An Experimental Study of Effects of Injection Molding Parameters on Shrinkage and Plastic Fill

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Abstract - *Injection molding is the growing and most promising industry for plastic products' mass production. Various issues are related to plastic molding where shrinkage and plastic fill are the most crucial quality characteristics. In this paper, plastic fill and shrinkage were evaluated to study the effects of various process parameters viz. mold temperature, melt temperature, fill time and injection pressure on injection molding with polypropylene (PP) material. Experiments were performed in an industry on injection molding machine. It was determined that the shrinkage was increased with the increase in mold temperature and melt temperature, and the decrease in fill time and injection pressure. Plastic fill was increased with the decrease in mold temperature and melt temperature, and the increase in fill time and injection pressure of plastic.*

Key Words: Injection molding, Plastic fill, Shrinkage, Polypropylene etc

1. INTRODUCTION

Plastic injection molding is getting a lot of usage in industries to manufacture a variety of plastic products for various applications. Injection molding has evolved as the most promising industry due to its extensive capability of manufacturing products of various shapes and complex sizes [1]. Injection molding is a process in which plastic pallets are poured inside a hopper and it is shaped inside mold under applied temperature and pressure. Problems occur with injection-molded thin wall plastic products. Various defects like, short shot, flash, sink marks, dimensional inaccuracy, shrinkage, warpage and burn marks are occurred due to improper setting of process parameters. Inadequate knowledge of effect of random adjustments in process parameter can lead to increase in production time and cost.

Plastic fill and shrinkage were identified as important quality indices in some studies [2-4]. There have been many process parameters addressed by several researchers in the field of injection molding and taken in present work [5-9]. Mold temperature, melt temperature, fill time and injection pressure were identified as process parameters that affect the shrinkage and plastic fill in the injection molded product. In many studies, several researchers have experimented with different materials to check the effects of process parameters on the defects occurred in injection molding process. In this work, an industrial grade recyclable virgin polypropylene (PP) material was taken for experimentation. The work was focused on running injection molded bucket experiments in an industry.

2. MATERIAL AND METHODS

2.1 Material Selection

The polypropylene (PP) material used in study is manufactured by Reliance Industries Ltd. Its density and melt flow index is 0.9 g/cm^3 and 12 g/10 min respectively. The material employs viscoelastic nature. Mold material is taken as steel P 20. Mold is a core component of injection molding machine. Mold acts as heat exchanger inside machine.

2.2 Injection molding machine

The selection of machine was done in such a manner that it should enable to carry out experiments for selected range of variables- 190 to 260 °C melt temperature, 40 to 60 °C mold temperature, 90 to 180 MPa injection pressure and 4 to 6 sec fill time. Therefore Milacron (Omega 775W) injection molding machine was selected. It has the maximum clamp tonnage of 775 ton. It runs on AC servo drive and enables fully automatic operation. Injection molding process test run were performed on PP bucket to observe shrinkage and plastic fill.

Fig -1: Injection molding machine

3. METHODOLOGY

In the study, experiments were conducted by varying one parameter for three levels, keeping remaining other parameter's value fixed at 45 °C mold temperature, 250 °C melt temperature, 180 MPa injection pressure and 5 sec injection time on injection molding machine. For an instance, mold temperature was varied in set of experiments for 40, 50 and 60 °C provided with melt temperature, fill time and injection pressure values of 250 °C, 5 sec and 180 MPa respectively. Injection pressure, melt temperature and fill time were measured by display controller and mold surface temperature was measured by infrared (IR) thermometer. Single cavity mold was used in the study with inverted dimensions of plastic bucket- upper diameter, lower diameter and height as 347 mm, 266 mm and 410 mm respectively. Weight of molded bucket was measured with weighing balance. The calculation of shrinkage for each dimension of bucket is given by equation 1 below,

$$\Delta D = \frac{D_i - D_f}{D_i} \times 100\% \qquad \text{........(1)}$$

Where, ΔD = Shrinkage percentage in dimension

D_i = Initial dimension in mm

D_f = Final dimension in mm

The determination of plastic fill is done by using equation 2,

Plastic fill = Weight of final product x Density of PP ....(2)

4. RESULTS AND DISCUSSION

In table 1, observation data obtained from injection molding machine were presented. In this table shrinkage, dimensions and plastic fill measured from the injection-molded bucket in the industry were showed.

Table -1: Observations obtained from injection molding machine

Process Parameter		Shrinkage (%)			Dimensions (mm)			Plastic Fill ($\times 10^3$ mm^3)
		ΔD_u	ΔD_l	ΔH	Upper Diameter (D_u)	Lower Diameter (D_l)	Height (H)	
Melt Temperature (°C)	190	0.85	0.73	1.08	344.03	264.06	407.52	883.33
	225	0.94	0.94	1.12	343.73	263.49	407.08	875.55

	260	1.10	0.99	1.40	343.18	263.37	406.23	865.55
Mold Temperature (°C)	40	0.91	0.71	1.10	343.85	264.10	407.46	867.78
	60	0.97	0.92	1.36	343.62	263.54	406.37	862.22
	80	1.13	0.95	1.42	343.07	263.48	406.13	857.78
Injection Pressure (MPa)	90	1.08	0.96	1.25	343.24	263.45	406.86	845.55
	135	1.01	0.84	1.19	343.47	263.76	407.11	872.22
	180	0.92	0.77	1.02	343.82	263.94	407.79	894.44
Fill Time (sec)	4	1.1	1.01	1.34	343.17	263.32	406.49	871.11
	5	1.04	0.95	1.12	343.38	263.48	407.37	874.44
	6	0.91	0.77	1.08	343.85	263.95	407.56	876.67

4.1 Effect of mold temperature

In Figure 2, it is presented that shrinkage was increased for upper diameter, lower diameter and height with the increase in mold temperature. On cooling, plastic starts to solidify layer by layer on the walls of mold. At low mold temperature, heat transfer is more than heat transfer in high mold temperature. Due to this action, overall heat can be more extracted due to effective heat transfer and less shrinkage occurred in plastic. With the increase in mold temperature, comparative high shrinkage is examined for plastic product. Also with the increase in mold temperature from 40 °C to 80 °C there is decrease in plastic fill. As more material can be injected for low mold temperature due to shrinkage during the flow of plastic, a comparative more plastic fill is examined than mold at high temperature.

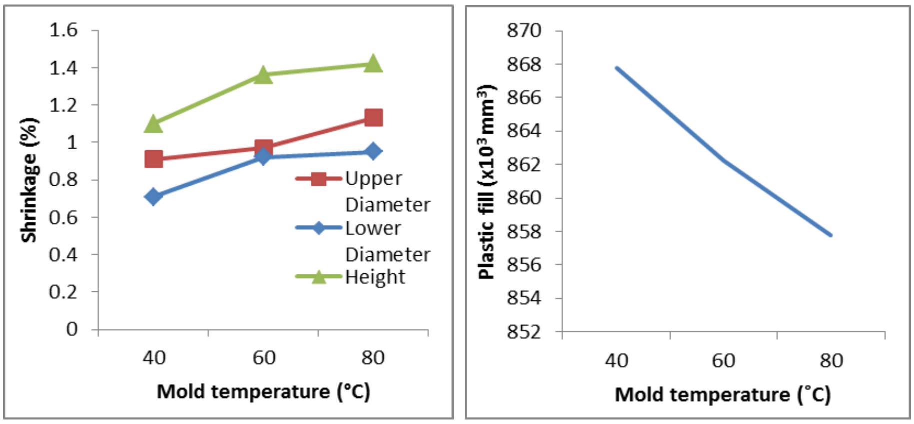


Fig -2: Effect of variation in mold temperature

4.2 Effect of melt temperature

It is presented in figure 3 that shrinkage was increased with increase in melt temperature from 190 °C to 260 °C, for upper diameter, lower diameter and height at 45 °C mold temperature, 180 MPa injection pressure and 5 sec fill time. As an action of cooling inside mold during the plastic processing, melted plastic solidifies and it started to contract. Shrinkage happened due to the contraction of molecules. Material subjected to high melt temperature tends to shrink more during solidification. Plastic fill decreases with the increase in melt temperature from 190 °C to 260 °C. Due to increase in melt temperature, the viscosity of material is decreased. Therefore the reach of melted plastic inside the mold is increased but the molecular weight of filled material is decreased. At low melt temperature, a comparative more quantity of less-viscous plastic can be filled inside mold.

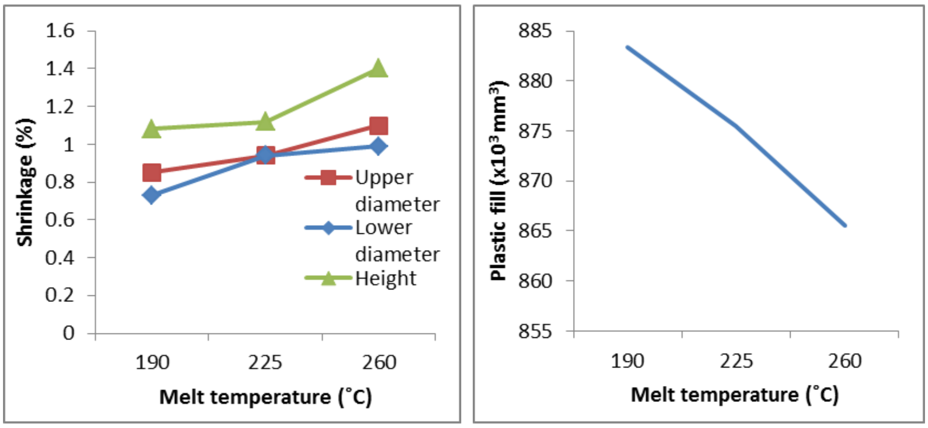


Fig -3: Effect of variation in melt temperature

4.3 Effect of fill time

In figure 4, it is showed that shrinkage was decreased for upper diameter, lower diameter and height with the increase in fill time. It is shown that with the increase in fill time from 4 sec to 6 sec there is decrease in plastic fill. With the increase in fill time, plastic solidifies more because time for melt to contact mold walls is more and hence the shrinkage is decreased. At high fill time more material can be inserted due to shrinkage during the plastic flow.

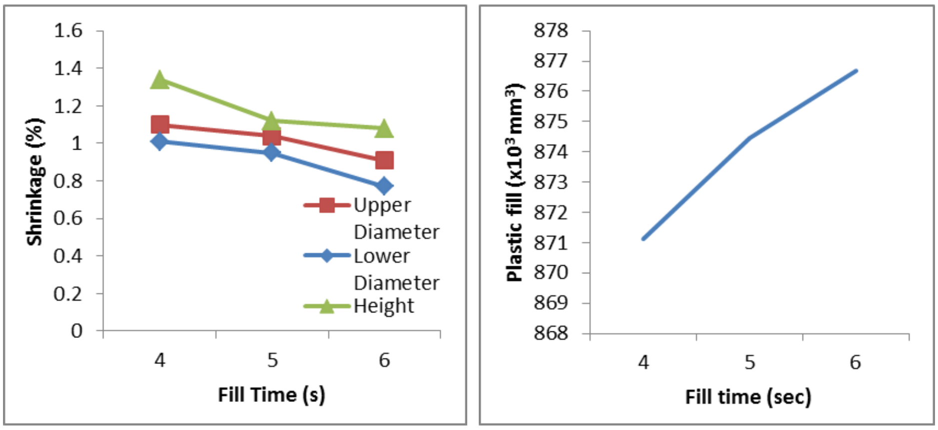
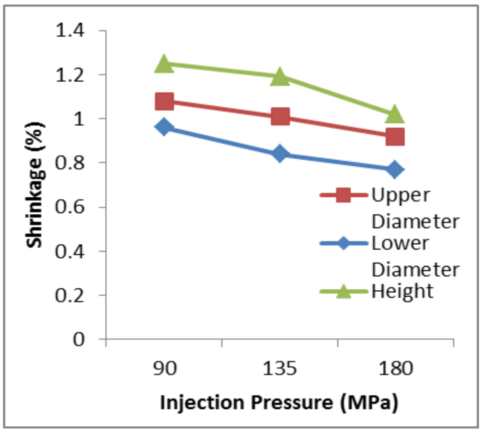


Fig -4: Effect of variation in fill time

4.4 Effect of injection pressure

It is presented in figure 5 that for upper diameter, lower diameter and height, shrinkage value decreased with the increase in injection pressure. At high injection pressure, time for melted plastic to reach extreme dimensions of cavity decreased but the plastic advancement inside the mold is high. Shrinkage during the flow is counterbalanced and decreased due to advancement of pressurized melt flow inside the mold cavity. It was observed that with the increase in injection pressure plastic fill was increased. At high injection pressure during the process, high density of plastic is examined at the end of filling. Hence high amount of plastic is filled with increase in injection pressure.



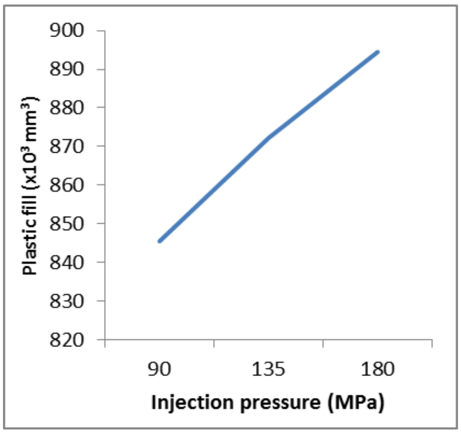


Fig -5: Effect of variation in injection pressure

5. CONCLUSIONS

In this study, following conclusions were drafted:

1. Defects and quality performance of thin-wall plastic products processed with injection molding has gained attention of many researchers and experts working in the field of plastics processing. Study was intended to find appropriate process parameters for production of plastic bucket on injection molding in an industry with lesser defects.
2. In the present work, experimental analysis was done on injection molding machine to study the effect of variation in process parameters on shrinkage and plastic fill. Experiments were performed on bucket mold of a manufacturer with PP as material. Plastic fill and shrinkage were measured for bucket in injection molding process.
3. It was found that for PP bucket, lower the melt and mold temperature, and increase in injection pressure and fill time led to reduce in plastic shrinkage percentage. Also it was found that the plastic fill was increased with the decrease in melt and mold temperature, and increase in injection pressure and fill time. Thus the effects of parameters were found to be significant on the injection molding process. A good quality plastic bucket can be manufactured with minimum shrinkage and higher plastic fill when injection molding with 190 °C melt temperature, 40 °C mold temperature, 190 MPa injection pressure and 6 sec fill time.

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