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ANALYSIS OF DELAMINATION IN DRILLING OF BASALT FIBER REINFORCED POLYMER COMPOSITES

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Abstract. Fiber reinforced polymer composites are used in many engineering applications because of their low strength to weight ratio. Delamination is one of the major problems in manufacturing of the polymer composites. In this work, the delamination of acid treated basalt fiber reinforced composites was studied through drilling operation. Basalt fiber reinforced composites is prepared by using hand layup techniques with unsaturated polyester. Taguchi design of experiment was used to investigate the effects of drilling parameters such as spindle speed [2500, 2750, 3000 rpm], feed rate (0.2, 0.4, 0.6 mm/rev) and point angle (90°, 118°, 135°). A series of experiments based on L_9 orthogonal arrays are conducted using CNC machine and resulting delamination factor was determined. It was observed that speed and point angles are highly influencing parameters than feed rate for the delamination of the basalt fiber reinforced polymer composites.

1. Introduction

Usage of fiber reinforced polymer composites in automobiles, aerospace, sport goods play a major role. Basalt fibre is a material made from volcanic ingenious rock. Basalt fiber reinforced polymer composites nowadays replaces the application of the glass fiber. According to Manikandan et al. [1], it is found that acid treated basalt fiber composites showed better mechanical properties than combinations like untreated; base treated and acid treated glass fiber composites. Carbon fiber reinforced plastic (CFRP) composite has been manufactured through hand layup techniques and analyze the delamination in drilling of CFRP composites. Response surface methodology results indicated that the model can be effectively used to predict the delamination [2]. Erol [3] investigated on the influence of drilling parameters, such as cutting speed, feed, and point angle on delamination produced when drilling glass fiber reinforced plastics (GFRP) composite. The experiments are conducted based on Box–Behnken design. Empirical models are developed to correlate and predict the drilling parameters and delamination factor in drilling of GFRP. The developed models for delamination factor at entrance and exit are proposed that agree well with the experiment [4]. A fuzzy rule based model is developed to predict the delamination in drilling of GFRP composites by Latha and Senthilkumar. The drilling was carried out based on L_9 orthogonal array of GFRP composite specimens using carbide drill bits [5]. Basavarajappa et al. made an attempt to investigate that the effect of spindle speed and feed on machinability aspects likes thrust force, hole surface roughness, and specific cutting coefficient during drilling of glass epoxy composites. The response surface methodology based mathematical models were developed for analyzing the effects of cutting conditions on machinability characteristics [6]. Cutting force influenced the quality of the holes generated on the carbon fiber reinforced polymer composites that was studied Guo et al. [7] the model for the

each with a diameter of 8 mm, but with different point angles such as 90°, 118°, 135° were purchased from S.S. Solutions Pvt Ltd, Chennai. The drill tool is shown in Fig. 2.

Fig. 1. Fabrication of composites.

Table 1. Properties of the composites.

Tensile strength	246 MPa
Flexural strength	128.65 MPa
Impact strength	2.855 J/mm

a) b) c)

Fig. 2. Drill bits with angles a) 90^o, b) 118^o, and c) 135^o.

2.5. Analysis of delamination. The typical drilled composite is presented in Fig. 3 and the measurement of data is shown in Fig. 4. The delamination of the drilled holes is measured by the optical microscope.

Fig. 3. Holes being laid over the finished sample.

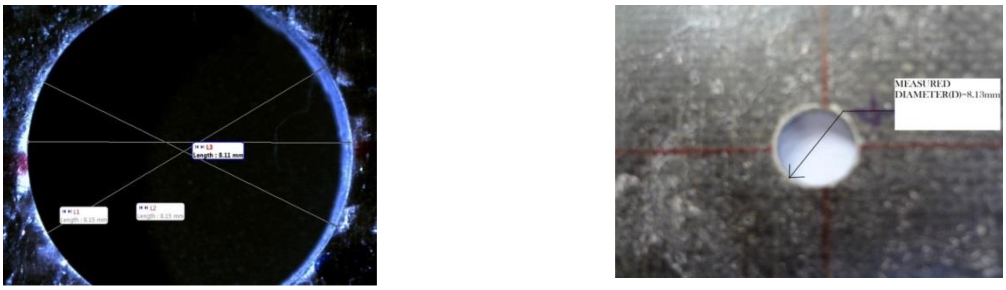

Fig. 4. Measured diameter of a drilled hole.

Table 3. Drilling parameters with response.

S. No	Speed, rpm	Feed rate, mm/rev	Drill bit angle, °	Delamination factor, mm	S/N ratio
1	2500	0.2	90	1.017	-0.14641
2	2500	0.4	118	1.0143	-0.12332
3	2500	0.6	135	1.0152	-0.13103
4	2750	0.2	118	1.0168	-0.14471
5	2750	0.4	135	1.0175	-0.15068
6	2750	0.6	90	1.017	-0.14641
7	3000	0.2	135	1.0112	-0.09674
8	3000	0.4	90	1.0158	-0.13616
9	3000	0.6	118	1.0154	-0.13274

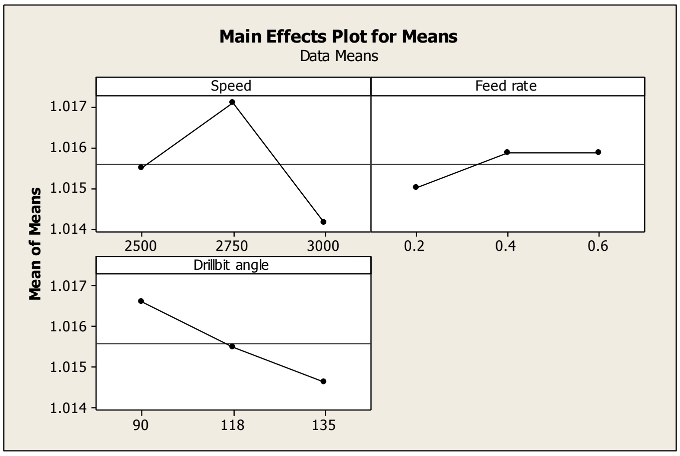

Fig. 5. Main effects plot for means.

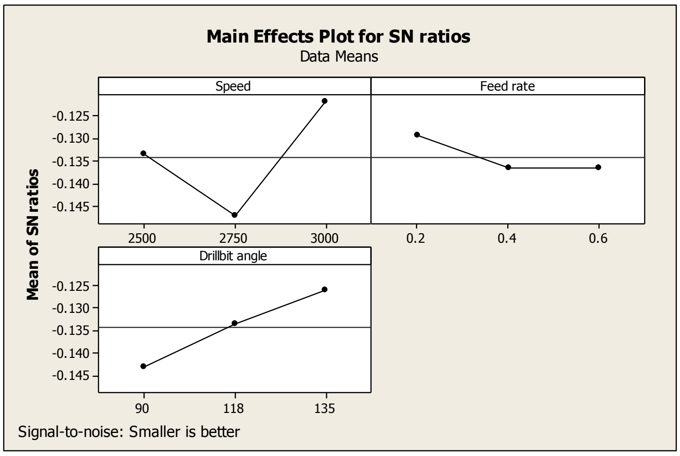

Fig. 6. Main effects plot for S/N ratios.

Table 4. Response table.

Factors / Avg. at factor level	Speed	Feed rate	Drill bit angle	Error
L1	-0.1279	**-0.1236**	-0.1370	-0.13673
L2	-0.1473	-0.1364	**-0.1222**	-0.12216
L3	**-0.1207**	-0.1359	-0.1370	-0.13702
Max - Min	0.0265	0.0129	0.0149	-0.01457

From Fig. 9 it was observed that at lower feed rate and higher drill bit angle has lowest delamination of the composites. Caprino and Tagliaferri [21] stated that damage induced in the composite during drilling operation was strongly depends on the feed rate. At higher feed rate the failure mode shows the impact damages like delamination [20].

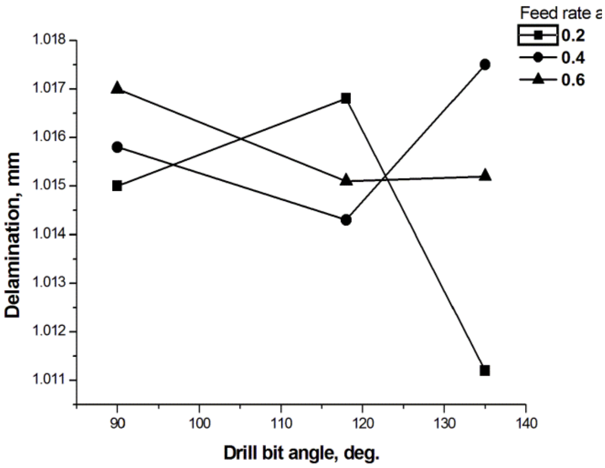

Fig. 9. Effect of Drill bit angle on delamination with different feed rate.

The delamination is significantly affected by the drill bit angle shown in Fig. 10. The point angle increases the delamination of the composites also increased for increasing of the spindle speed. At higher drill bit angle 135 degree and 3000 rpm, the delamination of the composites was observed higher.

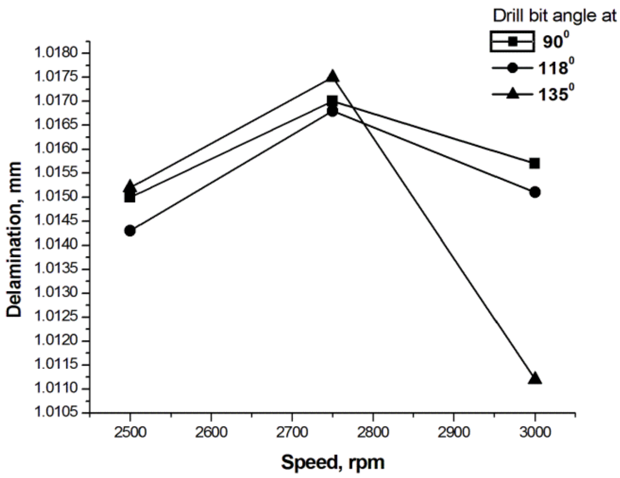

Fig. 10. Effect of speed on delamination with different drill bit angle.

5. Conclusion

The polymer composite with basalt fiber is prepared successfully by hand layup technique and the following conclusion can be drawn:

1. The Taguchi method successfully verified the optimum drilling parameters on the delamination of the composite using ANOVA.

2. The results of ANOVA revealed that speed was most significant drilling parameter which has greater influence on the delamination factors. The optimum parameter were cutting speed (3000 rpm), feed rate (0.2 mm/rev) and drill bit angle (135°). For achieving minimal delamination factor in the Basalt fiber always higher cutting speed, and higher drill bit angle to be preferred.

References

[1] V. Manikandan, J.T. Winowlin Jappes, S.M. Suresh Kumar, P. Amuthakkannan // *Composites Part B: Engineering* **43(2)** (2012) 812.

[2] A. Krishnamoorthy, S. Rajendra Boopathy. K Palanikumar // *Journal of Composite materials* **43(24)** (2009) 2885.

[3] Erol Kilickap // *Journal of Composite Materials* **45(6)** (2010) 727.

[4] Erol Kilickap // *Indian Journal of Engineering and Materials Sciences* **17** (2010) 265.

[5] B. Latha, V.S. Senthilkumar // *Journal of Reinforced Plastics and Composites* **28(8)** (2009) 9571.

[6] S. Basavarajappa, Abay Venkatesh, V.N. Gaitonde, S.R. Karnik // *Journal of Thermoplastic Composite Materials* **25(3)** (2012) 363.

[7] D.-M. Guo, Q. Wen, H. Gao, Y.-J. Bao // *Journal of Engineering Manufacture* **226(1)** (2012) 28.

[8] D.-M. Guo, Q. Wen, H. Gao, Y.-J. Bao // *Journal of Engineering Manufacture* **226(1)** (2012) 28.

[9] Ozden Isbilir, Elaheh Ghassemieh // *Composite Structures* **105** (2013) 126.

[10] T.V. Rajamurugan, K. Shanmugam, K. Palanikumar // *Materials and Design* **45** (2013) 80.

[11] Juan Carlos Campos Rubio, Leandro José da Silva, Wanderson de Oliveira Leite, Tulio Hallak Panzera, Sergio Luiz Moni Ribeiro Filho, João Paulo Davim // *Composites Part B: Engineering* **55** (2013) 338.

[12] D. Abdul Budan, S. Basavarajappa, M. Prasanna Kumar, Ajith G. Joshi // *Journal of Engineering Science and Technology* **6(6)** (2011) 733.

[13] D. Chandramohan, K. Marimuthu // *International Journal of Engineering Science and Technology* **2(10)** (2010) 6437.

[14] V. Krishnaraj, S. Vijayarangan, G. Suresh // *Indian Journal of Engineering and Material Sciences* **12** (2005) 189.

[15] R.A. Kishore, R. Tiwari, I. Signh // *Advances Production Engineering and Management* **4** (2009) 37.

[16] S. Jayabal, U. Natarajan // *International Journal of Advanced Manufacturing Technology* **51** (2010) 371.

[17] K. Palanikumar, J. Campos Rubio, A.M. Abrao, A. Esteves Correia, J. Paulo Davim // *Journal of Composite Materials* **42(24)** (2008) 2585.

[18] V.N. Gaitonde, S.R. Karnik, Juan Carlos Campos Rubio, Wanderson de Oliveira Leite, J.P. Davim // *Journal of Composite Materials* **48(1)** (2014) 21.

[19] V.N. Gaitonde, S.R. Karnik, J. Campos Rubio, A. Esteves Correia, A.M. Abrao, J. Paulo Davim // *Journal of Composite Materials* **45(22)** (2011) 2359.

[20] P.K. Rakesh, I. Singh. D. Kumar // *Journal of Composite Materials* 46(25) (2012) 3173.

[21] G. Caprino, V. Tagliaferri // *International Journal of Machine Tool Manufacturing* **35(6)** (1995) 817.