Simulating the Melting Behavior and Melt Temperature Inhomogeneity in The Injection Molding Processes

V. Yang, C-T. Huang, P-C. Tsai,
CoreTech System Co., Ltd, Hsinchu, Taiwan

J. Perdikoulias
Compuplast Canada, Inc., Mississauga, ON Canada

J. Vlcek
Compuplast International, Inc., Zlin, Czech Republic

Abstract

In the injection molding process, one of the most important process conditions is the temperature and/or temperature distribution of the polymer melt. Since the melt temperature can be the guideline to predict the quality of the molded parts. The ability to better predict and control the polymer melt temperature will help to obtain better products. However, the problem is that the true polymer melt temperature is very difficult to determine and so an estimate is used for the mold filling and packing simulation, which can provide misleading results. Hence, to better predict the melting temperature, the simulation of the injection screw in the injection molding system has been added. This paper shows how the ability to simulate the melting behavior will provide improved simulation accuracy to the entire injection molding process and a better prediction of product quality.

Introduction

Filling and packing are the key stages to fabricate a high quality molded part in the injection molding process. Although many factors will influence these key stages, the coupling of the process conditions and the material properties dominates. The process conditions will significantly affect the plastics properties, such as the viscosity. Therefore, how to precisely predict and then to control the process conditions is of high interest.

One of the most important process conditions is the temperature and/or temperature distribution of the polymer melt in the injection molding process. Since the melt temperature is not only the criterion for plastics to flow, but it also can be the guideline to predict the quality of the molded parts. The ability to better predict and control the polymer melt temperature will help to obtain better products. However, the problem is that the true polymer melt temperature is very difficult to determine and so an estimate is used for the mold filling and packing simulation, which can provide misleading results. Hence, to better predict the melting temperature, the simulation of the injection screw in the injection molding system has been added. This paper shows how the ability to simulate the melting behavior will provide improved simulation accuracy to the entire injection molding process and a better prediction of product quality.

Simulation Method and Procedures

The simulation is executed via a whole injection molding procedure from raw material to injected parts described in Fig. 1. It could be divided into two stages. First one is the screw process and the other is the injection molding process. Both processes are connected together by a nozzle.

1. Screw Process

In this process, the operation parameters in the system are simulated using the ScrewPlus simulator developed by Compuplast International, Inc. The detail parameters of the screw used here are listed in Table 1. The type of screw is conventional with smooth barrel. The inside operating data of the barrel and the screw are shown in Table 2. Basically, there are three sections for barrel. The temperatures of the barrel are controlled from 210^{o}C to 230^{o}C, where each section of barrel has a constant temperature. In addition, we assume that there are three sections for the screw as well. Of course, for a conventional screw, the first one is feed section. The second one is transition section. The final one is the metering section. Here the flow channel depth of the first section is 6mm. Further, that of the final section is a* mm. Here, to measure the effect of screw, various depths of the metering section a* of 1.5/2.0/2.5/3.0 mm have been studied. As the parameters of the screw changes, the behavior of melts will be affected. Then it will go further to influence the injection process.

2. Injection Molding Process

In this process, the melt is driven into cavity and then goes through filling/package/cooling/warpage to be a molded part. The physical properties and operating conditions can be simulated using Moldex3D simulator developed by CoreTech System, Co. The testing case in this process is a mouse shown in Fig. 6. Since it is a typical case of thin parts, the shell model is suitable for this class of simulation. In addition, the simulation parameters are listed in Table 3, where the material used is ABS-PA737 (CHI-MEI).

Results and Discussions

Fig. 2 describes the melting behavior inside of the screw. In general, when unmelted amount is approach zero before 70% of the total length of the screw, it is a good melting process. Then we can pay attention at the exit of the screw. Fig. 3 shows that the melt behavior at the exit position in the screw. Obviously, the melting temperature is not uniform. Since this ABS is high dissipation material, it accumulated viscous heating toward the center of melted. Therefore, the highest portion is in the center of the flows. At the exit, this temperature deviation is almost up to 10 ^{o}C compared with that of our expectation. It will result in melting properties occurred for further injection process. On the other hand, when the depth of the screw is modified, the melting behavior can be changed shown as Fig. 4. Moreover, melted material is delivered into cavity of injection molding via the nozzle. After considered the gap effect of screw, the temperature variation of bulk at the exit position of screw and of the melting at the entrance of injection mold can be exhibited in Fig. 5. It is clear that as long as the condition of screw changed, the temperature of melted plastics at the exit position of screw and the true melting temperature will be varied. Of course, the true melting temperature is neither the exit temperature of screw nor the barrel temperature.

Further, to measure the effect of the melting variation and the inhomogeneity in the injection process, it goes further using Moldex3D simulator. To make some comparison, we assume that some cases with constant melting temperatures of 230^{o}C and 220^{o}C are injected into mold. In addition, other cases are traced by measuring the screw operation. The melting temperatures need to be modified after melts exited from extruder. After completed filling/packing, the influence of various melting temperatures can be described by the sprue pressure and the clamping force. Fig. 7 and 8 show the sprue pressure and clamping tonnage of injected parts, respectively. First, comparing to 220^{o}C and 230^{o}C, due to higher melting temperature of ABS with easier flow behavior, the sprue pressure and the clamping force of 230^{o}C case are lower. Further, when considered the true melting temperature, the sprue pressure and the clamping force of both cases through screw are even lower. It is due to high dissipation occurred of ABS material flowing to increase the melting temperature. In fact, due to the complicated physical properties and operating conditions of system, the true melting temperature and its behavior will be varied. The issue will significantly influence the further injection molding process.

Conclusion

In this study, we have connected screw process and injection molding process together to measure the true melting temperature and its inhomogeneity theoretically. Results show that it could provide significant effect for the process. Indeed, the true melting temperature depends on the material properties and operating conditions through the whole process.

References

1. Flow2000, Extrusion Simulation Software, Compuplast International, Inc.
2. J. Perdikoulias, J. Vlcek, "Analysis of Film Extrusion Problems with Flow Simulation", 2003.

Key Words

injection molding, screw process, melt temperature

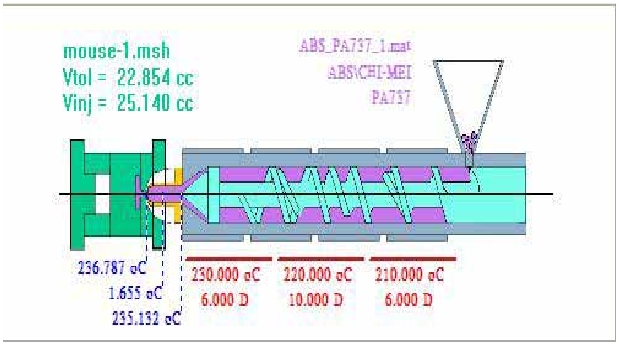

Figure 1. Schematics of injection process from raw material to injected products.

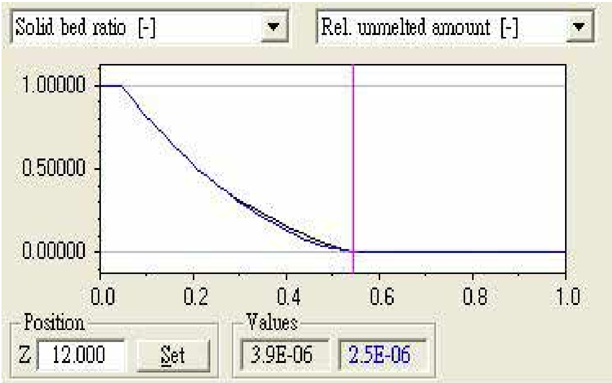

Figure 2. The melting behavior inside of the screw from the inlet to the outlet.

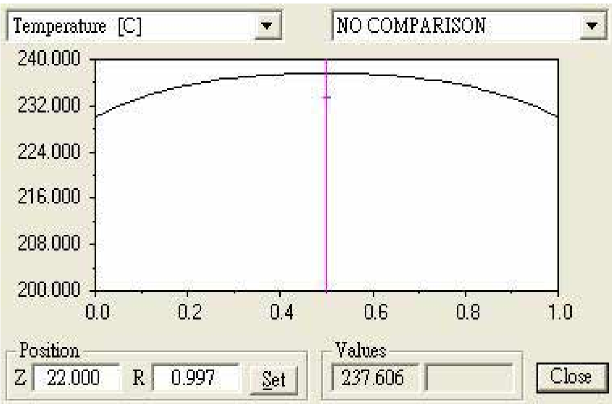

Figure 3. The melting behavior at the exit of screw described as the temperature distribution from the cross-section of the exit, where the depth of the channel is 2 mm.

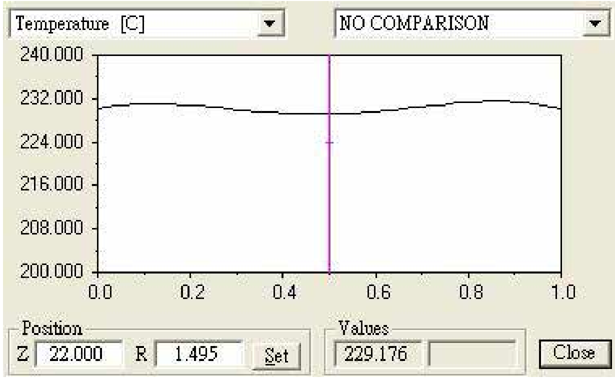

Figure 4. The melting behavior at the exit of screw described as the temperature distribution from the cross-section of the exit, where the depth of the channel is 3 mm..

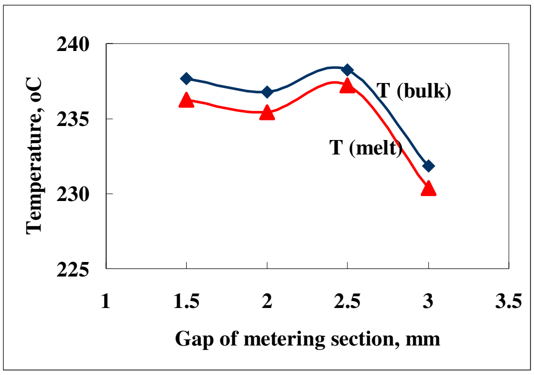

Figure 5. The bulk temperature (at the exit of the screw) and the melting temperature (at the entrance of the mold) varied with depths of the channel.

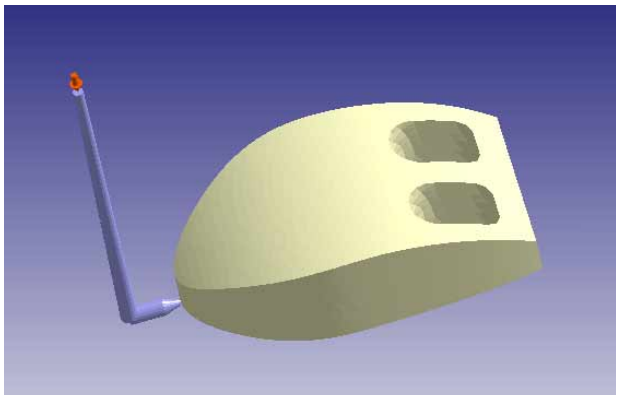

Figure 6. The study case for injection molding process, where the thickness of part is around 1.2 mm to 2mm.

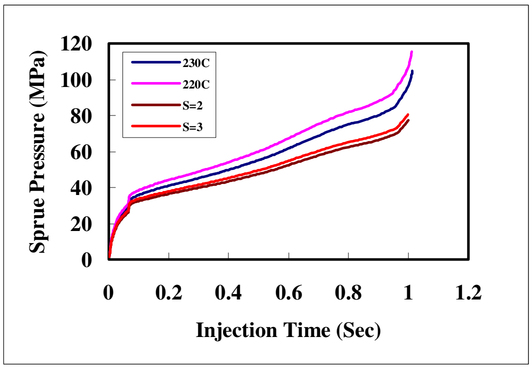

Figure 7. The sprue pressure of the injected parts, where S is the depth of the metering section in the screw; 220°C and 230°C mean the ideal cases with constant melting temperatures.

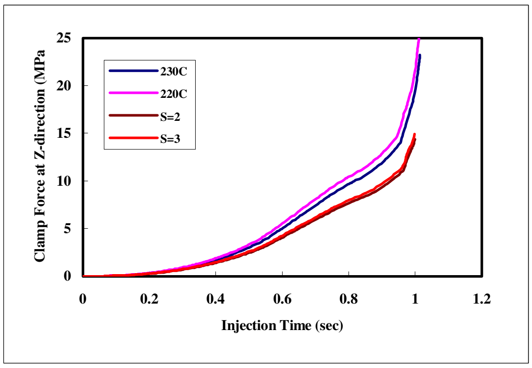

Figure 8. The clamping tonnage at Z-direction for the injected parts, where S is the depth of the metering section in the screw; 220°C and 230°C mean the ideal cases with constant melting temperatures.

Table 1. The screw parameters

Screw			
Type	Conventional	Barrel	smooth
D (diameter)	28mm	L/D	22
Screw pitch	28 mm	Flight width	2.8 mm
Friction coefficient Barrel-material	0.3	Friction coefficient Screw-material	0.2

Table 2.The detail information for barrel and screw

Barrel			Screw			
Sec	Length (D)	Temp (oC)	Sec	Length (D)	Depth (mm)	Speed (RPM)
1	6	210	1	6	6	100
2	10	220	2	10	6-a*	
3	6	230	3	6	a*-a*	

where a* is from 1.5 mm to 3 mm

Table 3. The operating conditions of injection molding

[Filling]			[Cooling]		
Stroke Time	1.09304	sec	Cooling Time	20	sec
Melt Temperature	230	oC	Open Time	1	sec
Mold Temperature	70	oC	Eject Temperature	120	oC
Max. Injection Pressure	168	MPa	Air Temperature	25	oC
Inject Volume	25.1399	cc			
[Packing]			Cycle Time	22.093	sec
Packing Time	0	sec	[Mold]	mouse-1	
Max. Packing Pressure	168	MPa	[Material]	ABS_PA	
Packing Switch	98	%	[Machine]	CHEN H:	137/50