**Optimisation of Warpage on Plastic Injection Moulding Part Using Response Surface Methodology (RSM)**

M H M Hazwan1,2,a), Z Shayfull1,4,b), S Sharif3,c), S M Nasir1,4,d) and N Zainal5,e)

1School of Manufacturing Engineering, Universiti Malaysia Perlis, Kampus Tetap Pauh Putra, 02600 Arau, Perlis, Malaysia.

2School of Engineering Technology, Universiti Malaysia Perlis, Kampus UniCITI Alam, Sungai Chuchuh, 02100 Padang Besar, Perlis, Malaysia.

3Faculty of Mechanical Engineering, UniversitiTeknologi Malaysia, 81310 UTM Skudai, Johor, Malaysia.

4Green Design and Manufacture Research Group, Centerof Excellence Geopolymer and Green Technology (CEGeoGTech), Universiti Malaysia Perlis, 01000 Kangar, Perlis, Malaysia.

5Faculty of Computing, UniversitiTeknologi Malaysia, 81310 UTM Skudai, Johor, Malaysia

a)Corresponding author: hazwanhanid@unimap.edu.my

b)shayfull@unimap.edu.my

c)safian@fkm.utm.my

d)nasirsaad@unimap.edu.my

e)ezayana@gmail.com

**Abstract.** Todays, there are various of optimisation methods that have been studied by many researchers in order to find the appropriate combination of processing parameters setting in the injection moulding process. From the previous literatures, the optimisation works have been proven will improve the moulded part quality. In this study, the application of optimisation work to improve warpage of front panel housing has been explored. By selecting cooling time, coolant temperature, packing pressure and melt temperature as the variable parameters, design of experiment (DOE) have been constructed by using the rotatable central composite design (CCD) approach. Response Surface Methodology (RSM) was performed in order to define the optimal processing parameters setting which will optimise the warpage condition. Based on the results, melt temperature is the most significant factor contribute to the warpage condition and warpage have optimised by 47.1% after optimisation. The findings show that the application of optimisation work offers the best quality of moulded part produced.

# Introduction

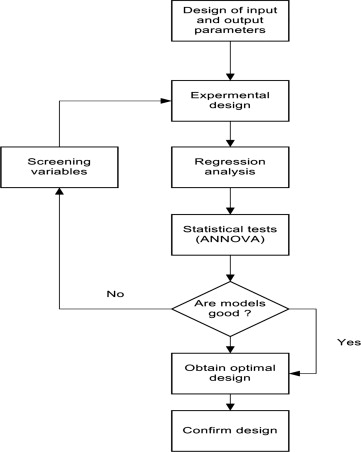
Nowadays, injection moulding technology has been widely used in modern industry activity to manufacture a complex geometry product because of the effectiveness in term of efficiency and cost. The injection moulding process consists of four main stages which are filling, packing, cooling and ejecting processes [[1](#_ENREF_1), [2](#_ENREF_2)]. However, the quality issues have become a challenge to the plastic manufacturer. One of a common problem for injection moulded products is warpage [[3](#_ENREF_3)]. Due to the design complexity and numerous influencing factors during the moulding process, warpage is difficult to avoid and this kind of defects will affect the assembly process like uneven clearance or interference especially in the thin wall component. The appropriate combination of injection moulding processing parameters can minimise this warpage condition [[4](#_ENREF_4)]. Previously, to overcome the warpage problem, most of the plastic manufacturers relied on trial-and-error approach in order to obtain the appropriate setting of injectionmoulding processing parameters. However, this technique consumesa lot of time and cost [[5](#_ENREF_5)].

To use this “Old Style Equation” as a “template,” highlight the entire line, then use cut and paste to the new location. Note that the equation number will automatically update (increment).

 (1)

# Response Surface Methodology

Response surface methodology (RSM) is a classical optimisation approach. It was used to demonstrate the relationship between variable parameters which influence the response condition in two or three-dimensional hyperbolic surface [[10](#_ENREF_10)]. The mathematical model function will be obtained by using the second-order polynomial regression model in this study. The necessary information to construct the response model are generally accumulated by the simulation works [[11](#_ENREF_11), [12](#_ENREF_12)]. Figure 1 shows the RSM flowchart in this study. This study wills accordingly the flow chart shown in Fig. 1.



**FIGURE 1.** Response Surface Methodology (RSM) flowchart.

**Notes:** **Cite all figures in the text consecutively. The word “Figure” should be spelled out if it is the first word of the sentence and abbreviated as “Fig.” elsewhere in the text. Place the figures as close as possible to their first mention in the text at the top or bottom of the page with the figure caption positioned below, all centered.**

## Design of Experiment Setup

In this research, four factors which are coolant inlet temperature, melting temperature, packing pressure and cooling time have been chosen as variables parameters that influencing warpage in the injection moulding process. The selected variable parameters range were defined by minimum and maximum levels as shown in Table 1. Then, full factorial design was selected as a DOE in order to predict the interactions of the variable parameters and the main effects which affect the warpage condition of the moulded part by using Design Expert 7.0 software.

**TABLE 1.** Selected variable parameters and levels.

|  |  |  |
| --- | --- | --- |
| Factors | Level | |
| Minimum | Maximum |
| Coolingtemperature, A (°C) | 25 | 65 |
| Melt temperature, B (°C) | 220 | 260 |
| Packing pressure, C (MPa) | 46.74 | 56.74 |
| Cooling time, D (s) | 25 | 40 |

# Results and Discussions

## Results

The results tabulate the warpage value for each run with the specified variable parameters condition which obtained from the DOE. The specified variable parameters condition was set and simulated in the AMI 2013 software.

## *Parameters Results*

Warpage value obtained from simulation analysis was shown in Table 6. The results tabulate the warpage value for each run with the specified variable parameters condition which obtained from the DOE. The specified variable parameters condition was set and simulated in the AMI 2013 software.

**TABLE 2.** Simulation analysis results for each run.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Standard Order | Data Source | Variable parameters for injection moulding simulation | | | | Response |
| Cooling temperature (°C) | Melt temperature (°C) | Packing Pressure (MPa) | Cooling time (s) | Warpage (mm) |
| 1 | DOE | 25 | 220 | 46.74 | 20 | 0.220 |
| 2 | 65 | 220 | 46.74 | 20 | 0.155 |
| 3 | 25 | 260 | 46.74 | 20 | 0.305 |
| 4 | 65 | 260 | 46.74 | 20 | 0.225 |
| 5 | 25 | 220 | 56.74 | 20 | 0.215 |
| 6 | 65 | 220 | 56.74 | 20 | 0.170 |
| 7 | 25 | 260 | 56.74 | 20 | 0.310 |
| 8 | 65 | 260 | 56.74 | 20 | 0.235 |
| 9 | 25 | 220 | 46.74 | 35 | 0.175 |
| 10 | 65 | 220 | 46.74 | 35 | 0.130 |
| 11 | 25 | 260 | 46.74 | 35 | 0.255 |
| 12 | 65 | 260 | 46.74 | 35 | 0.185 |
| 13 | 25 | 220 | 56.74 | 35 | 0.175 |
| 14 | 65 | 220 | 56.74 | 35 | 0.135 |
| 15 | 25 | 260 | 56.74 | 35 | 0.245 |
| 16 | 65 | 260 | 56.74 | 35 | 0.190 |
| 17 | Centre | 45 | 240 | 51.74 | 27.5 | 0.215 |
| 18 | 45 | 240 | 51.74 | 27.5 | 0.215 |
| 19 | 45 | 240 | 51.74 | 27.5 | 0.215 |
| 20 | 45 | 240 | 51.74 | 27.5 | 0.215 |
| 21 | Axial | 5 | 240 | 51.74 | 27.5 | 0.240 |
| 22 | 85 | 240 | 51.74 | 27.5 | 0.140 |
| 23 | 45 | 200 | 51.74 | 27.5 | 0.170 |

# Conclusions

This study is helpful in enhancing the quality of moulded parts produced where the objective is to optimisewarpage of the front panel housing moulded part have been achieved. Based on the results, the warpage has been optimised by using Response Surface Methodology (RSM) approach. The results also show that:

* By using RSM, the significant mathematical model function can be obtained in order to predict warpage value with reasonable accuracy.
* From the ANOVA results, melt temperature is the most significant factor influencing the warpage condition on the moulded part, follow by coolant temperature and cooling time.
* The optimal processing parameter obtained from RSM has optimisedwarpage by 47.1% which is from 0.2650mm from the simulation result to 0.1403mm after optimisation.

# Acknowledgments

The authors acknowledge School of Manufacturing Engineering, Universiti Malaysia Perlis for the lab facilities. Special thanks to those who contributed to this project directly or indirectly.

# References

1. W. Michaeli and G. Potsch, "Injection Molding: An Introduction" (Munchen: Hanser, Fachbuchverlag, 1995).

2. D. Annicchiarico and J. R. Alcock, Mater. Manuf. Proces. 29, 662-682 (2014).

3. Y. C. Lam, L. Y. Zhai, K. Tai and S. C. Fok, Int. J. Prod. Res. 42, 2047-2061 (2004).

4. D. Montgomery, "Design and Analysis of Experiments" (6th edn., John Wiley and Sons, New York, 2005).

All Referencing must be in Times new Roman, Font Size 10

**Referencing from Journals**

**Author Names, Journal Names (in abbreviations) volume, page number-page number year (in bracket).**

1. D. Annicchiarico and J. R. Alcock, Mater. Manuf. Proces. 29, 662-682 (2014).

**List of abbreviations can be obtained from any reliable sources such as;**

[**http://www.efm.leeds.ac.uk/~mark/ISIabbr/A\_abrvjt.html**](http://www.efm.leeds.ac.uk/~mark/ISIabbr/A_abrvjt.html)

[**https://www.ieee.org/documents/trans\_journal\_names.pdf**](https://www.ieee.org/documents/trans_journal_names.pdf)

**OR if in case the abbreviation is not available after a thorough search, you may put the full name of the journal names.**

**Example :**

1. Y. Nasir, Y. J. Farizuan, Y. S. Zhu and H. Dang, International Journal of Atmospheric Environment 41, 13-19 (2015).

**Referencing from Conferences / Symposium / Seminar / Proceedings**

**Names of authors, Proceeding’s name in full (all italics), year (in bracket)**

**Example :**

1. C. Kinlin, “The Future of Asian Optical Communication” (*Conference on Optical Fiber Communication & Optoelectronic Exposition & Conference*, 2006), pp. 1-3.

2. A. Mansor, Y. N. Phua, M. Othman, Nurul Shahrizan Shahaduddin and Z. Yusoff, “Double-Frequency Spaced Multiwavelength Brillouin-Erbium Fiber Laser in a Hybrid Linear-Ring Configuration” (*IEEE International Conference on Photonic*, 2011), pp. 1-3.

3. M. A. Toor, N. A. M. Ahmad Hambali, H. A. Abdul-Rashid and Z. Yusoff, “Multiwavelength Brillouin-Raman fiber laser utilizing a partially fiber Bragg grating in L-band” (*IEEE on International Conference Photonics*, 2014), pp. 90-92.

**Referencing from Patent**

**Authors name, Name of patent with patent number, year (in bracket)**

**Examples**

1. M. Effendi and G. Nasirudin, U.S. Patent No. 5692966 (2010)
2. M. Exposito, R. Rodenkyiev and P. Todomin, R.F. Patent No. 112458a (2014)

**Referencing from Theses / Books / Reports**

**Names of authors, “Book’s / Thesis / Report name in full” (Region/Country: Publisher, Year (in bracket)**

**Examples**

1. W. Michaeli and G. Potsch, "Injection Molding: An Introduction" (Munchen: Hanser, Fachbuchverlag, 1995).

2. H. A. Keukonhoeff, “Methods in Applied Computing” (University of New York, 2014).

3. J. Steven, “Basic Chemistry of Polymeric Systems” (France, Polymer Press, 2011).

4. A. J. Kinloch, “Adhesion and Adhesives: Science and Technology” (Springer Science and Business Media, 1987).

**Referencing from online websites/portal/recognizable or reputable blog**

**Please write down as below examples ;**

1. Information on <http://worldofscience.com.my/aboutchemistry.html>
2. Information on [www.computingbasic.com.html](http://www.computingbasic.com.html)

NOTE:

* Please make sure all pictures/graph are clear and readable.
* Do not insert page number for all manuscript.