IOP Conf. Series: Materials Science and Engineering **324** (2018) 012073 doi:10.1088/1757-899X/324/1/012073

The Optimisation of Processing Condition for Injected Mould Polypropylene-Nanoclay-Gigantochloa Scortechinii based on Melt Flow Index

M.H.Othman, M.S.Rosli, S.Hasan, A.M. Amin, M.Y.Hashim, O.M.F.Marwah and S.Y.M. Amin.

Department of Manufacturing and Industrial Engineering, Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor Darul Takzim
hilmi@uthm.edu.my

Abstract. The fundamental knowledge of flow behaviour is essential in producing various plastic parts injection moulding process. Moreover, the adaptation of advanced polymer-nanocomposites such as polypropylene-nanoclay with natural fibres, for instance Gigantochloa Scortechinii may boost up the mechanical properties of the parts. Therefore, this project was proposed with the objective to optimise the processing condition of injected mould polypropylene-nanoclay-Gigantochloa Scortechini fibres based on the flow behaviour, which was melt flow index. At first, Gigantochloa Scortechinii fibres have to be preheated at temperature 120^0C and then mixed with polypropylene, maleic anhydride modified polypropylene oligomers (PPgMA) and nanoclay by using Brabender Plastograph machine. Next, forms of pellets were produced from the samples by using Granulator machine for use in the injection moulding process. The design of experiments that was used in the injection moulding process was Taguchi Method Orthogonal Array -$L_9 3^4$. Melt Flow Index (MF) was selected as the response. Based on the results, the value of MFI increased when the fiber content increase from 0% to 3%, which was 17.78 g/10min to 22.07 g/10min and decreased from 3% to 6%, which was 22.07 g/10min to 20.05 g/10min and 3%, which gives the highest value of MFI. Based on the signal to ratio analysis, the most influential parameter that affects the value of MFI was the melt temperature. The optimum parameter for 3% were 170^0C melt temperature, 35% packing pressure, 30% screw speed and 3 second filling time.

1. Introduction

It has been estimated that almost 170 million tons of plastics were produced worldwide during the year 2003 [1]. The use of thermoplastics has been continuously increasing in the last few years and penetrated the various fields, such as automotive and aerospace industry, household and sport appliances. Polypropylene (PP) composites have better material properties such as good strength, better stiffness, improve of ductility; good stability and thermal expansion; and low cost of production. Nevertheless, these properties depend on the matrix phase, the phase dispersion of fillers and strengthening mechanism, shapes and arrangements of filler particles and the bonding interface between filler and the matrix [2].

Polymer nanocomposites can be prepared by various processing techniques such as solution process, in-situ polymerization and melt blending. Each technique has an influence on the final characteristics

and properties of the composites. The performance of this polymer system also can be upgraded to better properties with the presence of natural fibres as the filler material [3].

Direct intercalation by the molten polymer method of preparation of nanocomposites has greatest advantages over other methods as this method is environmentally benign due to the absence of organic solvents and is compatible with current industrial process, such as extrusion and injection moulding [4]. Most of these polymer nanocomposites were transformed into useful parts by using an injection moulding process. Unfortunately, it has been found difficult to control the properties of the material in order to manufacture consistently a part with no defect [5]. Hence, the synthesis of knowledge about the injection moulding processing might lead to solutions in producing good products. Therefore, the needs of optimising the processing condition shall be the priority in the injection moulding manufacturing process [6].

The increase of the resistance to flow and flow stability of the former system can be attributed to the improvement of the compatibility and interfacial adhesion between the filler and matrix as well as the dispersion of the filler in the matrix. Beside optimisation, studies about melt flow behaviour of polypropylene composites also need to be clarified [7].

2. Experimental

The experiment started from preparation of material. Then the injection moulding process was carried out according to the Taguchi Orthogonal Array. Flow behaviour evaluation was made after that, and optimisation through Signal to Noise Ratio was made at the end of the project.

2.1. Preparation of Materials

The polymer-nanocomposite are divided into two sections, the matrix and the fillers. For the matrix, the material that's been used in this research are polypropylene (PP) and for the fillers, the materials that been used are polypropylene-grafted-maleic anhydride (PPgMA), nanoclay (NC) and Gigantochloa Scortechinii (GS). Table 1 shows the compounding of these materials based on the formulation.

Table 1. Formulation of Polymer-Nanocomposites

No	PP	PPgMA	NC	GS	Label
1	84%	15%	1%	0%	0%GS
2	81%	15%	1%	3%	3%GS
3	78%	15%	1%	6%	6%GS

The material preparation starts from processing the GS which is a type of bamboo fibres. The fibres were chopped and refined to become short fibres. These fibres need to be pre-heated at 120°C. The process of mixing was made by using twin screw Brabender Lab-compounder KETSE 20/40 machine to make it into compounding. After that the mixture was formed into small pieces or it is called pallets with diameter less than 5mm by using Granulator SLM 50Fy machine before entering the injection moulding process.

2.2. Injection Moulding Process via Taguchi Orthogonal Array Method

In the injection moulding process, the sample that produce by using injection moulding machine usually influenced by the injection moulding parameters. Samples shall be produced by using an injection moulding process were prepared according to the Taguchi Optimisation Orthogonal Array Method, with selected formulation of polypropylene-nanoclay-Gigantochloa Scortechinii fibres. The injection moulding machine that used in this project was 0.7 tonne Nissei NP7F from Japan. The parameters that were considered were the melt temperature, packing pressure, screw speed and filling time. There were three levels and four parameters that had been analysed by using Taguchi Optimisation

Orthogonal Array Method based on level ($L_9 3^4$). The process parameter based on Orthogonal Array ($L_9 3^4$) was shown in Table 2.

Table 2.Orthogonal Array selected based on level ($L_9 3^4$)

No.	Melt Temperature (°C)	Packing Pressure (%)	Screw Speed (%)	Filling Time (s)
1	165	30	25	1
2	165	35	30	2
3	165	40	35	3
4	170	30	25	3
5	170	35	30	1
6	170	40	35	2
7	175	30	25	2
8	175	35	30	3
9	175	40	35	1

2.3. Flow Behaviour Evaluation

The analysis was carried out by comparison of the sample without using an injection moulding process and the sample after used the injection moulding process. The samples that have been produced in the injection moulding process was crushed using Granulator SLM 50Fy machine to become pellets. After that, the pellets were used to determine the flow behaviour of the melt polymer-nanocomposites, which is Melt Flow Index (MFI) by using Plastomer (Ceast type 6841) according the ASTM D1238 Standard.

2.4. The Optimisation of Processing Condition

In this research, signal to noise (S/N) ratio for melt flow behaviour properties were obtained and optimum level of the injection parameters was determined through S/N values to achieve maximum melt flow index result [6]. In this study, the larger the better was chosen to solve melt flow index based on the S/N ratio [8]. The calculation of this ratio was assisted by using Minitab 16 statistical software.

3. Results and Discussion

Table 3 shows the value of MFI based on the injection moulding process via Taguchi Method Orthogonal Array ($L_9 3^4$). The highest value of MFI was at formulation of 3% GS and the lowest value was at formulation 0% GS. When the value of GS increased from 0% to 3%, the value of MFI was also increased. However, when the value of GS increased from 3% to 6%, the MFI value was decreased.

Table 3.Value of MFI (g/10min)

Case No	0% GS	3% GS	6% GS
Before Moulding	15.35	18.77	18.44
1	16.90	19.25	18.08
2	16.15	20.39	18.34
3	16.33	20.08	18.63
4	17.32	22.07	20.00
5	17.78	21.28	19.33
6	17.29	20.46	19.31
7	16.75	19.35	17.97
8	16.57	20.70	18.77
9	15.70	21.35	20.05

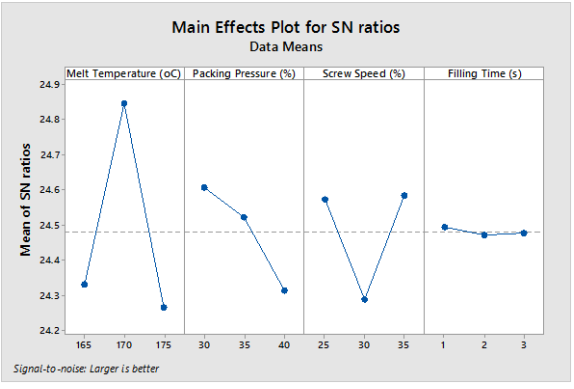

Fig. 1 Main Effect Plot for S/N ratio for 0% GS

For formulation 0% GS, the highest value for the MFI was in case number 5 which was 17.78 g/10min. The lowest value was in case 9 which is 15.7 g/10min compared with the MFI value without using an injection moulding process, which was 15.35 g/10min. When the injection moulding process was applied, the value of MFI increased in all case numbers from 1 to 9 compared to the value of melt flow index without injection moulding process.

As for 3% of GS, the highest MFI value was in case number 4, which was 22.07 g/10min. The lowest value was in case 1, which was 19.25 g/10min. This value was higher compared with the MFI value without using an injection moulding process (18.77 g/10min). When the injection moulding process via Taguchi orthogonal array method was applied, the value of MFI increased in all case numbers from 1 to 9 compared to the value of MFI before injection moulding process.

The analysis of MFI continued for 6% GS, whereby the highest value for the MFI was in case number 9 (20.05 g/10min) and the lowest value was in case 7 (17.97 g/10min). The value of melt flow index without injection moulding process was 18.44 g/10min. When the injection moulding process was applied, the value of MFI increased in case numbers 3, 4,5,6,8 and 9 but the value of MFI decreased in case number 1, 2, and 7 compared to the value of melt flow index without injection moulding process.

3.1. Optimisation of process condition based on Conceptual S/N Ratio Approach for Melt Flow Index (MFI) Results.

Figure 1, 2 and 3 shows the values of S/N responses at three levels for MFI based on formulation 0% GS, 3% GS and 6% GS. Based on the result for formulation 0% GS, the best combination parameter for optimising the value of MFI for 0%GS were 170^0C for melt temperature, 30% of packing pressure, 35% of screw speed and 1 second for filling time. For the formulation 3% GS, the best combination parameter for optimising the value of MFI for 3%GS were 170^0C for melt temperature, 35% of packing pressure, 30% of screw speed and 3 seconds for filling time. For the third formulation (6% GS) the optimum combination parameter for maximizing the value of MFI were 170^0C for melt temperature, 40% of packing pressure, 30% for of screw speed and 1 second for filling time. Based on these findings, in can be rectified that by using the same orthogonal $L_9 3^4$, the data for melt temperature at level 2 usually provide the optimum level [9].

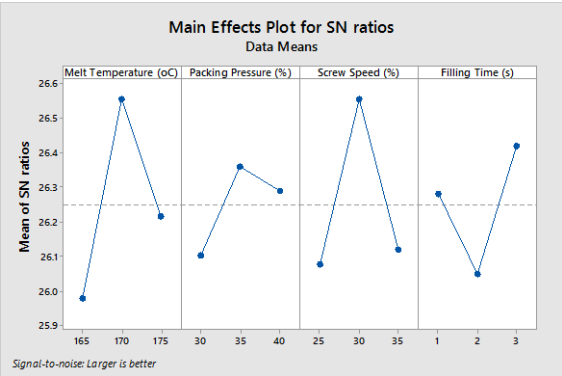

Fig. 2 Main Effect Plot for S/N ratio for 3% GS

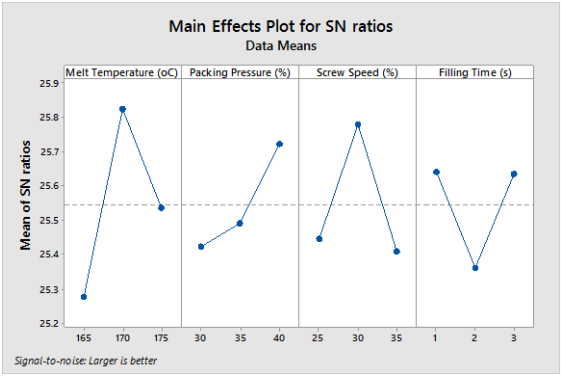

Fig. 3 Main Effect Plot for S/N ratio for 6% GS

4. Conclusion

In the conclusion, the highest value of MFI was found at formulation 3% GS which was 22.07 g/10min. The lowest value of MFI was at formulation 0% GS which is 17.78 g/10min. Based on the S/N ratio method, the optimum value for each formulation of the 0% GS, 3% GS and 6% GS were achieved. Based on these 3 formulations (0% GS, 3% GS and 6% GS), the melting temperature must at level 2 which was 170^0C so that the optimum value of MFI can be achieved.

5. Acknowledgment
The highest appreciation dedicated to the Ministry of Higher Education Malaysia for sponsoring this research under the Fundamental Research Grant Scheme, FRGS (UTHM) Vot 1590 and Vot 1595. Exceptional recognitions to Universiti Tun Hussein Onn Malaysia for providing equipment and facilities, specifically at Advanced Material and Manufacturing Centre (AMMC) and Faculty of Mechanical and Manufacturing Engineering (FKMP).

References
[1] Achilias, D.S., Chemical recycling of polymer (methyl methacrylate) by pyrolysis. Potential use of the liquid fraction as a raw material for the reproduction of the polymer, Europe Polymer J, 43 (6), 2564-2575 (2007)
[2] H. Ismail, Komposit Polimer Diperkuat Pengisi dan Gentian Pendek Semulajadi. Pulau Pinang: Penerbit Universiti Sains Malaysia. (2004) 1-18.
[3] Albdiry, M., & Yousif, B. (2013). A critical review on the manufacturing processes in relation to the properties of nanoclay/polymer composites. Journal of Composite Materials, 47(9), 1093-1115
[4] Ray SS, Okamoto M. Polymer/layered silicate nanocomposites: a review from preparation to processing. Program Polymer Science 2003;28:1539–44.
[5] Dumitrescu, O. R., Baker, D. C., Foster, G. M., & Evans, K. E. (2005). Near infrared spectroscopy for in-line monitoring during injection moulding. *Polymer Testing*, *24*(3), 367–375.
[6] Ozcelik, B. (2011). Optimization of injection parameters for mechanical properties of specimens with weld line of polypropylene using Taguchi method. International Communications in Heat and Mass Transfer, 38(8), 1067-1072.
[7] Liang J.Z., Chen C.Y., Zou S.Y., Tsui C.P., Tang C.Y., Zhang S.D. (2015) Melt flow behaviour of polypropylene composites filled with multi-walled carbon nanotubes during extrusion, Polymer Testing, 45, pp. 41-46.
[8] Hasan, O., Tuncay E., Ibrahim, U. (2015). Application of Taguchi Optimization Technique in Determining Plastic Injection Molding Process Parameters for a Thin-shell Part.
[9] Ozcelik, B., Ozbay, A., Demirbas, E. (2010). Influence of Injection Parameters and Mold Materials on Mechanical Properties of ABS in Plastic Injection Molding, *International Communications in Heat and Mass Transfer*. ICHMT-02183; pp. 7.