Performance of Assessment Model for Injection Moulding Parameters

Nur Qurratul Ain Adanan, Faiz Mohd Turan, Kartina Johan, Anis Izzati Md Yusoff, and Yuen Weng Yee

Abstract In order to manufacture a better quality of plastic product, the best injection moulding parameters have to be identified. Therefore, this research studies the performance of assessment model for injection moulding parameters using Taguchi and ANOVA method. The objective of this research is to identify the best injection moulding parameters in producing plastic pallets in term of compressive strength when subjected to a constant load. Melting temperature, charging speed and holding pressure and polypropylene material were chosen as the parameters to study their effect on compressive strength. According to the results obtained, the melting temperature of 230 °C, charging speed of 93 rpm and holding pressure of 25 MPa were found to be the best combination of injection moulding parameters to fabricate the better performance of plastic pallet which give the maximum ultimate load with 6376.7 kg. Based on the statistical ANOVA analysis results, the most significant parameter affecting the compressive strength of plastic pallet is melting temperature, which is indicated by the percentage contribution of P = 63.67%, followed by holding pressure with 21.79%. Charging speed is the least significant parameter with 2.96%. To conclude that, Taguchi and ANOVA method show that melting temperature is the most significant parameter in order to get the best compressive strength.

Keywords Injection moulding · Compressive strength · Taguchi · ANOVA

1 Introduction

Nowadays, injection moulding is one of the most common process to manufactured various plastic products from the smallest bottles to entire body of cars. Injection moulding is a simple manufacturing process where the material is fed into the barrel, and injected into the mold and the parts will be produced [1]. Besides that, the product design in plastic injection molding had become more complicated and the quality

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requirements also become more stringent. The quality of the products is depending on material properties, mold design, part design and selection of molding parameters [2, 3]. However, the part design and mold design are done at initial stage of product development, it cannot be change easily [4]. So, the proper selection of injection parameters is the only method to decrease defects and increase quality [5]. Even in this high-tech era, proper selection of injection molding parameters is depending on the experience technician and trial and error process [6]. In order to solve this problem, optimization of injection molding parameters is a must.

This study was focused to optimize the injection molding parameters of plastic pallet in term of compressive strength which is reflected by the compressive deflection when subjected to a constant load. Polypropylene will be used in this study. Therefore, design of experiment in Taguchi method will be used to optimize the injection molding parameters of plastic pallet in term of compressive strength. Lastly, ANOVA is used to analyses the results and identify the most influence factor among the injection molding parameters.

2 Methodology

In this study, the injection moulding process parameters which influence product mechanical properties are based on the research of literature review. Polypropylene is choosing as a raw material are used to produce plastic pallet with the help of JU2400, Haitian injection molding machine. Polypropylene plastic pallet is processed by using different set of process parameters like melting temperature, holding pressure and changing speed. Each parameter has three levels which are low, medium and high. After the parameters was chosen, an appropriate orthogonal array will be selected to conduct the experiments. The flow chart of this study is shown in Fig. 1.

In Fig. 2, L9 orthogonal array is chosen which have 3 injection moulding parameters with 3 level of factors. Next, using the Minitab software, it will generate the experiment condition and run the injection moulding. After the plastic pallet is produced, the quality test of compressive strength on the pallet will be conducted. The compressive strength results obtained is used to calculate the S/N ratio to identify the best combination of the injection moulding parameters. Furthermore, a statistical analysis of variance (ANOVA) is performed to analyses and identify which injection moulding parameters have the most significant effect on compressive strength of the pallet when subjected to a constant load by calculating the F-value and percentage of contribution. With the S/N and ANOVA analyses, the optimal combination of the process parameters can be predicted.

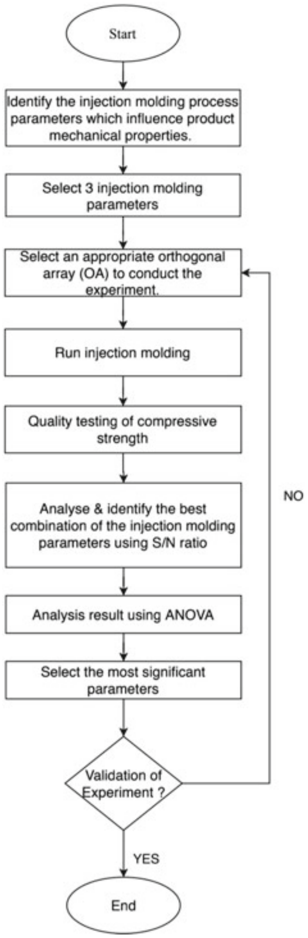

Fig. 1 Research flow chart

Number of Levels	Number of Parameters (P)														
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
2	L4	L4	L8	L8	L8	L8	L12	L12	L12	L12	L16	L16	L16	L16	L32
3	L9	L9	L9	L18	L18	L18	L18	L27	L27	L27	L27	L27	L36	L36	L36
4	L'16	L'16	L'16	L'16	L'32	L'32	L'32	L'32	L'32						
5	L25	L25	L25	L25	L25	L50	L50	L50	L50	L50	L50				

Number of Levels	Number of Parameters (P)														
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
2	L32	L32	L32	L32	L32	L32	L32	L32	L32	L32	L32	L32	L32	L32	L32
3	L36	L36	L36	L36	L36	L36	L36								
4															
5															

Fig. 2 Orthogonal array selection

2.1 Selection of Injection Moulding Parameters

There are 3 injection molding parameters namely melting temperature, holding pressure and charging speed are used to investigate the effect on the performance of a plastic pallet in term of compressive strength when subjected to a constant load. The parameters in this study have three level, the melting temperature is select in the

Table 1 The selected parameters in 3 level

Symbol	Process parameters	Level 1	Level 2	Level 3
A	Melting temperature (°C)	210	220	230
B	Charging speed (rpm)	88	93	98
C	Holding pressure (MPa)	25	35	45

range at 210–230 °C. The range of Charging speed is choosing at 88–98 rpm and holding pressure is select in the range at 25–45 MPa. The selected injection molding process parameters along with their levels are shown in Table 1.

3 Results and Discussions

In this study, the experimental results obtained are analyzed using statistical analysis. The analysis will conclude the optimum parameter that will be implemented in the compressive strength testing process to achieve the project's objective which is to identify the best combination of injection molding parameters that give the best performance of a plastic pallet in term of compressive strength when subjected to a constant load. Therefore, the optimum parameters obtained from the Taguchi method will be analyzed using Minitab software. As the final step, the data collected from the experiments will be analyzed and discussed.

All the process parameter was set accordingly based on the Taguchi experimental design. Each specimen came together with specimen for tensile test and specimen for flexural testing. The tests were carried out according to ASTM D638 using a Type 1 tensile bar on a tensile test machine with a 5 kN load cell and flexural assessed in accordance with ASTM D790.

3.1 Signal to Noise (S/N) Ratio

This study is focuses on the effect of three process parameters of the mechanical performance of the polypropylene plastic pallet. All the results obtained from the testing determine the compressive strength when subjected to a constant load and analyzed and discussed statistically based on the Taguchi method. This study uses the S/N ratio to convert the experimental results as single response instead of using the average value to analyzed the compressive strength. The S/N ratio is the statistical quantity representing the power of a response signal divided by the power of the variation in the signal due to noise. Using the S/N ratio data (in dB) in Table 2, the average performance or main effects for each factor are computed. As show in Table 2, since S/N ratios have not changed significantly, no abnormal were introduced in the calculations or measurements. According to the ultimate load test data shown in

Table 2 Summary of results of tests and S/N ratio values

Experimental number	Process parameter			Ultimate load test ($\times 10^3$ kg)	S/N ratio (dB)
	Melting temperature (°C)	Charging speed (rpm)	Holding pressure (MPa)		
1	230	98	45	5.1602	74.2533
2	230	93	35	6.3767	76.0919
3	230	88	25	6.0911	75.6939
4	220	98	35	4.4078	72.8844
5	220	93	25	4.9000	73.8039
6	220	88	45	4.4549	72.9768
7	210	98	25	5.6267	75.0051
8	210	93	45	4.7161	73.4717
9	210	88	35	4.8104	73.6436

Table 2, it seems that higher melting temperature might have increase the ultimate load in some of the experiment runs.

By using the Minitab19 software, the main effect graph in Fig. 3 shows the changes in compressive strength due to variations of injection moulding parameters and the sets of process parameters can be estimated further. There are three types of S/N ratio used to predict the optimal sets namely the smaller the better, the nominal the best, and the larger is better. In this framework, the larger is better quality characteristic is chosen to improve the mechanical properties of the part produced through the optimal

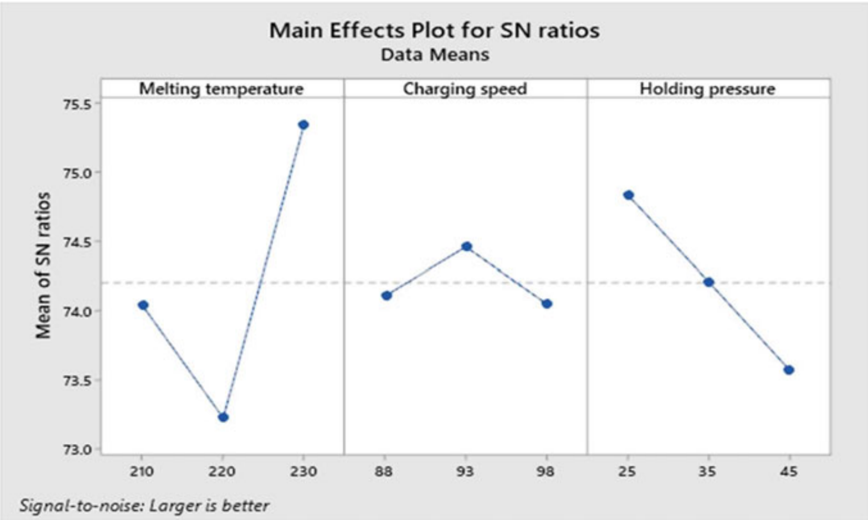

Fig. 3 Main effects plot of S/N ratios for compressive strength

levels of processing parameters. The best combination injection moulding parameters in order to get better compressive strength of product when subjected to a constant load is based on the graph of main effects plot for S/N ratios in Fig. 3. From Fig. 3, the main effects plot for S/N ratios show that the higher melting temperature, the higher the S/N ratio while the lower the holding pressure, the higher the S/N ratios. From the result, the higher melting temperature with lower holding pressure are the most significant parameters and it will give best result of compressive strength. The best combination of the injection moulding parameters is 230 °C melting temperature, 93 rpm charging speed and 25 MPa holding pressure as shown in Fig. 3.

3.2 Analysis of Variance (ANOVA)

From the F-distribution statistic table, the $F_{(0.05,2,8)} = 4.46$ for a level of significant factor equals to 0.05 (or 95% confidence level). Melting temperature (A) [F-statistic = 5.50 > 4.46] is thus identified as significant factor. The ANOVA result of the experiment shows the melting temperature have a greatest influence on compressive strength when subjected to a constant load. For charging speed (B) [F-statistic = 0.26 < 4.46] and holding pressure (C) [F-statistic = 1.88 < 4.46] show that both factors are not significant to the compressive strength. From this, it indicates the significant and insignificant factors to compressive strength. Referring to Table 3, there are 2 out of 3 processing parameters selected in the experiment show P values greater than 5%. As a level of confidence of 95% is used in this study, melting temperature and holding pressure are significantly affect the quality characteristics while charging speed is least significantly affected. In Table3, the most significant factor for the compressive strength of the plastic pallet is melting temperature, which is about 63.67%. Holding pressure is the second most influential factor, which is about 21.79% and lastly the charging speed contribute the least to the compressive strength with 2.96%.

Table 3 ANOVA summary for the compressive strength

Source	DOE	SS	V	F	P(%)
Melting temperature	2	2,555,408	1,277,704	5.50	63.67
Charging speed	2	118,679	59,340	0.26	2.96
Holding pressure	2	874,645	437,322	1.88	21.79
Error	2	465,022	232,511		
Total	8	4,013,754			100

4 Conclusion

In conclusion, the injection moulding parameters which influence product mechanical properties is identified which are melting temperature, charging speed and holding pressure. In this framework, the optimization of injection moulding parameters has been successfully developed through the design of experiments by Taguchi method. The melting temperature of 230 °C, charging speed of 93 rpm and holding pressure of 25 MPa are found to be the best combination of injection moulding parameters to fabricate the better performance of plastic pallet which give the maximum ultimate load with 6376.7 kg. Based on the statistical ANOVA analysis results, the most significant parameter affecting the compressive strength of plastic pallet is melting temperature, which is indicated by the percentage contribution of P = 63.67%, followed by holding pressure with 21.79%. Charging speed is the least significant parameter with 2.96%. To conclude that, Taguchi and ANOVA method show that melting temperature is the most significant parameter in order to get the best compressive strength.

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References

1. Mengistu N, Koneru S, Indra Reddy A, Koteswararao B (2019) Design and development of hand operated injection moulding machine for manufacturing recycled plastic articles. Int J Recent Technol Eng 8:2544–2554
2. Panneerselvam V, Turan FM (2019) Optimization of process parameters of injection moldings for plastic pallets manufacturing industry. J Manuf Syst Technol 02:75–83
3. Panneerselvam V, Turan FM (2020) Multi response optimisation of injection moulding process parameter using Taguchi and desirability function. J Manuf Syst Technol. SympoSIMM 2019, LNME 252–264
4. Kumar D, Kapoor A (2019) Optimization of process parameters in injection-molding by recent methods for optimization—literature review. In: National conference on sustainable and emerging trends in mechanical engineering “NCSETME 2018” at: Poornima Group of Institutions, Jaipur
5. Shi H, Xie S, Wang X (2013) A warpage optimization method for injection molding using artificial neural network with parametric sampling evaluation strategy. Int J Adv Manuf Technol 65:343–353
6. Singh G, Pradhan MK, Verma A (2018) Multi response optimization of injection moulding process parameters to reduce cycle time and warpage. Mater Today Proc 5:8398–8405