

Part weight verification between simulation and experiment of plastic part in injection moulding process

M. A. M Amran¹, N. Idayu¹, K. M. Faizal¹, M. Sanusi¹, R. Izamshah¹, and M. Shahir¹

¹Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

E-mail: mohdamran@utem.edu.my

Abstract. In this study, the main objective is to determine the percentage difference of part weight between experimental and simulation work. The effect of process parameters on weight of plastic part is also investigated. The process parameters involved were mould temperature, melt temperature, injection time and cooling time. Autodesk Simulation Moldflow software was used to run the simulation of the plastic part. Taguchi method was selected as Design of Experiment to conduct the experiment. Then, the simulation result was validated with the experimental result. It was found that the minimum and maximum percentage of differential of part weight between simulation and experimental work are 0.35 % and 1.43 % respectively. In addition, the most significant parameter that affected part weight is the mould temperature, followed by melt temperature, injection time and cooling time.

1. Introduction

Injection moulding is considered as one of the important process to produce plastic part especially thermoplastic and almost all plastic industries use injection moulding machine to convert the material into a desired products [1-2]. In 2009, Nagahanumaiah studied the effect of injection moulding parameters on plastic part quality such as weight and shrinkage. The higher the weight of the part, the stronger the moulded part because it can help in checking bubbles or void and other deviations from filling rate of the cavity. Furthermore, melt temperature and injection speed have significant influence on the quality of plastic part [3].

The variation of process parameters of plastic part on part weight was investigated and by increasing the injection temperature, it decreased the part weight due to an increase of specific volume of the molten material [4]. It was reported that the weight of product increases with the decrease of injection temperature because of the density of product material increases with a decrease in its injection temperature. In addition, the increase of the injection time has decreased the product weight. [5].

In injection moulding process, there were several researcher have performed a numerical analysis using the Autodesk Simulation Moldflow Insight for optimization in injection moulding process. Amran et al. [6] investigated the effect of using different runner layouts in family mould to predict defect in plastic part. By using mould flow software, prediction of defect in plastic quality can be made. Gheorghe et al. [7] also optimized injection moulding process with the aid of simulation software to improve part quality. Cost and time consuming was reduced in term of design and



production. In addition, Wang et al. [8] implemented numerical experiment and yield less than 4% error between predicted and experimental data in confirmation experiments.

Some researchers implemented Taguchi approach as Design of Experiment (DoE) in injection moulding process [9–12]. The Taguchi method is one of optimization methods and by using Taguchi's orthogonal array, time and cost required were reduced to carry out experiments. The S/N ratio in Taguchi method measures the quality characteristic and the sensitivity of a parameter to uncontrollable factors in the experiment. A greater S/N ratio shows better quality characteristics.

The main objective of this paper is to determine the percentage difference of part weight between experimental and simulation work and to find the optimum injection moulding parameters level for plastic part.

2. Experimental set-up

2.1. Processing material for both experimental and simulation

Polypropylene was selected as the material for this study. The plastic material used for experiment was supplied by Lotte Chemical Titan (M) Sdn. Bhd. The melt mass-flow rate of material was 4 g/10 min and has density of 0.9 g/cm³. In addition, the material used in the simulation also has the same density and melt flow rate value in the experiment. The PP material properties used in both simulation and experiment is simplified in Table 1.

Table 1. Comparison of material properties between simulation and experimental

Material Details	Simulation	Experiment
Family Name	Polypropylene (PP)	Polypropylene (PP)
Manufacturer	Basell Polyolefins Europe	Lotte Chemical Titan (M) Sdn. Bhd.
Density (g/cm ³)	0.9031	0.9
Melt Mass-flow Rate (g/10 min), at 230°C	4.0	4.0

First, plastic part specimen was drawn by using CATIA V5 as shown in Figure 1. Next, the part drawing was imported to Autodesk Simulation Moldflow Insight environment in Figure 2 to get the recommended process parameters for the part.

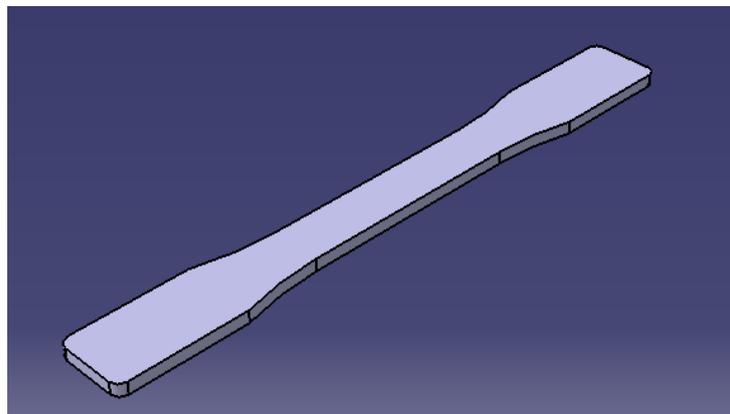


Figure 1. Drawing of plastic part using CATIA V5

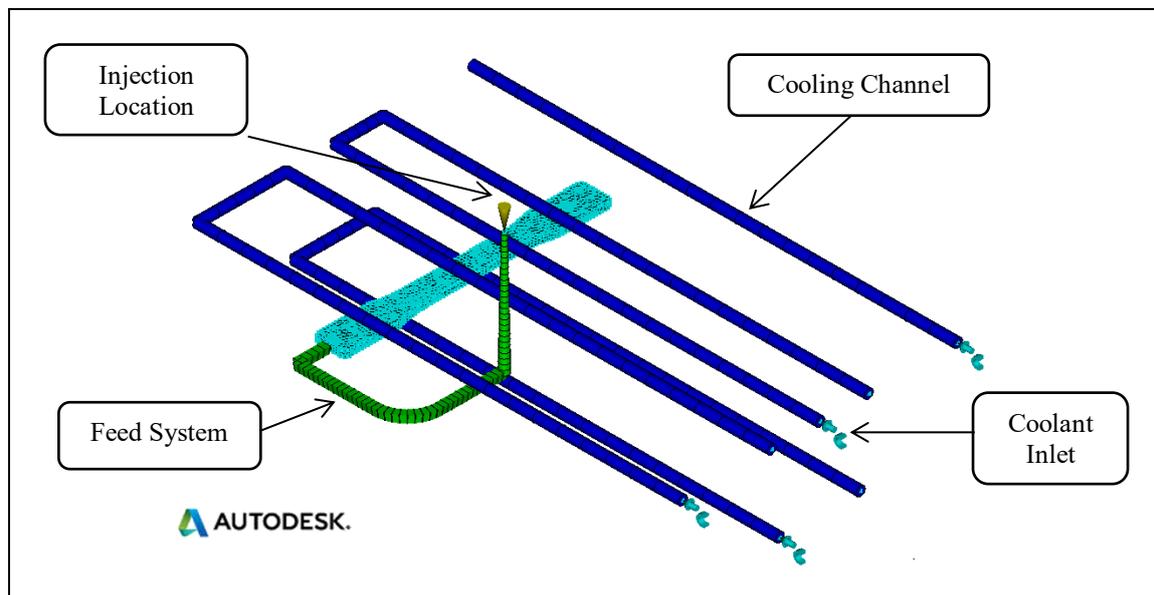


Figure 2. Moldflow simulation environment of plastic part

2.2. Processing parameters of plastic parts

The processing parameters were obtained from the moldflow software. The software has recommended the parameters such as mould temperature 56°C, melt temperature 280°C, injection time 0.7s. The 14s of cooling time also was obtained from the software. Taguchi method with L9 orthogonal array was implemented and three (3) level designs were used that are low level, medium level and high level.

According to Wang et al. [13], determination for low level and high level was made by minus and plus 10% of medium value. Therefore, the recommended parameters are set as middle level and Table 2 shows the process parameters setting for the experiment and simulation run. In addition, the injection moulding used for the experiment was Allrounder 370 H 600-170 Hybrid machine (ARBURG).

Table 2. Experimental and simulation parameter setting for injection moulding process

Process Parameters	Level		
	Low	Medium	High
Mould Temperature, (°C)	50	56	62
Melt Temperature, (°C)	250	280	310
Injection Time (s)	0.63	0.70	0.77
Cooling Time (s)	12.6	14.0	15.4

3. Results and discussions

3.1. Simulation and experimental result of part weight

For experimental work, after the product was completely solidified, the weight of ejected product was measured by using top loading balance. The results for both simulation and experiment are shown in Table 3.

Table 3. Part weight result for both simulation and experiment

Run	Mould Temperature (°C)	Melt Temperature (°C)	Injection Time (s)	Cooling Time (s)	Part Weight (g)		Percentage Difference (%)
					Simulation	Experimental	
1	50	250	0.63	12.6	7.0266	6.9842	0.61
2	50	280	0.70	14.0	6.9534	6.9822	0.41
3	50	310	0.77	15.4	6.8891	6.9888	1.43
4	56	250	0.70	15.4	7.0252	6.9807	0.64
5	56	280	0.77	12.6	6.9524	6.9798	0.39
6	56	310	0.63	14.0	6.8904	6.9853	1.36
7	62	250	0.77	14.0	7.0254	6.9773	0.69
8	62	280	0.63	15.4	6.9538	6.9784	0.35
9	62	310	0.70	12.6	6.8903	6.9800	1.29

From the result obtained, there is a good agreement between both simulation and experimental when the highest percentage difference is 1.43% only. It is also supported by Rusdi et al. [14] that has discrepancies with 2.21% and 4.35% of the simulation and experimental results in their studies.

3.2. Taguchi analysis of experimental result.

Table 4 shows the S/N ratio value for each experimental run. Higher weight is desirable in the study. Therefore, the larger-the-better characteristic S/N ratio was applied to measure the process performance characteristics.

Table 4. S/N ratio value for each run

Run	Part weight (g)	S/N ratio
1	6.9842	16.8823
2	6.9822	16.8798
3	6.9888	16.8881
4	6.9807	16.8780
5	6.9798	16.8769
6	6.9853	16.8837
7	6.9773	16.8737
8	6.9784	16.8751
9	6.9800	16.8771

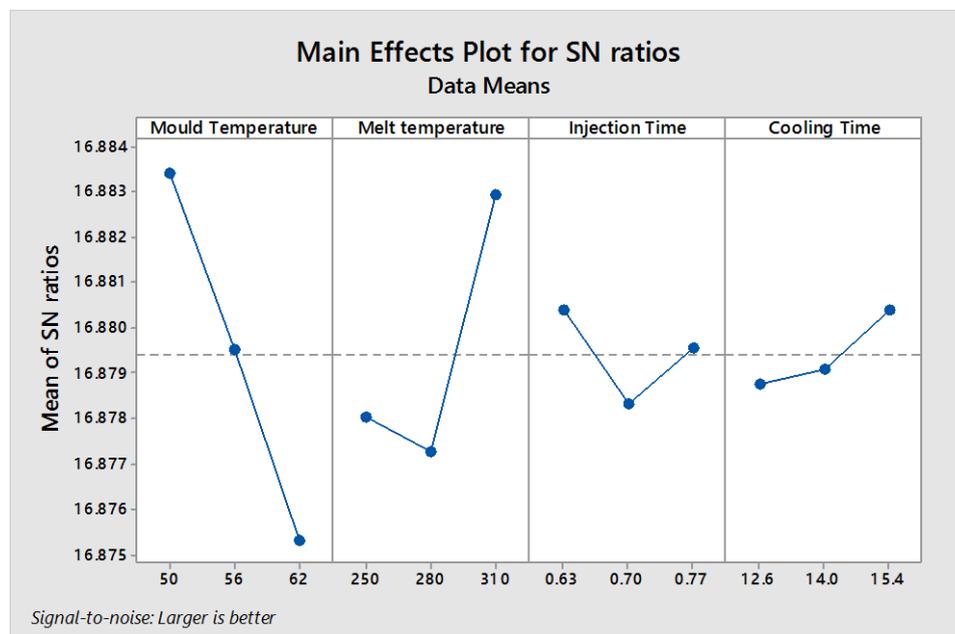
3.2.1. The optimum parameters levels based on S/N ratio

The value of S/N response table is shown in Table 5. From the S/N ratio graph and response table, it is found that mould temperature is significantly affected the part weight of plastic part.

Table 5. Response table for S/N ratio

Level	Mould Temperature (°C)	Melt Temperature (°C)	Injection Time (s)	Cooling Time (s)
1	16.8834	16.8780	16.8804	16.8788
2	16.8795	16.8773	16.8783	16.8791
3	16.8753	16.8830	16.8796	16.8804
Delta	0.0081	0.0057	0.0021	0.0016
Rank	1	2	3	4

Figure 3 shows the S/N ratio graph for the experiment result. From the graph, it is concluded that the optimum parametric combination are mould temperature 50°C (Level 1), melt temperature 310°C (Level 2), injection time 0.63s (Level 1) and cooling time 15.4s (Level 3).

**Figure 3.** Signal to noise (S/N) graph for part weight

By using the optimum parametric combination, prediction of part weight can be made. In Minitab software, Taguchi can predict the result of response for these optimal setting. By using the optimal parameter setting the new optimize part weight is 6.9895g which is greater than 6.9888g from run 3.

4. Conclusion

In this paper, part weight verification between simulation and experimental work was studied. By using Taguchi method, the most significant parameter that affects part weight is the mould temperature, followed by melt temperature, injection time and cooling time. It is found that the verification of part weight between minimum and maximum experimental are 0.35 % and 1.43 % respectively. Furthermore, part weight is nearer to the perfect shape. It means the end product can be produced completed to near net shape. The part weight is also increased by using the optimal parameter setting. Therefore, it shows that mould flow simulation software can be used by manufacturers to predict the quality of plastic part.

Acknowledgements

The authors would like to thank Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka for providing facilities for this research to be conducted successfully. This research is funded by the Ministry of Higher Education through Research Acculturation Grant Scheme RAGS/1/2014/TK01/FKP/B00075.

References

- [1] M. Huszar, F. Belblidia, H. M. Davies, C. Arnold, D. Bould, and J. Sienz, "Sustainable injection moulding: The impact of materials selection and gate location on part warpage and injection pressure," *Sustain. Mater. Technol.*, vol. 5, pp. 1–8, 2015.
- [2] Y. Yang, B. Yang, S. Zhu, and X. Chen, "Online quality optimization of the injection molding process via digital image processing and model-free optimization," *J. Mater. Process. Technol.*, vol. 226, pp. 85–98, 2015.
- [3] B. R. Nagahanumaiah, "Effects of injection molding parameters on shrinkage and weight of plastic part produced by DMLS mold," *Rapid Prototyp. J.*, vol. 15, no. 3, pp. 179–186, 2009.
- [4] A. López, J. Aisa, A. Martinez, and D. Mercado, "Injection moulding parameters influence on weight quality of complex parts by means of DOE application: Case study," *Measurement*, vol. 90, pp. 349–356, 2016.
- [5] H. Hassan, "An experimental work on the effect of injection molding parameters on the cavity pressure and product weight," *Int. J. Adv. Manuf. Technol.*, vol. 67, pp. 675–686, 2013.
- [6] A. Mohd Amran, N. Idayu, R. Jaafar, M. Hadzley, Y. Yaakob, A. R. Samsudin, and M. R. Salleh, "Comparison Between Star and Linear Runner Layout of Family Plastic Injection Mold," *Asian Res. Publ. Netw. (ARPN)*, vol. 10, no. 15, pp. 6263–6268, 2015.
- [7] O. C. Gheorghe, T. D. Florin, G. T. Vlad, and D. T. Gabriel, "Optimization of Micro Injection Molding of Polymeric Medical Devices Using Software Tools," *Procedia Eng.*, vol. 69, pp. 340–346, 2014.
- [8] G. Wang, G. Zhao, H. Li, and Y. Guan, "Multi-objective optimization design of the heating/cooling channels of the steam-heating rapid thermal response mold using particle swarm optimization," *Int. J. Therm. Sci.*, vol. 50, no. 5, pp. 790–802, 2011.
- [9] D. Chen, G. Lu, L. He, W. Li, and J. Yuan, "Warpage of injection-molded automotive B pillar trim fabricated with ramie fiber-reinforced polypropylene composites," *J. Reinf. Plast. Compos.*, pp. 1–9, 2015.
- [10] E. Hakimian and A. B. Sulong, "Analysis of warpage and shrinkage properties of injection-molded micro gears polymer composites using numerical simulations assisted by the Taguchi method," *Mater. Des.*, vol. 42, pp. 62–71, 2012.
- [11] E. Kuram, E. Tasci, A. Ihsan, M. Metin, F. Yilmaz, and B. Ozcelik, "Investigating the effects of recycling number and injection parameters on the mechanical properties of glass-fibre reinforced nylon 6 using Taguchi method," *Mater. Des.*, vol. 49, pp. 139–150, 2013.

- [12] A. Mohd Amran, N. Idayu, M. Sanusi, A. Aziz, and M. Hadzley, "Optimisation of Process Parameters in Linear Runner Family Injection Mold Using Moldflow Simulation Software," *Asian Res. Publ. Netw. (ARPN)*., vol. 11, no. 4, pp. 2475–2482, 2016.
- [13] Y. Wang, J. Kim, and J. Song, "Optimization of plastic injection molding process parameters for manufacturing a brake booster valve body," *Mater. Des.*, vol. 56, pp. 313–317, 2014.
- [14] M. S. Rusdi, M. Z. Abdullah, A. S. Mahmud, C. Y. Khor, M. S. Abdul Aziz, Z. M. Ariff, and M. K. Abdullah, "Numerical Investigation on the Effect of Pressure and Temperature on the Melt Filling During Injection Molding Process," *Arab. J. Sci. Eng.*, vol. 41, no. 5, pp. 1907–1919, 2016.