IOP Conference Series: Materials Science and Engineering

PAPER • OPEN ACCESS

Simulation-Based Optimization of Plastic Injection Molding Parameter for Aircraft Part Fabrication Using Response Surface Methodology (RSM)

To cite this article: M.U. Rosli *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **551** 012108

IOP Conf. Series: Materials Science and Engineering **551** (2019) 012108 doi:10.1088/1757-899X/551/1/012108

Simulation-Based Optimization of Plastic Injection Molding Parameter for Aircraft Part Fabrication Using Response Surface Methodology (RSM)

M.U. Rosli[1,*], Muhammad Ikman Ishak[1], Mohd Riduan Jamalludin[1], C.Y. Khor[1], M.A.M. Nawi[1], Mohamad Syafiq A.K.[1]

[1]Faculty of Engineering Technology, Universiti Malaysia Perlis (UniMAP), Level 1, Block S2, UniCITI Alam Campus, Sungai Chuchuh, 02100, Padang Besar, Perlis, Malaysia.

Email: uzair@unimap.edu.my

Abstract. The small size and thin part characteristics of the honeycomb floor panel for the aircraft part product may cause problems in injection molding fabrication process. The objectives of this study is to find the most appropriate parameter in injection molding process for honeycomb floor panel by simulation using MoldFlow software and optimize the quality of injection molding process parameter by using Response Surface Methodology (RSM) as to obtain an optimal response and meets the requirement specification in the aviation scope. The crucial responses are shrinkage and warpage. Melt temperature, filling pressure and injection time are selected as the most influential factor for shrinkage and warpage. Model response was fitted by quadratic model. As the results, the optimum value suggested by the software were melt temperature of 360.02c, 60 MPa filling pressure and 4.70s injection time. With small differences error value between solution and simulation, 0.3% for shrinkage and 0.6% for warpage, the results was acceptable.

1. Introduction

In vehicles engineering, mainly in aircraft industries, floor panel is made up from honeycomb. Honeycomb for flooring in commercial aircraft product fabrication is the process of producing the component or part in light weight for requirement in specific strength with high accuracy and precision. Light in weight is one of the most important characteristic in the aerospace industry, parallel with the current trend in the automotive industry and manufacturing [1,5,8,10]. In the field of aerospace, the honeycomb panel is optimized by characterizing in light structure with the good stiffness, strength and good energy absorption properties [2]. The basic method of manufacture of the honeycomb involves printing stripes of adhesive onto flat foils which are subsequently stacked, bonded to each other and then expanded to form a series of hexagonal cells making up the honeycomb blocks. The type of the process that has been chosen to produce honeycomb for the floor panel product is injection molding. In injection molding, there are various material can be used that meet the requirement in aircraft for light weight [3,6,7]. Injection molding is a machining process to produce a complex shape product and mostly used because injection molding can produce a product in short cycle time, high product accuracy and can be fabricated in large quantities.

Based on the previous research for honeycomb fabrication, there are numbers of the researcher has used the invention of honeycomb in injection molding process but not in aircraft fabrication. From a research by Scharkowski, an injection molding process was used in a honeycomb-shaped hollow body plastic, preferably polyolefins [4]. This simulation based research used polyetheretherketone (PEEK) as the material selection to produce the honeycomb for floor panel. The type of the product is in light weight and for requirement in specific strength with the high accuracy and precision. Simulation based optimization is the most effective way to study the strength of plastic honeycomb floor panel before the actual fabrication processes begin

IOP Conf. Series: Materials Science and Engineering **551** (2019) 012108 doi:10.1088/1757-899X/551/1/012108

[9,12]. The injection molding parameters are considered in this project to determine the most significant factor and accurate molding process parameter setting [10].

2. Methodology

2.1 Response Surface Methodology (RSM)

In the honeycomb floor panel fabrication process, the most crucial aspect is the accuracy and precision without changing the lightweight aspect ratio. By using the Response Surface Methodology (RSM) method, the most suitable parameters can be defined to control the warpage and shrinkage. Melt temperature, filling pressure, injection time is the process factor that is the most significant parameters that effecting the warpage and shrinkage of an injection molded part. The different value order of processing parameter that generates from the Design Expert software was completed in 60 times of numerical run. Table 1 shows the summary of the design expert software which evaluates the minimum and maximum of the two responses that would like to be controlled in this project that is warpage and volumetric shrinkage. The two values were generated from Moldflow software. The minimum value for a warpage is 4.08 and maximum is 18.53. For shrinkage, the minimum and maximum value are 15.56 and 24.95, respectively.

Table 1. Design of experiment.

Response	**Name**		**Obs**	**Min**	**Max**	**Trans**	**Model**
Y1	Warpage		60	4.08	18.53	None	Quadratic
Y2	Shrinkage		60	15.56	24.95	None	Quadratic
Factor	**Name**	**Unit**	**Type**	**Low Actual**	**High Actual**	**Low Coded**	**High Coded**
A	Melt temperature	C	Numeric	360.00	400.00	-1	1
B	Filling pressure	Mpa	Numeric	60.00	100.00	-1	1
C	Injection time	s	Numeric	2.00	5.00	-1	1

3. Results and Discussion

3.1 3D Surface

In this study, the important goals that need to achieve are the minimum value of the response volumetric shrinkage and warpage. The 3D surface response and contour plots of the warpage and shrinkage were plotted using Design Expert software to study the interactive relationship between each factor and responses. The maximum or minimum value of the most optimal result for shrinkage and warpage can be displayed in the 3D surface plot. In the 3D surface response, the selection of two variables and a constant variable was determined according to the level of sensitivity towards the responses that depended on the perturbation plots. Filling pressure and melt temperature are the most sensitive factor toward warpage. Figure 1 shows the most optimal warpage in 30% of fiberglass at 4.23. The optimized (lowest value) warpage can be achieved at higher filling pressure 100Mpa and higher melt temperature 380 °C.

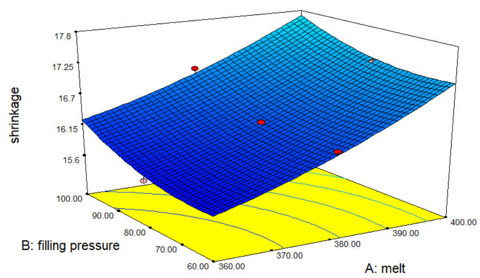

Figure 1. 3D Plot for warpage in 30% fiber glass material.

The most influential factor for shrinkage was filling pressure and melt temperature. For shrinkage, to find the most optimize result (the lowest value) of shrinkage must at higher filling pressure and lower melt

IOP Conf. Series: Materials Science and Engineering **551** (2019) 012108 doi:10.1088/1757-899X/551/1/012108

temperature. In Figure 2, the most optimal result for shrinkage is 16.38 at 100 MPa and 380 °C in 30% fiber glass.

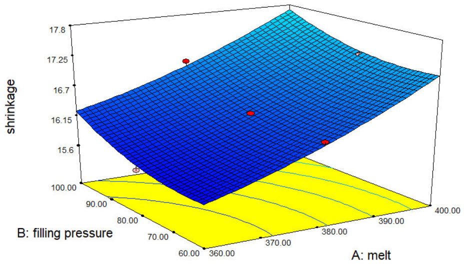

Figure 2. 3D Plot for shrinkage in 30% fiber glass material.

3.2 Optimization of Design Parameters

From the design expert analysis, there are 56 solutions were generated by RSM. The recommended solution with the highest desirability in Table 2 is solution number one. The warpage and shrinkage value of a selected solution are 4.1884 and shrinkage 15.56. The solution for the optimized factors in order to minimize the responses as suggested by the Design Expert software was examined through the Moldflow simulation at melt temperature 360.02, filling pressure 60 MPa and injection time 4.70s.

Table 2. Recommend solution.

No	Melt temp	Filling pressure	Injection time	Warpage	Shrinkage	Desirability
1	360.02	60.00	4.70	4.1884	15.56	0.996
2	360.04	60.00	4.75	4.18856	15.5572	0.996
3	360.01	60.03	4.76	4.18873	15.5553	0.996
4	360.17	60.00	4.87	4.18917	15.5525	0.996
5	360.49	60.01	4.89	4.1896	15.5598	0.996
6	360.00	60.01	4.93	4.18937	15.5433	0.996
7	360.63	60.00	4.95	4.19008	15.559	0.996
8	360.11	60.31	4.72	4.19033	15.5772	0.996
9	360.00	68.44	4.83	4.22979	15.56	0.995

3.2 Validation of Simulation Results

The comparison results between model response and simulation are listed in Table 3. The predicted value from the selected solution and the result run from Moldflow software based on recommending processing parameter as shown in Table 3. From this result, the percentage error can be calculated by using the formula. The percentage of error for shrinkage was only 0.3 % and warpage 0.6 %, which the value difference between the solution and simulation in small difference and acceptable.

Table 3. Result and percentage of error.

	Predicted	Simulation	% Differences
Warpage	4.1884	4.217	0.6
Shrinkage	15.56	15.51	0.3

Figure 3 and Figure 4 show the result in Moldflow software by using the selected solution for three parameters (i.e., melt temperature, filling pressure and injection time). The suggested optimize factor value was examined in Moldflow software, and the result was compared to the predicted value for response in the design expert software. The value for volumetric shrinkage is 15.61 and 4.217 for the warpage. In summary, the optimum values for each factor were successfully determined by RSM.

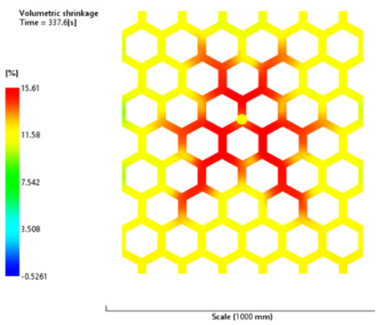

Figure 3. Result for warpage.

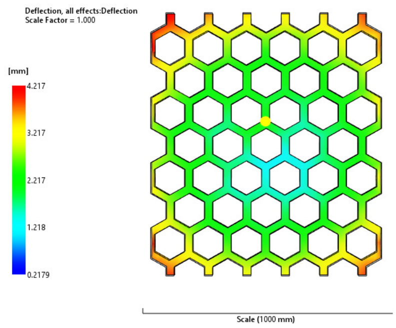

Figure 4. Result for shrinkage.

4. Conclusions

In conclusion, factor of melt temperature, filling pressure and injection time are selected as the most influential factor for shrinkage and warpage. As the results, the optimum value suggested by the software were melt temperature of 360.02ºC, 60MPa filling pressure and 4.70s injection time. With small differences error value, 0.3% for shrinkage and 0.6% for warpage, the results was acceptable. It is significant to optimise parameters setting for injection molding in order to reduce the material waste and cost of a high accuracy finishing product.

Acknowledgements

The research was supported by Faculty of Engineering Technology, Universiti Malaysia Perlis (UniMAP) for experiment facilities and finically supported under Short Term Grant (STG) through project number 9001-00503.

References

[1] Rosli M.U *et al* 2013 *International Journal of Engineering and Technology* **5** 3158-3167.
[2] Giglio M *et al* 2012 *Computational Materials Science* **56** 69.
[3] Rosli M U *et al* 2017 *MATEC Web of Conferences* **97** 01039.
[4] Scharkowski J 1999 U.S. Patent No. 5,922,438. Washington, DC: U.S. Patent and Trademark Office.
[5] Rosli M U *et al* 2014 *International Journal of Mechanical & Mechatronics Engineering* **14** 62.
[6] Huang R *et al 2016 Journal of Cleaner Production* **135** 1559
[7] Ganesh B *et al* 2015 *International Journal of Advanced Engineering and Global Technology* I **3** 1451.
[8] Rosli M U *et al* 2013 *International Journal of Materials, Mechanics and Manufacturing* **1** 32
[9] Jizat N M *et al* 2017 *AIP Conference Proceedings* 1885
[10] Jou Y T *et al* 2014 *Applied Mathematics & Information Sciences* **8** 1277
[11] Ishak M I *et al* 2017 *MATEC Web of Conferences* 97
[12] Ramdan D *et al* 2012 *Packaging and Manufacturing Technology* **2** 1786