Optimising Casting Film Parameters for LPDE Material Assessment

Nur Qurratul Ain Adanan, Faiz Mohd Turan, Kartina Johan, Anis Izzati Md Yusoff, and Wong Hui Xin

Abstract The growing demand for disposable gloves, especially from the healthcare industry amidst the ongoing Covid-19 pandemic and rising awareness about Healthcare-Associated Infections (HAIs). One of the ways to produce disposable gloves is using cast LDPE film machine. The quality of the products depends on material resin used, machine casting film design, part design and the selection of process parameters. However, the part design and casting film design are done at the initial stage of product development, it cannot be change easily. To manufacture a better quality of cast LDPE gloves, the best LDPE casting film parameters have to be identified. This research aims to identify the best LDPE casting film parameters in producing disposable gloves in terms of strong sealed but edges failed defect rate in production line. The three LDPE casting film parameters such as tensile strength, melt flow index (MFI) and load weight of resin were chosen to study their effect on the defect rate. In this research, the Taguchi method is used to optimize the best process parameters. On the other hand, an orthogonal array (OA), signal-to-noise (S/N) ratio, and ANOVA were employed to investigate the strong sealed but edges failed defect rate. According to the results obtained, the tensile strength of 34 MPa, melt flow index of 3 g/10 min and load weight of 2 kg were found to be the best combination of LDPE casting film parameters to fabricate the better performance of LDPE disposable gloves which give the lowest strong sealed but edges failed defect rate with 2%. Based on the statistical ANOVA analysis results, the most significant parameter affecting the strong sealed but edges failed defect rate of LDPE disposable gloves is tensile strength, which is indicated by the percentage contribution of P = 55.56%, followed by melt flow index with 38.89%. The load weight of LDPE resin is the least significant parameter with 5.55%. To conclude, Taguchi and ANOVA method show that tensile strength is the most significant parameter to get the least strong sealed but edges failed defect rate.

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A. S. Abdul Sani et al. (eds.), *Enabling Industry 4.0 through Advances in Manufacturing and Materials*, Lecture Notes in Mechanical Engineering,
https://doi.org/10.1007/978-981-19-2890-1_7

Keywords Low-density polyethylene · Orthogonal array · Melt flow index · Load weight

1 Introduction

Polymer mechanical characteristics, particularly as a function of temperature and strain rate, are critical for the use of these polymers in design. The response of low-density polyethylene (LDPE) was examined in this research over a wide range of strain rates and temperatures. The mechanical reaction is considered to be temperature and strain rate dependent, with stress increasing with rising strain rate or reducing with temperature.

The key substance of the CPE gloves is all LDPE, LLDPE and some MLLDPE, much the same but different manufacture. CPE gloves are fitted with a casting film. The casting film device can output as thin as 18 microns, and the thickness and consistency can be very stable, even better than the blowing machine, and the machines are therefore much larger than the blowing film machines. Since different film projects trigger a very different kind of results. CPE gloves are much better than PE gloves, but they're more costly than PE gloves, and they cannot be that thinner.

Quality requirements of Low-Density Polyethylene (LDPE) glove products have become more stringent. The relationship of tensile strength, melt flow index and load weight of casting LDPE is the crucial on in this project. According to Lyondell-Basell, melt flow index and its tensile strength are tightly co-related to each other as mentioned in titled research paper named A Guide Polyolefin Film Extrusion [1]. The paper concluded that when the melt flow index (MFI) higher, the tensile strength of its LDPE resin will be reduced.

Nevertheless, both the design of the component and the design of the cast are mostly carried out at the initial stage of product creation, which cannot be modified quickly and directly. Therefore, the correct selection of process parameters is the best way to minimize errors and boost efficiency [2, 3]. Taguchi's approach is one of the versatile methods for developing the right quality framework. Taguchi concepts are committed to a simple, effective and comprehensive approach to optimization, cost and quality. In comparison, the research conceptual model allows the study of more than ten parameters without a considerable amount of testing, making it possible to implement much of the technical challenges [4]. The Taguchi approach is generally used worldwide for product design and process optimization. The lower number of experiments required by this approach resulted in a substantial reduction in costs and time [5].

This study was focused to investigate the optimum cast LDPE glove parameters in disposable film glove processing machine. Taguchi and ANOVA method will be used to optimize identified LDPE casting process parameters. In addition, this research will determine the significant process parameters of cast LDPE glove' resin material between Lotte and Muntajat.

2 Methodology

In this study, the cast LDPE film process parameters which influence product mechanical properties are based on the review of the literature. Low-density polypropylene is choosing as a raw material are used to produce LDPE disposable gloves with the help of XND-65/100/80x2350, cast LDPE film machine. Low-density polyethylene disposable gloves are processed by using different set of process parameters that is tensile strength, melt flow index and load weight. Each parameter has three levels which are low, medium and high. In Fig. 1, after the parameters was selected, L9 orthogonal array is chosen to conduct the experiments will be selected based on the condition that have 3 cast LDPE film process parameters with 3 level of factors. Next, Minitab software will be used to generate the experiment condition and run

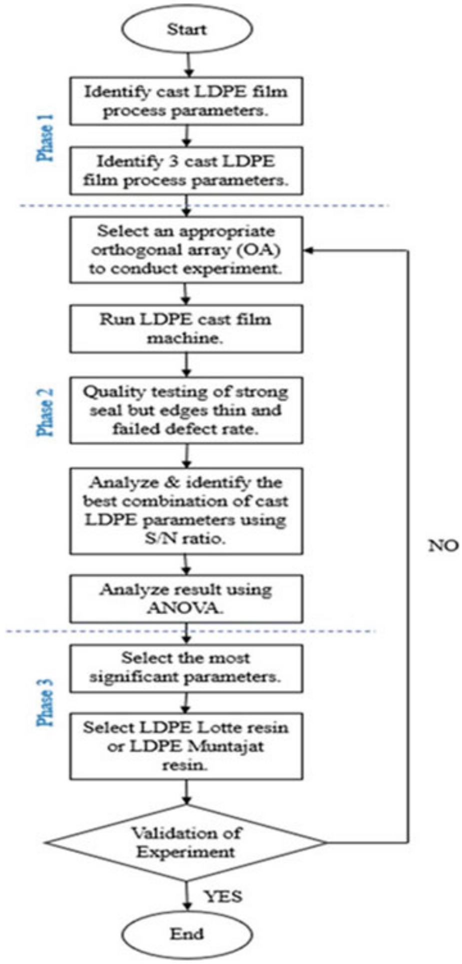

Fig. 1 Research flowchart

the LDPE cast film. After the LDPE disposable glove is produced, the quality test of strong seal but edges thin and failed defect on the gloves will be conducted. The defect rate results obtained is used to calculate the S/N ratio to identify the best combination of the cast LDPE film parameters. Furthermore, a statistical analysis of variance (ANOVA) is performed to analyses and identify which cast LDPE film process parameters have the most significant effect on strong seal but edges thin and failed of the LDPE disposable gloves by calculating the F-value and percentage of contribution. With the S/N and ANOVA analyses, the optimal combination of the process parameters and best LDPE resin can be predicted.

3 Results

In this study, the experimental results obtained are analyzed using statistical analysis. The analysis will conclude the optimum parameter that will be implemented in collecting strong seal but edges thin and failed defect rate to achieve the project's objective which is to identify the best combination of cast LDPE film parameters that give the best performance of LDPE disposable gloves in term of lowest defect rate. 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.

3.1 Selection of Cast LDPE Film Parameters

There are 3 cast LDPE film 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 tensile strength is select in the range at 20–34 MPa. The range of melt flow index is choosing at 1–3 g/10 min and load weight is select in the range at 1–3 kg. The selected cast LDPE film process parameters along with their levels are shown in Table 1.

Table 1 The selected parameters in 3 level

Predictor symbol	Process parameters	Level 1	Level 2	Level 3
A	Tensile strength (MPa)	20	25	34
B	Melt flow index (g/10 min)	1	2	3
C	Load weight (kg)	1	2	3

3.2 Signal to Noise (S/N) Ratio

This study is focuses on the effect of three process parameters of the mechanical performance of the low-density polyethylene disposable gloves. All the results obtained from the testing determine the strong seal but edges thin and failed, 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 defect rate. 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, it seems that higher tensile strength might have less defect rate in some of the experiment runs, melt flow index increase, the ultimate load decrease. According to the S/N ratio response as shown in Table 2, the highest difference value from each factor can be chosen as the best combination of parameters. The rank shows which factor affects the strong sealed but edges thin and failed the most starting with tensile strength in the first rank followed by melt flow index and the least affecting factor that is the load weight.

By using the Minitab19 software, the main effect graph in Fig. 2 shows the changes in strong sealed but edges failed due to variations of LDPE casting parameters and the sets of process parameters can be estimated further. In this framework, the smaller is better to get better quality characteristic is selected to get less defects of LDPE gloves produced through the optimal levels of processing parameters. The best combination LDPE casting parameters in order to get smaller defect rate is based on the graph of main effects plot for S/N ratios in Fig. 2. From Fig. 2, the main effects plot

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

Experiment number	Process parameter			Defect rate (%)	S/N ratio (dB)
	Tensile strength (MPa)	Melt flow index (g/10 min)	Load weight (kg)		
1	20	1	1	8	−18.0618
2	20	2	2	7	−16.9020
3	20	3	3	6	−15.5630
4	25	1	2	7	−16.9020
5	25	2	3	6	−15.5630
6	25	3	1	5	−13.9794
7	34	1	3	5	−13.9794
8	34	2	1	4	−12.0412
9	34	3	2	2	−6.0206

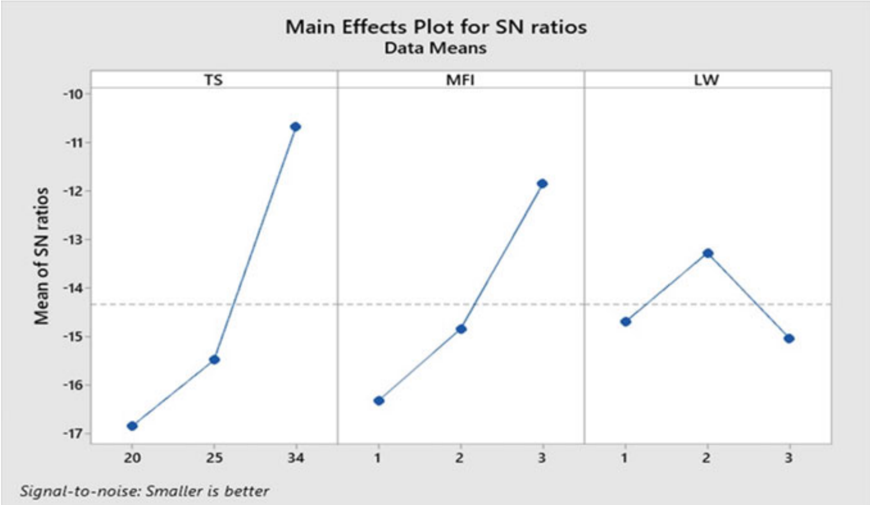

Fig. 2 Main effects plot of S/N ratios for strong seal but edges thin and failed defect rate

for S/N ratios show that the higher tensile strength, the higher the melt flow index while the medium or moderate the load weight, the higher the S/N ratios. From the result, the higher tensile strength with higher melt flow index are the most significant parameters and it will give lowest strong sealed but edges failed defect rate. The best combination of the LDPE casting parameters are 34 MPa tensile strength, 3 g/10 min melt flow index and 2 kg load weight in Fig. 2.

3.3 Analysis of Variance (ANOVA)

This study is to determine whether any of the differences between the means are statistically significant, compare the *p*-value to your significance level to assess the null hypothesis. From Table 3 shows *p*-value is 0.000, which is less than the significance level of 0.05. Reject the null hypothesis and conclude that one of the LDPE casting resins have different means and it is statistically significant.

Use the interval plot to display the mean and confidence interval for each group. The interval plots show the following: Each dot represents a sample mean. Each

Table 3 Outcome for analysis of variance (ANOVA)

Source	DF	Adj SS	Adj MS	F-value	*p*-value
Factor	1	96.10	96.10	61.37	0.000
Error	38	59.50	1.57		
Total	39	155.60			

interval is a 95% confidence interval for the mean of a group. From Fig. 3, LDPE Lotte has the lower defect rate and LDPE Muntajat has the lower defect rate. It cannot be determined from Fig. 3 whether any differences are practically significant. To determine practically significance, assess the confidence intervals for the differences of means.

From Table 4, LDPE Lotte and LDPE Muntajat has a confidence interval for its mean strong sealed but edges failed defect rate. The multiple comparison results for these data show that defect rate of Lotte is significantly lower than Muntajat. That LDPE Lotte is better than LDPE Muntajat does not show that LDPE Lotte is good enough for the requirement of quality of LDPE gloves. The confidence interval for the group mean is better for judging whether LDPE Lotte is less defect and good enough.

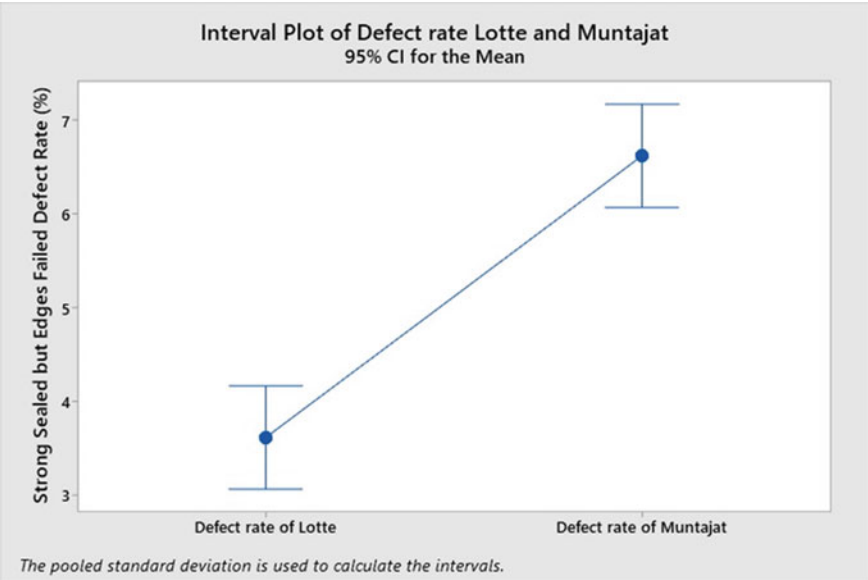

Fig.3 Interval plot of defect rate LDPE Lotte and LDPE Muntajat

Table 4 Means of LDPE Lotte and LDPE Muntajat in Minitab

Factor	N	Mean	StDev	95% CI
Defect rate of Lotte	20	3.550	1.234	(2.984, 4.116)
Defect rate of Muntajat	20	6.650	1.268	(6.084, 7.216)
LDPE Muntajat–LDPE Lotte				(2.984, 7.216)

4 Conclusion

This paper reports the attempt to find best combination of process parameters and analysis to select LDPE Lotte or LDPE Muntajat resin for good quality gloves. In addition, strong seal but edges thin and failed defect rate is also integrated in the proposed method. Once the least defect rate condition is met, the best combination of process parameters is selected and thus best resin is chosen. In this framework, the optimization of LDPE casting parameters has been successfully developed through the design of experiments by Taguchi method. The tensile strength of 34 MPa, melt flow index of 3 g/10 min and load weight of 2 kg are found to be the best combination of LDPE casting parameters to fabricate the better performance of LDPE gloves which give the minimum defect rate with 2%. Based on results, the most significant parameter affecting the strong sealed but edges failed defect is tensile strength, which is indicated by the percentage contribution of $P = 55.56\%$, followed by melt flow index with 38.89%. Load weight is the least significant parameter with 5.55%.

To conclude that, Taguchi and ANOVA method show that tensile strength is the most significant parameter in order to get the lower defect rate. LDPE Lotte is more suitable selection to produce LDPE disposable gloves than LDPE Muntajat. The research can be extended to use combining between Taguchi method with another method such as Neural Network, Response Surface Methodology (RSM) and Regression model through Tensile strength and Charpy impact test to get the better results.

Acknowledgements The authors would like to thank the Ministry of Higher Education for providing financial support under Fundamental Research Grant Scheme (FRGS) No. FRGS/1/2019/TK10/UMP/02/10 (University reference RDU1901158) and Universiti Malaysia Pahang for the facilities.

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