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Research paper

Injection Moulding Parameter Optimisation to Improve the Quality of Sample Made from Polymer Nanocomposites with Gigantochloa Scortechinii Fibres

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Abstract

This article presents about how to optimise the parameter setting for plastic manufacturing process to reduce shrinkage and warpage. The plastic used for this experiment was a mixture, consist of polymer, nanofiller and natural fibre. The polymer chosen was polypropylene. The selected nanofiller was nanoclay and the type of natural fibre was Gigantochloa Scortechinii or bamboo fibre. Few parameter settings were chosen based on previous findings. Initial preparation was made to prepare the compound with two different formulation. One formula was made with the additional fibre and another was without fibre, for comparison purpose. To optimise the setting, Taguchi Method was used with L9 orthogonal array setting due to limited number of samples. The results showed that the optimal parameter setting for 3 wt. % fibre is 175^{0}C for melt temperature, followed by 40% of packing pressure. The optimum setting for screw speed was 35% and for filling time was 2 seconds. In conclusion, the objective of this research had been successfully achieved by providing the knowledge how to control the quality of the advanced material product via optimisation of the manufacturing process.

Keywords: *Injection moulding; Polypropylene-nanoclay Nanocomposite; Gigantochloa Scortechinii, Taguchi Method, Shrinkage, Warpage.*

1. Introduction

Many plastic parts made through injection moulding process. Massive quantity of parts could be produced through this process. However, experts of injection moulding need an effective method to decide the optimum parameter setting, in order to reduce number of defects. The optimum parameter was critical because each parameter usually dependent on each other, and slight changes will affecting the results (Mehat and Kamaruddin, 2011).

Several engineers and statistician have proposed a systematic technique called Taguchi Method to optimise injection moulding parameters, such as optimisation of parameter and mould of acrylonitrile butadiene styrene (Ozcelik, Ozbay, and Demirbas, 2010), minimization of sink mark (Mathivanan,Nouby, & Vidhya, 2010), weld line of polypropylene (Ozcelik, 2011), and the strength of high density polyethylene with natural fibre (Ibrahim, Zainol, Othman, Amin, and Asmawi, 2014).

In this project, before optimising the parameter setting, initial experiment need to be carried out through simulation and screening process. The example of injection moulding simulation study have been performed by the author such as shrinkage and warpage effects through Cadmould 3d-F software, (Othman, Shamsudin, and Hasan, 2012), the weld lines strength effects through parameter and mould design control (Othman, Shamsudin, Hasan, and Rahman, 2012) and defect control towards hinges samples (Othman, Hasan, & Rasli, 2013). A review of nanocomposites preparation, properties and the application also have been summarized (Othman, Sulaiman and Wahab, 2014).

The natural fibre selected for this project was bamboo fibre or Gigantochloa Scortechinii. Supported by previous findings, the reinforcement of bamboo fibres provide good properties of the prepared composites (Bahari, & Krause, 2013), provided with a proper control of content and the usage of compatibilizer (Bonse, Mamede, da Costa, & Bettini, S. 2010). Therefore, the needs of monitoring for properties and quality of moulded products after mixing with natural fibres will be very important issue in advanced injection moulding process.

Based on all of these motivations, therefore this project was carried out to explore about how to optimise the parameter setting for plastic manufacturing process to reduce shrinkage and warpage, specifically for polypropylene-nanoclay nanocomposites, with Gigantochloa Scortechinii as the additional natural fibres.

2. Materials and Methods

The plastic used for this experiment was a mixture, consist of polymer, nanofiller and natural fibre. The polymer chosen was polypropylene. The selected nanofiller was nanoclay and the type of natural fibre was Gigantochloa Scortechinii or bamboo fibre. Few parameter settings were chosen based on previous findings. Initial preparation was made to prepare the compound with two different formulation. One formula was made with the additional fibre content (3 wt. %) and another was without fibre, for comparison purpose. The formulation for 3 wt. % bamboo fibre will consist of 77 wt. % of polypropylene, 15 wt. % of compatibilizer and

5 wt. % of nanoclay. The type of compatibilizer used was polypropylene-grafted-maleic anhydride (PPgMA). The brand of nanoclay selected was Cloisite 20-A. A twin screw mixer, (Plastograph Brabender) was used to mixed the composites, and then this mixture was crushed by Granulator SLM 50Fy machine. After that the injection moulding process was performed to produce the samples. Figure 1 shows the sample of injected mould produced The injection moulding process uses the machine Nissei NP-71F with ISO R527-2 standard sample mould, located at Polymer and Ceramic Laboratory, Faculty of Mechanical and Manufacturing, UTHM.

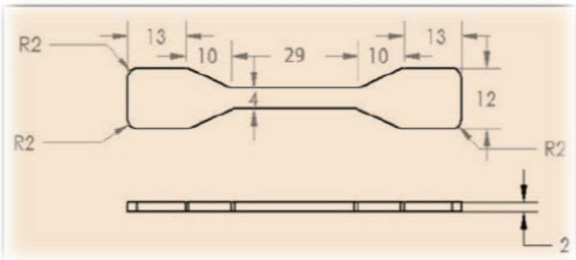


Fig. 1: Sample of injected mould product with dimension (in millimetre)

In Taguchi method, the affecting factor need to be decided based on screening and previous findings. As for this project, the setting chosen was $L_9 3^4$, which means there are nine trials, three factor levels, and four parameter setting. Each trials have three replication, which means there are total of 27 samples produced via injection moulding process. Table 1 shows the Taguchi orthogonal array parameter setting for this experiment.

3. Results and Discussion

The formula was set with the additional fibre content (3 wt. %) and for comparison of shrinkage and warpage affect towards fibre content, another formula was made without fibre. Table 2 shows the results of warpage and shrinkage for both formulation. It shows that the smallest value of warpage was 0.024 mm, without the existence of fibre. The smallest value of shrinkage, was 1.58 % for the same formulation. As for results for 3 wt. % of fibre in samples, the smallest value of warpage was obtained from trial no 9, which is 0.009 mm. If comparison have been made from the lowest value of warpage for samples without fibre, it shows that the fibre have reduced the warpage effectively. Consequently, it can be summarized that Gigantochloa Scortechinii fibre had affecting warpage. In term of value of shrinkage, the smallest value was 1.6 % for samples without fibre and 1.68% for samples with 3 wt. % of Gigantochloa Scortechinii fibre. Technically the value of shrinkage had a small increase with the existence of Gigantochloa Scortechinii fibre. Hence, the fibre not has much impact towards shrinkage.

Table 1: Taguchi Orthogonal Array Parameter Setting

No	Screw Speed	Fill Time	Melting Temperature	Packing Pressure
1	25%	1 s	165^0C	30%
2	30%	2 s	165^0C	35%
3	35%	3 s	165^0C	40%
4	25%	3 s	170^0C	30%
5	30%	1 s	170^0C	35%
6	35%	2 s	170^0C	40%
7	25%	2 s	175^0C	30%
8	30%	3 s	175^0C	35%
9	35%	1 s	175^0C	40%

In this research, the utilization of signal to noise was manipulated to optimise the parameter. The graph of main effect plots for signal to noise Ratio (warpage) for formulation without Gigantochloa Scortechinii fibre and 3 wt. % Gigantochloa Scortechinii fibre were displayed from Figure 2. From the graph, the best parameter that was chosen to produce a good value for shrinkage, specifically for compound without fibre, shall be 175^0C for melt temperature, followed by 40% of packing pressure, 35% screw speed and 3 seconds for filling time. The value of shrinkage obtained from this setting was 1.58 %. As displayed in Figure 2, for 3 wt. % fibre loading, the parameter was 170^0C for melt temperature, followed by 35% of packing pressure, 35% screw speed and 3 seconds for filling time. The value of shrinkage obtained from this setting was 1.34 %. Therefore, it was proven that by using the optimised setting, the value of shrinkage can be reduced.

Meanwhile, the signal to noise ratio (shrinkage) was displayed in Figure 3 for both compound without fibre and for compound with 3 wt. % loading. It shows a different pattern based on the result for all parameters, whereby the value was slightly increased for compound without fibre and slightly decreased with the existence of 3 wt. % of Gigantochloa Scortechinii fibre. Table 3 summarized the optimum parameter to get minimize value for shrinkage and warpage, for both formulation.

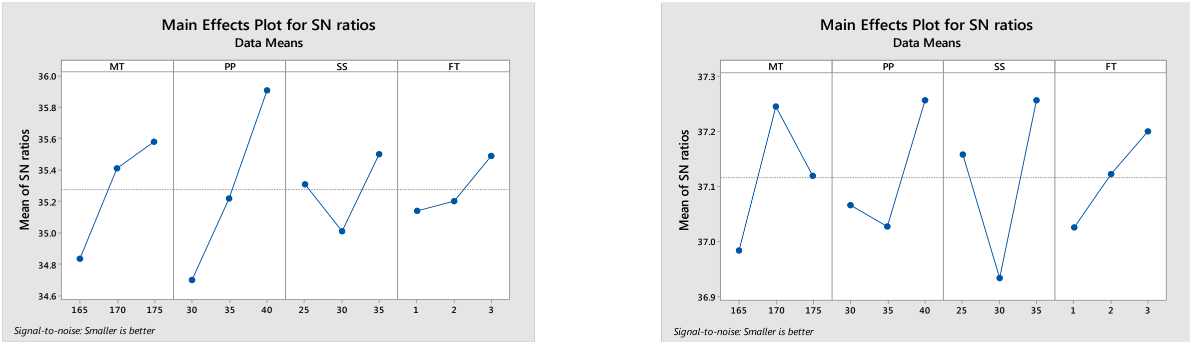
4. Conclusion

As for the summary, the objective of this research had been successfully achieved by providing the knowledge how to control the quality of the advanced material product via optimisation of the manufacturing process. The main optimum parameter setting for 3 wt. % of Gigantochloa Scortechinii fibre were 175^0C for melt temperature, subsequently 40% of packing pressure, 35% of screw speed and 2 seconds for filling time.

Table 2: Warpage and Shrinkage Results

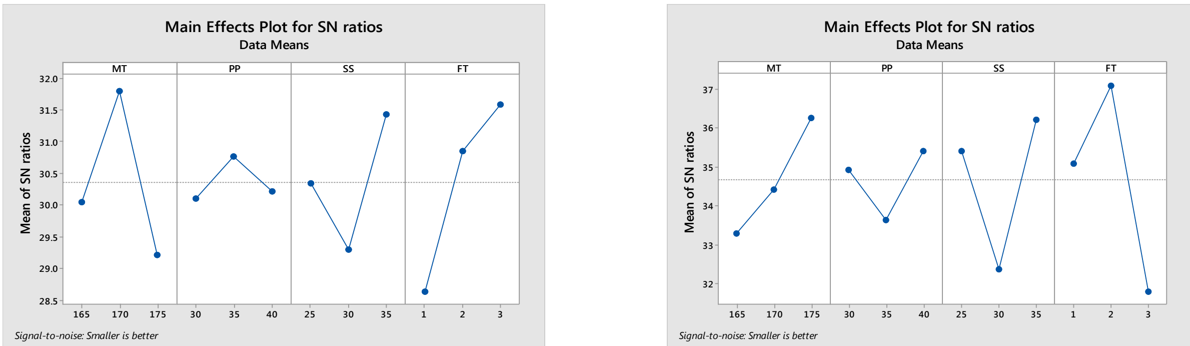
Trial	0 wt. % fibre				3 wt. % fibre			
	Z (mm)	S (%)	S/N Z	S/N S	Z (mm)	S (%)	S/N Z	S/N S
1	0.039	1.960	28.045	34.157	0.010	2.190	34.740	36.884
2	0.032	1.890	29.883	34.440	0.016	1.940	32.396	36.720
3	0.024	1.600	32.214	35.905	0.008	1.840	32.725	37.347
4	0.026	1.820	31.719	34.784	0.009	2.070	29.530	37.096
5	0.026	1.690	31.555	35.443	0.019	1.980	35.380	37.204
6	0.024	1.580	32.133	36.004	0.020	1.690	38.355	37.431
7	0.030	1.750	30.526	35.153	0.016	1.690	40.529	37.214
8	0.029	1.630	30.845	35.771	0.011	1.680	33.109	37.153
9	0.048	1.620	26.285	35.813	0.012	1.710	35.172	36.986

Z is warpage, S is shrinkage, S/N is signal to noise ratio.



Formulation without Gigantochloa Scortechinii fibre 3 wt.% Gigantochloa Scortechinii fibre

Fig. 2: Signal to Noise Ratio (Warpage) for formulation without Gigantochloa Scortechinii fibre and 3 wt. % Gigantochloa Scortechinii fibre



Formulation without Gigantochloa Scortechinii fibre 3 wt.% Gigantochloa Scortechinii fibre

Fig.3: Signal to Noise Ratio (Shrinkage) for formulation without Gigantochloa Scortechinii fibre and 3 wt. % Gigantochloa Scortechinii fibre

Table 3: Optimum parameter for reducing shrinkage and warpage

Quality	Fibre Content	MT (^{0}C)	PP (%)	SS (%)	FT (s)	S (%)
Shrinkage	0%	175	40	35	3	1.580
	3%	170	35	35	3	1.340
Warpage	0%	170	35	35	3	0.024
	3%	175	40	35	2	0.009

[#] MT is melt temperature, PP is packing pressure, SS is screw speed and FT is filling time.

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