Predicted directions of gas flow in gas assisted injection molding under the geometry of various cavities composed of pipes and runners

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INTRODUCTION

Mold-design should be performed for gas to flow to the intended directions in the gas-assisted injection molding (GAIM). If gas goes in a wrong direction, many problems occur including a phenomenon called "blow through" and another phenomenon called "penetration into thin walled region". If the gas does not enter where it is expected, a problem like sink mark occurs. The control of gas direction is thus one of the most critical aspects in the application of the technology.
The rule of thumb on the direction of gas flow for GAIM has been investigated [Lim and Soh,1999; Soh, 2000; Soh and Lim, 2002] and simulation packages were used to verify the gas direction predicted by the rule of thumb. Lim and Soh [1999] assumed that pressure difference between a gas injection point and appropriate vent areas at both sides of well-maintained molds are equal. Consequently the pressure drops at both sides are equated to compare the resistances and to predict the gas direction. If the resistance in the sentence of "Gas goes to the direction of the least resistance" is the resistance to flow rates, this statement is not always correct. The resistance to flow rates cannot be a criterion in the prediction of gas flow direction in GAIM. Soh [2000] qualitatively treated the special case that the same resistances to flow rates for both sides resulted in the same flow rates for both sides under the geometry that two same set of two different pipes connected in series are located in parallel. Soh and Lim [2002] suggested the definition of the resistance to velocity to predict the gas-preferred direction under the simplest geometry of two different pipes connected at one connection point. However if more complicated geometries are involved, the change of velocity of melt resin becomes unavoidable. Therefore as a rule of thumb more developed-precise definition of the resistance to velocity should be established.

METHODS

1. Theory

The steady state flow of a pseudo plastic liquid through conduit with the radius of R is given by

$$\frac{\Delta p}{2L} = \left(\frac{Q(3n+1)}{\pi n}\right)^n \left(\frac{m}{R^{(3n+1)}}\right) \qquad (1)$$

where

m, n = power law indices
L = length of pipe in direction of flow
R = pipe radius excluding frozen layers adjacent to mold surface
Δp = pressure drop across the distance

It is suggested that a pseudo-plastic fluid through conduit may be treated as a Newtonian fluid in such a qualitative approach as the rule of thumb to determine gas direction in GAIM. The expression of pressure drop of the steady state flow of a Newtonian liquid through a conduit with diameter of *D* is given in terms of average velocity *V* as Eq. (2) by McCabe *et al.* [1986]

$$\Delta p = \frac{32\mu VL}{D^2} \qquad (2)$$

Eq. (2) may be rewritten in terms of flow rate Q as

$$\Delta p = \frac{128\mu LQ}{\pi D^4} \qquad (3)$$

2. Resistance of four conduits with same length and different diameter connected in series and parallel

In such a complex situation as runners or thick cavity of two square plates connected to cavities composed of four pipes with same length and different diameter connected in series and parallel, a developed concept of a criterion in the prediction of gas flow direction of GAIM may be proposed as the resistance to the initial velocity of melt polymer at the nearest geometry to a gas injection point.

Figures 1 and 2 shows a cavity composed of two pipes, pipe 1 and pipe 2, connected in parallel. Thick cavities of two square plates and runners are attached to each side of these pipes for Fig. 1 and Fig 2, respectively. Pipe 1 is composed of pipe 11 and pipe 12 connected in series, and pipe 2 is composed of pipe 21 and pipe 22. These four pipes have the same length and may or may not have the same diameter. The polymer and gas injection points are located at the center of the front side of a thick cavity between two square plates in the left hand side. Pipe 1 is located at the upper side and pipe 2 is at the lower side. Subscript 11 and subscript 12 denote the first pipe and the second pipe from the left hand side at the upper side respectively while subscript 21 and subscript 22 denote the first pipe and the second pipe from the left hand side at the lower side respectively.

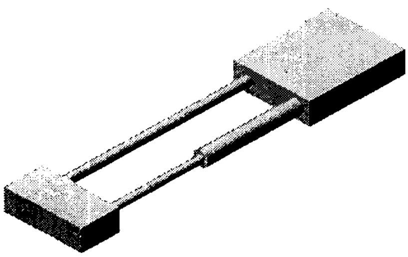

Fig. 1

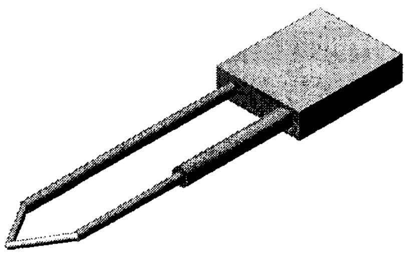

Fig. 2

3. Definition of proposed resistance

The definition of resistance may be developed and proposed to be Ω* of a resistance to the initial velocity of melt polymer at the nearest geometry to a gas injection point while the resistance to flow rate (Ω) was previously defined.

RESULTS AND DISCUSSION

One may consider a situation where a resin fluid is flowing to the direction of right hand side at steady state under such a geometry as in Fig. 1 where, at the upperside, pipe 11 with a diameter of 5 mm and a length of 50 mm is connected to pipe 12 with the same diameter and the same length as pipe 11. At the lower side, pipe 21 with a diameter of 8 mm and a length of 50 mm is connected in series to pipe 22 with a diameter of 4 mm and a length of 50 mm. Then consider the case where the nitrogen gas is injected into the gas injection point after both pipe 1 and pipe 2 are completely filled and a thick cavity between two square plates in the right hand side is partially filled.

The ratio of the resistances to flow rate(Ω_2/Ω_1) becomes less than the ratio of the resistances to initial resin velocity(Ω_2^*/Ω_1^*). However both ratios are greater than unity. In this case it was purely coincident that the path with a higher flow rate was characterized as that with higher initial resin velocity. Figure 3 shows a simulation result of commercial software, Moldflow, that is consistent to the prediction that the gas did not pass through pipe 2 but through pipe 1. All the white region represent the cavity with 100 % polymer, and the colored regions represent the cavity where gas entered. The gas time in colored region shows the time when the gas was reached.

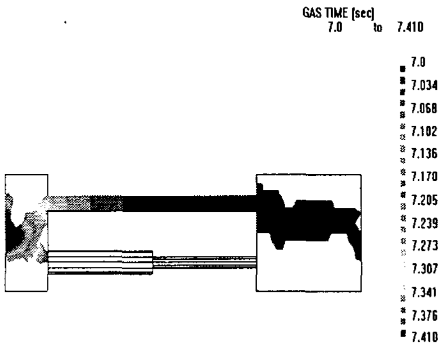

Fig. 3

When the same pipes are used and the lower pipes are flipped horizontally, the ratio of the resistances to flow rate(Ω_2/Ω_1) becomes greater than unity. However the ratio of the resistances to initial resin velocity(Ω_2^*/Ω_1^*) becomes less than unity. Figure 4 shows a simulation result of commercial software, Moldflow. The simulation result is consistent to the result of rule of thumb using the ratio of the resistances to initial resin velocity(Ω_2^*/Ω_1^*). Thus one should not use the resistance to resin flow rate but use the resistance to initial velocities to predict the gas direction since the gas bubble is first seen in the direction of higher velocity. This case shows an example where the least resistance to initial resin velocity should be a required condition to determine the gas flow directions instead of that to flow rates.

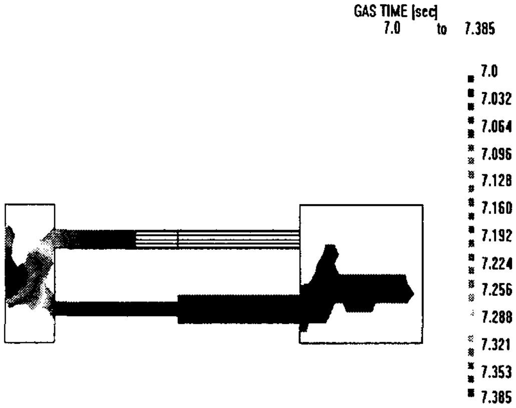

Fig. 4

CONCLUSION

The gas path was predicted to change by flipping the lower side pipes, pipe 2, which was consistent to the result of simulation. Neither the flow rate ratio nor the ratio of resistances to flow rates can be a criterion in the prediction of preferred direction of gas. The resistance to initial resin velocities should be a criterion in the prediction of preferred direction.

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