Optimization of compression moulding parameters for multi filler polymer composite using Taguchi method

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ABSTRACT – The purpose of this study is to determine the compression moulding parameters on Graphite (G) / Carbon Black (CB) / Carbon Fiber (CF) / Polypropylene (PP) composites through Taguchi method. L_9 Orthogonal Array with four factors and three levels has been choose as a DOE for composition of G/CB/CF/PP with weight percentage of 50/25/5/20. The electrical conductivity value was analysed through Taguchi Method using signal to noise (S/N) ratio to determine the optimum parameters. This result is important to fabricate the potential G/CB/CF/PP composites as conductive polymer composite (CPC), and also very useful for further application as bipolar plate (BP) for PEMFC.

1. INTRODUCTION

Nowadays CPC becomes one of the most attractive options to researchers. CPC can be used in various application such as sensors, batteries, bipolar plates in fuel cell systems, electromagnetic interference (EMI) and radio frequency interference (RFI) [1-2]. CPC with carbon based is the ideal material to be used to produce BP and it is promising a good mechanical properties and low cost. Therefore, in this study G, CB and CF were used as fillers in order to improve the electrical conductivity and mechanical properties of the composites. Meanwhile, PP was selected as the binder.

In this paper the Taguchi Method with L_9 Orthogonal Array was used to optimize the compression moulding parameters and the experimental results are then transformed into S/N ratio. With S/N ratio, the optimum hot compression moulding parameters can be predicted. Then, the confirmation experiment was conducted to determine the optimum parameters obtain from the parameter design. Taguchi Method using S/N ratio proposed a design of experiment (DOE) which minimize the number of experiment to a practical level for optimization process and it is proven to be an effective way in order to produce high quality of composite with low cost and short time [2].

2. METHODOLOGY

A series of nine samples were prepared by using G, CB and CF as fillers and PP as a binder. Nine samples of composites based on the composition of G/CB/CF/PP with a weight percentage of 50/25/5/20 were selected. The composition of G/CB/CF/PP was mixed by using a ball mill machine for 3 hours and high speed mixer for 10 minutes. The mixture was poured into mould with dimension of 50 mm x 50 mm in square size then being pressed in the hot compression moulding machine. The mould was cooled by air until it reaches room temperature before the sample being released from the mould. The L_9 Orthogonal Arrays which consist of four factors which are temperatures (A), loads (B), preheating times (C) and compressing times (D) with three levels were followed as shown in Table 1. Electrical conductivity test for G/CB/CF/PP composites were measured by Jandel Multi Height Four Point Probe combined with RM3 Test Unit.

Table 1 The compression moulding factors for three levels Taguchi design.

Factors	Variables	Level		
		1	2	3
A	Temperature (°C)	175	180	185
B	Loads (ton)	5	10	15
C	Preheating time (min)	5	7	10
D	Compression times (min)	5	10	15

3. RESULTS AND DISCUSSION

The electrical conductivity of all samples was measured and the results shown in Table 2. Based on requirement from US Department of Energy (DOE) for BP, the electrical conductivity value must be greater than 100 S/cm [3-4]. The result shown in Table 2 shows that the electrical conductivity of this composite was larger than 100 S/cm and it achieved the required value. CB with complex morphology that being used as filler helps to fill the holes and gap in the composite [5]. The electrical conductivity value was analyzed by Taguchi Method using S/N ratio to determine the optimized factor. According to the optimum condition of larger is better for response graph, the levels of the factors that contributed to the highest values are determined as shown in Figure 1. From the response graph as presented in the Figure 1, it shows that the highest electrical conductivity obtained from the combination of optimum condition which are A1 (temperature), B1

(load), C3 (pressing time) and D3 (compressing time). The optimized level of the factors that contributed to the highest value for G/CB/CF/PP composites is shown in Table 3.

Table 2 Results of electrical conductivity for G/CB/CF/PP composite.

No. of Experiment	Electrical Conductivity (S/cm)			
	E1	E2	E3	Average
1	309.99	312.82	334.92	319.24
2	374.79	379.44	357.84	370.69
3	316.62	324.29	338.58	326.50
4	285.20	289.58	289.36	288.05
5	256.49	277.72	241.29	258.50
6	204.04	180.08	195.69	193.27
7	273.11	263.45	256.82	264.46
8	263.13	229.74	236.71	243.19
9	194.15	159.30	199.39	184.28
			Average	272.02
			Maximum	370.69
			Minimum	184.28

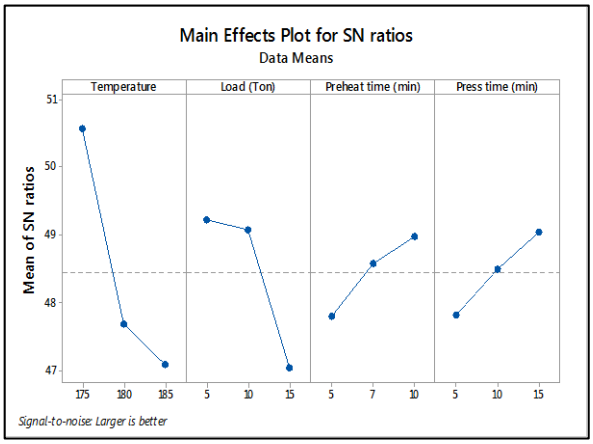

Figure 1 Response graph for S/N ratios.

Table 3 Optimized factors for G/CB/CF/PP composite.

Temperature (°C)	Load (Ton)	Preheating time (min)	Compressing time (min)
175	5	10	15

From the Taguchi Method analysis using S/N ratio, the predicted value for electrical conductivity with optimum condition was 382.40 S/cm and it is higher than any other value from the experimental results. Finally, to confirm the optimum parameters obtain from the Taguchi method analysis, the confirmation experiment has been done based on the optimum parameters and the result shown in Table 4. Based on the result shown in Table 4, it shows that the new electrical conductivity value with optimum parameters had increased which is 393.49 S/cm and 3 % higher than the predicted value from the Taguchi Method analysis. From the results, it is proven that the optimum parameters obtained from the Taguchi Method improved the electrical conductivity of the composite. The process or procedures in order to fabricate the sample is also important to improve the result and it is proven by the result from the confirmation experiment was higher than the predicted value from Taguchi Method analysis.

Table 4 Confirmation experiment of electrical conductivity with optimum condition.

No. of Exp.	Electrical Conductivity (S/cm)			
	E1	E2	E3	Average
1	393.78	397.45	389.23	393.49

4. CONCLUSION

The compression moulding parameters for G/CB/CF/PP composite with 25% of CB and 5% of CF have been studied and determined through Taguchi method using S/N ratio. Based on the result, it can be concluded that the optimum parameters obtained through Taguchi Method improved the electrical conductivity of this composite. The results of this study are important to fabricate the potential G/CB/CF/PP composites as conductive polymer composite, and can very useful for further application as bipolar plate (BP) for PEMFC.

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REFERENCES

[1] A. Kasgoz, D. Akın, and A. Durmus, "Rheological and electrical properties of carbon black and carbon fiber filled cyclic olefin copolymer composites," *Compos. Part B Eng.*, vol. 62, pp. 113–120, Jun. 2014.

[2] M.Z. Selamat, J. Sahari, and N. Muhamad, "Simultaneous Optimization for multiple responses on the compression moulding parameters of composite graphite – polypropylene using Taguchi method," vol. 472, *Key Engineering Materials*, pp. 361–366, 2011.

[3] Y. Sadelil, J. W. Soedarsono, B. Prihandoko, and S. Harjanto, "The effects of gompression pressure applied on the manufacture of carbon composite bipolar plate for PEMFC by Utilizing Graphite Waste Products," *Adv. Mater. Res.*, vol. 42, pp. 6–66, 2012.

[4] H. Suherman, J. Sahari, and A.B. Sulong, "Effect of small-sized conductive filler on the properties of an epoxy composite for a bipolar plate in a PEMFC," *Ceram. Int.*, vol. 39, no. 6, pp. 7159–7166, Aug. 2013.

[5] E. Planes, L. Flandin, and N. Alberola, "Polymer composites bipolar plates for PEMFCs," *Energy Procedia*, vol. 20, pp. 311–323, 2012.