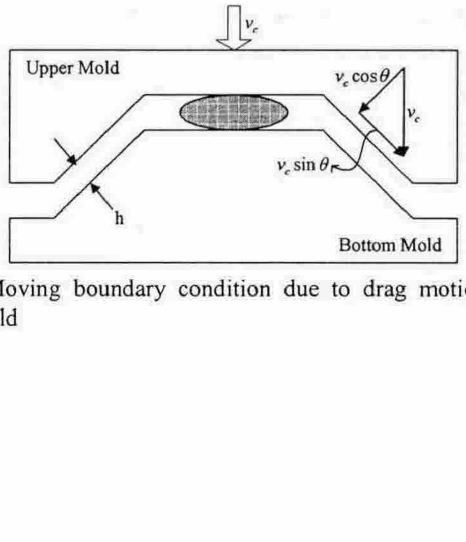


Fig. 1 Moving boundary condition due to drag motion of upper mold

· The filled node : The node is completely filled up the control volume with the resin(f=1).

· The melt-front node : The node is partially filled up the control volume with the resin($0<f<1$).

· The unfilled node : The node is not filled up the control volume with the resin(f=0).

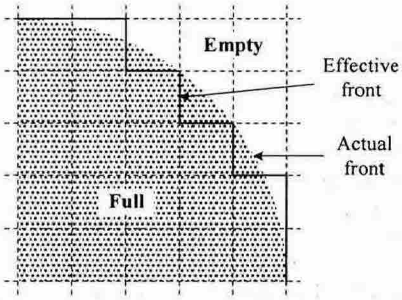


Fig. 2 Node definition for melt front advancement

At any time, we assume zero for the pressure of melt-front nodes, and compute the systems of equation in the numerical methods with the mass conservation. As a result, The volume of high viscoelastic fluid is computed using the control volume of the melt-front node and time interval. According to time interval, f is renovated.

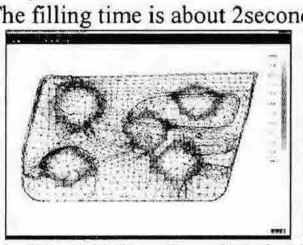
4. RESULT

4.1 Distribution of Melt-Front Advancement

Fig. 3 and Fig. 4 show the filling time distribution of 5 gates system in the front door trim(FDT) and 3 gates in the rear door trim(RDT). It can be seen that the contour interval in Fig 3 became suddenly narrow between the center and the right gate.

It was predicted to occur the melt-front velocity decrease within narrower region than the other regions. As a results, to the short shot and the injection pressure increase cause the clamping force increase and the quality deterioration. So the appropriate injection time and the gates location are selected because of the balance filling pattern. Fig. 4 shows the filling time distribution of 3 gate system in RDT.

In Fig. 4, the contours between gates in the downward RDT are narrow. The right and the left corner of the downward RDT became wider between the contours. Especially, when the resin completely filled at the corners, the pressure at the corners is increaser than the other regions. Therefore, the density increase and shrinkage decrease in the regions cause the problems. such as internal stress increase, stiffness drop. The filling time is about 2second.



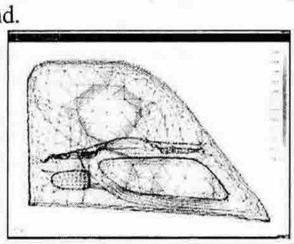
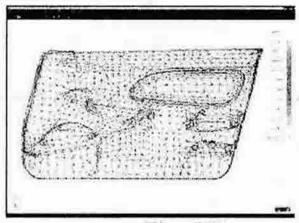


Fig. 3 Filling time distribution of 5gate system in FDT
Fig. 4 Filling time distribution of 3gate system in RDT

4.2 Pressure Distribution

Fig. 5 shows the pressure distribution about the front door trim. In Fig. 5, the pressure distribution at the right upper was lower than those of the other regions. This is due to the unbalanced gate location. The injection-pressure decrease, as a mentioned above, the maximum flow length is maintained short using the number of gate and the gate location. In order to fill the cavity, the required pressure is about 22 MPa.

Fig. 6 shows the pressure distribut- ion about the rear door trim. Polymer melt is injected into the cavity, and compressed by the press(moving platen) at a controlled speed. The high viscoelastic fluid temperature increase. So the high viscoelastic fluid resistance decrease. and the pressure travelled to the mold rapidly. In order to fill the cavity, the required pressure is about 15 MPa.



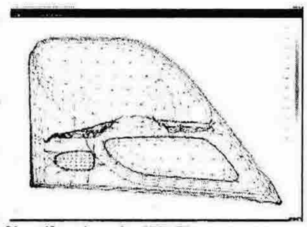


Fig. 5 Pressure distribution in FDT
Fig. 6 Pressure distribution in RDT

4.3 Determine the Initial Thickness

Fig. 7 shows the mold-closing velocity for each element. For the element number 1(*e1*), *se* is equal to the *sm* since the normal direction is at zero angle with the mold-closing one. For the element number 3(*e3*), no thickness change varies with time, since the normal direction is at 90 angles with the mold-closing one. The mold-closing vector is lower at angle with the normal one for the element. so the mold-closing velocity increase.

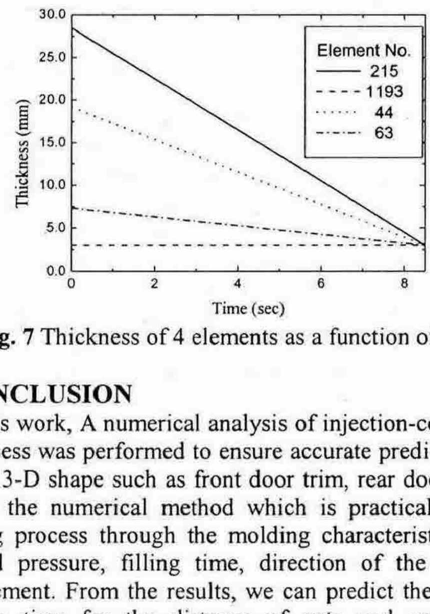


Fig. 7 Thickness of 4 elements as a function of time

5. CONCLUSION

In this work, A numerical analysis of injection-compression fill process was performed to ensure accurate prediction about various 3-D shape such as front door trim, rear door trim. we suggest the numerical method which is practically use the molding process through the molding characteristic such as required pressure, filling time, direction of the melt-front advancement. From the results, we can predict the change of injection time for the distance of gate and position, the required pressure and found out the molding characteristic for the amount of resin which is injected initially.

6. REFERENCES

[1] R. J. Silva-Nieto, B. C. Fisher, and A. W. Birely, Polym, Compos., 1, 14, 1980.
[2] L. J. Lee, L. F. Marker and R. M. Griffith, *Polym, Compos.*, 2, 209, 1981.
[3] C. L. Tucker and F. Folgar, *Polym. Eng. Sci.*, 23, 69, 1983.
[4] Hieber, C. A. and Shen, S. F., *J. Non -Newtonian Fluid Mech.*, 7, P. 1, 1980.