The Solutions for Reducing the Plastic Flow Hesitation and It's Application for Solving the Defect of Auto Part.

Supachart Thunyakasemsan[1*], Niwat Moonpa[1], Jen-An Chang[2] and Belinda Changkajonsakdi[3]

[1] Mechanics, Materials and Engineering Design Research Group, Rajamangala University of Technology Lanna. 128 Huay Kaew Road, Muang, Chiang Mai, Thailand, 50300

[2] R&D Center for Smart Manufacturing (SMC), Chung Yuan Christian University. 200 Chung Pei Road, Chung Li, Taoyuan, Taiwan, 32023

[3] Mold Technology Center, Thai-Taiwan (BDI) Technological College. 46/7 Village No. 12, Bangplee-Kingkaew Road, Bangplee, Samut Prakan, Thailand, 10540

[*]Corresponding Author: Supachart.thunyakasemsan@gmail.com. Phone Number 06-2929-1451

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Abstract

The hesitation phenomena occur while the molten plastic flows into a cavity with variable thickness. When the molten plastic entering a cavity is filling a thin section and a thick section, the flow velocity of the molten plastic in each area is different, resulting in the flow position difference (FPD). When the flow hesitation happens, defects will occur on the part surface, such as weld line, air trap and short shot, etc. Therefore, the objective of this study is to present solutions for reducing the occurrence of hesitation phenomena by using various thickness design with difference thickness ratio (THK ratio) and injection speed to control the flow hesitation phenomena. Seven basic testing models with different THK ratio (1.2, 1.4, 1.6, 1.8, 2.0, 2.2 and 2.4) combine with different injection speeds are used for simulating. Through the simulation, we can get a different flow hesitation level (Flow Position Difference, FPD). The engineering plastic material ABS is applied for the simulation testing to build up the database and produce the design guidelines. Eventually, the results of this study were used to solve the weld line issue caused by flow hesitation on the actual molding part. The study result shows the THK ratio design is the main effect for the final FPD. The injection speed is a key parameter to reduce the FPD with different THK ratio. In the max THK ratio 2.4 design case, the FPD can be reduced by 70% (from 156.23 mm to 46.56 mm) by speed control. For the actual molding case of the motorcycle part, the serious weld line defect can be reduced about 69% by speed control solutions.

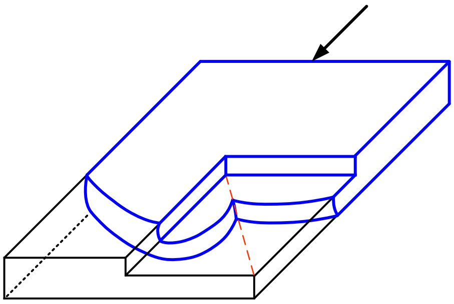
Keywords: flow hesitation, injection molding simulation, flow position difference, various part thickness design.

1. Introduction

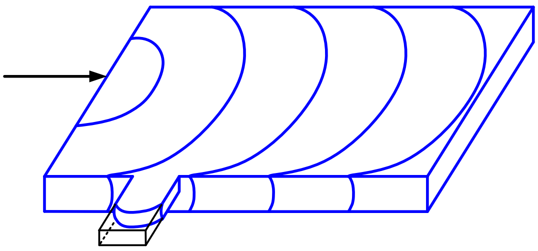
The injection molding is the most popular process in the plastic parts manufacturing industry, especially the automotive parts manufacturing industry due to the high production rate and the ability to produce complex parts precisely [1]. For the parts of automotive, the surface quality is always important. Even the part's surface needs to paint, a good surface quality still can improve the yield rate for the painting process.

The flow hesitation is a surface defect that results from the stagnation of polymer melt flow over a thin-sectioned area or an area of abrupt thickness variation. When the flow hesitation happens, it will occur the defect on the part surface, such as weld line (Fig. 1a) [2-3] and short shot, flow unbalanced or hesitation mark (Fig. 1b). Therefore, a lot of research attempts to study the flow hesitation [4] to find ways to limit or reduce this situation.

The team of the simulation software, Moldex3D, collects data of analyzing and solving injection problems that occur in the industry. The flow hesitation is one of the case studies, the result shows the flow hesitation can be eliminated [5] by changing the gate position. The other found that when increasing the width and thickness of microfeatures can reduce the flow hesitation [6] and another research shows the injection speed and the injection pressure are the key factors affecting the flow hesitation [7]. Combining these research findings, we can find that there are many reasons for the hesitation of the flow. However, they have one thing in common. In the hesitant



(a)



(b)

Fig. 1. The flow hesitation cause (a) weld line and (b) short shot, flow unbalanced or hesitation mark.

area, the viscosity of the plastic will be significantly different due to the unbalanced flow rate.

In this study, we focused on two key factors, injection speed and part thickness ratio (THK ratio), which both helped to reduce the difference in flow viscosity. By using simulation to find out the relationship between the injection speed and the different THK ratios. Then, develop a guideline to address the shortcomings caused by hesitation, especially automotive parts.

2. Principal of viscosity relative to shear rate

The flow of molten plastic in injection molding filling is driven by the pressure that overcomes the melt resistance to flow also known as "Viscosity". A high viscosity will increase the flow resistance. Viscosity is expressed as the ratio of shear stress to the shear rate [8], as shown in (1)

$$\eta = \frac{\tau}{\dot{\gamma}} \tag{1}$$

where η is viscosity, τ is shear stress and $\dot{\gamma}$ is shear rate. In general, the molten plastic used in the injection molding process is usually non-Newtonian fluid. Therefore, viscosities are a function of the shear rate. When the shear rate is increased, the viscosity decreases. As shown in Fig. 2.

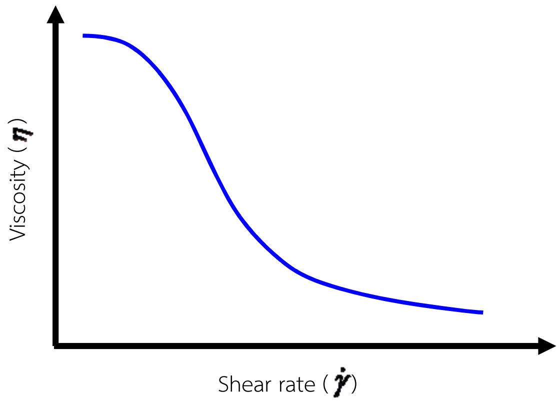


Fig. 2. The relationship of viscosity to shear rate.

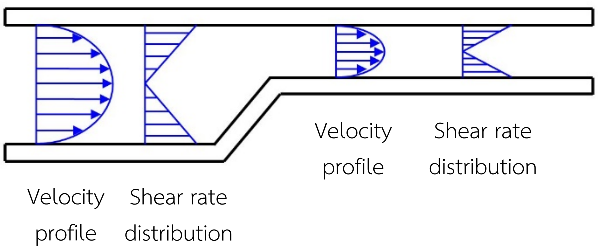


Fig. 3. The flow behaviour and related features regarding the variation of the thickness in filling stage.

From (1), when considering shear rate found that the shear rate is the relationship between the velocity of flow and the depth of the flow channel, which is in the form of velocity gradient, as shown in (2). Therefore, changing the geometry, such as the depth of the flow channel or the velocity of flow, significant affecting viscosity [9].

$$\dot{\gamma} = \frac{dv}{dy} \tag{2}$$

where v is the velocity of flow and y is the depth of the flow channel. The relationship of the depth of the flow channel, velocity of flow, shear rate and viscosity can be explained as shown in Fig. 3, the higher depth of the flow channel leads to lower flow resistance (viscosity decrease) due to shear rate is higher, which results in easier flow of the molten plastic (velocity of flow increase). On the other hand, when the lower depth of the flow channel leads to higher flow resistance due to the shear rate is lower, which results in difficult flow of the molten plastic [10].

As described above, it was found that the thickness and flow velocity were the most important factors affecting the flow of molten plastic. Therefore, this study focuses on the thickness and flow velocity and specifies that these two variables are the initial parameters to control the flow hesitation or reduce the occurrence of flow position difference (FPD).

3. Experimental Works

The model of part used for the flow simulation in this research has been designed to have different thicknesses, the sides are thicker than the middle as shown in Fig. 4, by creating 7 part model showing details as shown in Table 1. Then choose 2 types of mesh to create the part model is triangular prism and tetrahedral and Set the mesh size to 1 mm as shown in Fig. 5.

Table 1. Details of model size of part for flow simulation.

No.	Width (mm)	Length (mm)	Thickness (mm)		THK Ratio
			Thick	Thin	
Model 1	180	210	3.6	3.0	1.2
Model 2	180	210	4.2	3.0	1.4
Model 3	180	210	4.8	3.0	1.6
Model 4	180	210	5.4	3.0	1.8
Model 5	180	210	6.0	3.0	2.0
Model 6	180	210	6.6	3.0	2.2
Model 7	180	210	7.2	3.0	2.4

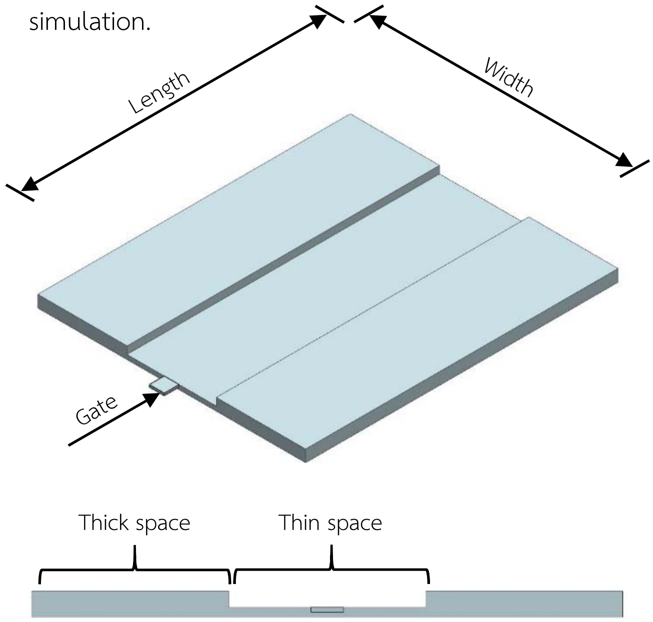


Fig. 4. The shape of part model for simulation.

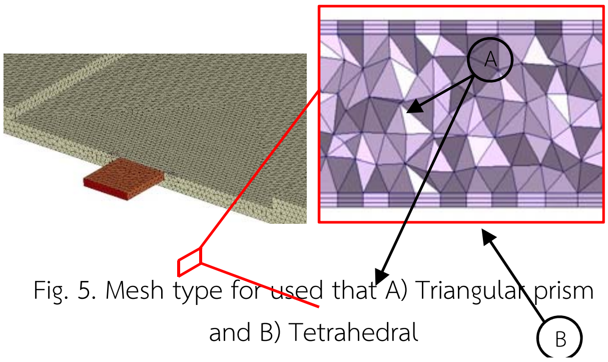


Fig. 5. Mesh type for used that A) Triangular prism and B) Tetrahedral

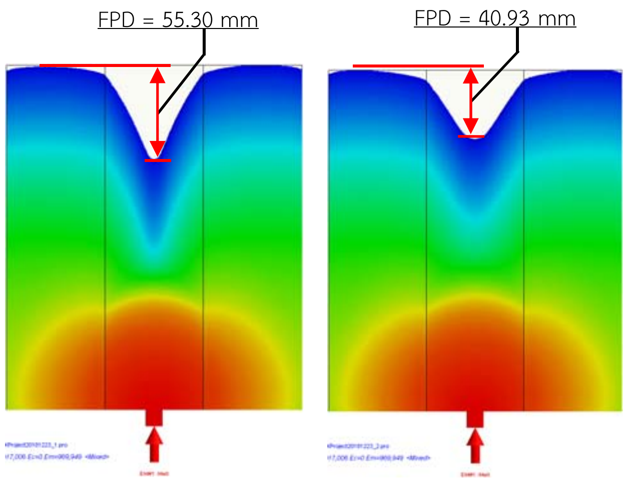


Fig. 6. Example for flow simulation result and measurement of flow position difference of the model 4 (THK ratio 1.8) at injection speed 10% and 20%

Determining the boundary conditions for the flow simulation, the polymer material used is ABS (Acrylonitrile Butadiene Styrene), the melt temperature is 210 °C and the mold temperature is 60 °C, then injection speed setting is 10%, 20%, 30%, 40%, 50%,60%, 70%, 80% and 90% of the maximum injection speed of the injection molding machine.

Then simulate the flow of molten plastic of all 7 part models at various injection speeds as shown

Table 2. Measurement results of flow distance difference from simulation of all 7 models at different injection speeds.

No.	THK Ratio	Flow Position Difference, FPD (mm)								
		Injection Speed								
		10%	20%	30%	40%	50%	60%	70%	80%	90%
Model 1	1.2	18.75	10.94	9.38	9.37	9.38	9.37	9.37	9.38	9.06
Model 2	1.4	26.87	23.12	21.25	19.37	18.75	18.07	17.50	17.19	16.87
Model 3	1.6	41.24	31.25	28.12	26.56	25.00	24.06	24.06	23.75	23.44
Model 4	1.8	55.30	40.93	36.56	34.06	32.18	31.25	30.31	30.00	29.37
Model 5	2.0	88.43	52.81	45.62	42.18	39.68	38.24	36.24	35.93	35.31
Model 6	2.2	121.24	64.68	54.37	49.06	45.93	44.06	42.81	41.87	40.62
Model 7	2.4	156.23	82.18	65.62	58.43	54.37	51.87	49.37	47.49	46.56

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in Fig. 6. In order to explain the flow results of the difference THK ratio, we define the Flow Position Difference, FPD. The FPD is the distance between the hesitation areas to the end of the flow.

4. Results and Discussion

Table 2 shows the results of the simulation of flow hesitation phenomena by measuring FPD that occurs under difference THK ratio with various injection speed. Then make a relationship graph between the FPD and injection speed at the 7 difference THK ratio as shown in Fig. 7. From the graph shows that the relationship between thickness ratio and injection speed has a significant effect on FPD formation. We can find that the higher THK ratio design will get higher FPD. In particular, at the injection speed 10% (with very low speed), the increase of the FPD is very serious (from 18.75 mm at the THK ratio 1.2 to 156.23 mm at the THK ratio 2.4). When the injection speed increases, the FPD value decreases. In particular, the injection speed to 20% and 30%, the FPD will decrease rapidly. If we keep increasing the injection speed, we can see the FPD will tend to steadily decrease until the reduction of FPD values is beginning to stabilize at the injection speed by 70% to 90%. In a high THK ratio design case such as 2.0, 2.2 and 2.4 (the max THK ratio), the FPD can be

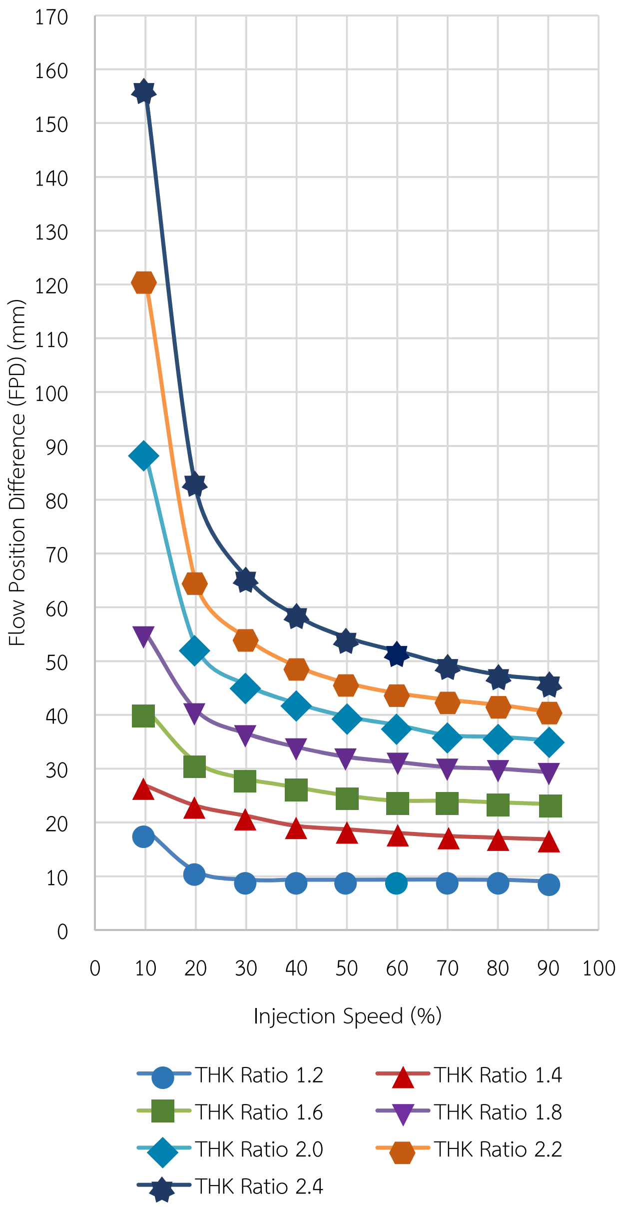
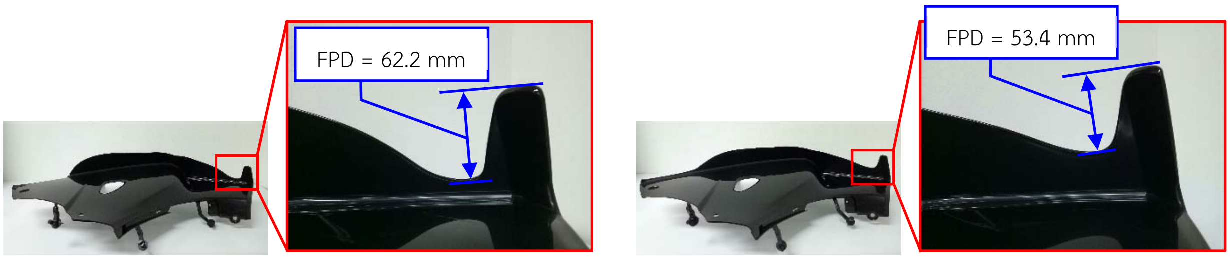


Fig. 7. Comparison of measurement results of flow distance difference from simulation of all 7 models at different injection speeds.

Fig. 8. The thickness of the edge of an actual case study about 6.3 mm and the thickness of the middle of the parts about 3.2 mm.



Original (Low injection speed, 30%) After (High injection speed, 60%)

Fig. 9. Case study for reducing the FPD for auto part by injection speed control, the FPD can be reduced by 14.15% (from 62.2 mm to 53.4 mm).

Original (weld line length is 23.38 mm) After improvement (weld line length is 7.23 mm)

Fig. 10. The weld line length that occurs on surface of the parts before and after the improvement, we can find that the length of the weld line can be reduced.

reduced around 60% (from 88.43 mm to 35.31 mm), 66% (from 121.24 mm to 40.62 mm) and 70% (from 156.23 mm to 46.56 mm) respectively by controlling the injection speed to increase. On the other hand, in a low THK ratio design case such as 1.2 (the lowest THK ratio) and 1.4, the flow hesitation is not clear causes the FPD is very small. Therefore, the injection speed control affects less the FPD. From explaining the results of the experiment show that the thickness ratio is important to cause the FPD or hesitation phenomenon. Meanwhile, injection speed control is the best solution for solving this issue.

This database and study results can be applied for solving of the weld line defect in the real molding part. By using the motorcycle's fender part for an actual case study which the edge of the parts is thicker than the middle of the parts as shown in Fig. 8. The solution is increasing the injection speed (from 30% to 60%), we can get the FPD has been improved from 62.2 mm to 53.4 mm (14% improvement) as shown in Fig. 9. As a result, the weld line length on the part surface can be reduced by 69% (from 23.38 mm to 7.23 mm), as shown in Figure 10.

5. Conclusions

Different part thickness designs are a common cause of plastic flow hesitation and many molding problems. In this study, the basic shape part design has been used to obtain a THK ratio (Thickness ratio) relative to the FPD (Flow Position Difference) database. According to the simulation and experimental results, the THK ratio is the main influence of the final FPD, and the injection speed is a key parameter for reducing the THK ratio of FPD. As with the maximum THK design of 2.4, FPD can be reduced by approximately 70% (from 156.23 mm to 46.56 mm) by speed control. Finally, the actual forming box for the motorcycle parts. Through the speed control solution, severe weld defects on the surface of the part can be improved, and the FPD can be reduced by 14% (from 62.2 mm to 53.4 mm). This results in a 69% reduction in the weld length of the part surface (from 23.38 mm to 7.23 mm).

6. Acknowledgment

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