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ANALYTYCAL EVALUATION OF DRILLING PHASE OF HYBRID COMPOSITS USE SYSTEM TAGUCHI

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ABSTRACT

Drilling is the most much of the time utilized activity of auxiliary machining for fiber-strengthened materials inferable from the requirement for joining structures. Boring of composite materials is fundamentally influenced by harm propensity of these materials under activity of push power. In penetrating activity, the nature of opening is a significant necessity for some applications. In this manner, the decision of advanced procedure parameters is fundamental for controlling the necessary opening quality. The goal of the current work is to advance procedure parameters specifically, shaft speed and feed in boring of cross breed composites. In this work, tests were done according to the Taguchi exploratory plan and a L9 symmetrical exhibit was utilized to examine the impact of different mixes of procedure parameters on gap quality. Investigation of difference (ANOVA) test was led to decide the criticalness of each procedure parameter on boring. The outcomes demonstrate that feed rate is the most huge factor affecting the push power followed by speed. Speed is the most critical factor influencing the surface harshness of the opening followed by feed. This work is helpful in choosing ideal estimations of different procedure parameters that would limit the push power as well as diminish the delamination and improve the nature of the penetrated gap. Better quality in opening geometry is accomplished by setting the ideal conditions got through the examination.

Key words:, Taguchi Method, Hybrid composites, ANOVA

1. INTRODUCTION

Composite materials play an important role in the field of engineering applications as well as advanced manufacturing processes in response to requirements in aircrafts, aerospace and automotive industries [1, 2]. These materials have low specific gravity that makes their properties particularly superior in strength and modulus to many traditional engineering materials such as metals. As a result of intensive studies into the fundamental nature of materials and better understanding of their structure property relationship, it has become possible to develop new composite materials with improved physical and mechanical properties [3]. These new materials include high performance composites such as hybrid composites. Machining of composites becomes still more difficult when it consists of more than one type of fiber accompanied by the generation of airborne dust that pollutes the environment [4]. Poor hole quality accounts for major percentage of part rejections. Since holes are drilled in finished products, part rejections due to poor quality hole prove very costly [5]. Surface finish and hole geometry are important parameters in drilling operations.

Much of the literature [6–8] reported on drilling of FRP material by conventional tools has shown that the quality of the cut surface is strongly dependent on the cutting parameters, tool geometry, tool material, work piece material, machining process, etc. An improper selection of these parameters can lead to unacceptable material degradation, such as fiber pullout, matrix cratering, thermal damage and widespread delamination. Miner [9] and Mackey [10] studied the complexities of machining of the two-phase composite materials and concluded that not only new concepts of tooling but also different realms of cutting conditions are needed. Koplev [11] was the first declared that chip formation in composite removal is a process of serial material fractures. Enemuoh et al. [12] realized that with the application of the technique of Taguchi and a multi-objective optimization criterion, it is possible to achieve cutting parameters that allow the absence of damage in drilling of fiber reinforced plastics. Caprino and Tagliaferri [13] compared the interaction mechanisms between drilling tool and workpiece. The results obtained are useful in describing the history and helping design drill geometries specifically conceived for composite machining.

Taguchi proposed that the engineering optimization of a process should be carried out in three step approach: the system design, the parameter design and the tolerance design [14]. The Taguchi method uses orthogonal arrays from design of experiments theory to study a large number of variables with a small number of experiments. The orthogonal arrays reduce the number of experimental configurations to be studied. Furthermore, the conclusions drawn from small scale experiments are valid over the entire experimental region spanned by the control factors and their settings [15]. The experimental results are then transformed into a signal-to noise (S/N) ratio. It uses the S/N ratio as a measure of quality characteristics deviating from or nearing to the desired values.

Delamination is a major problem associated with drilling fiber reinforced composite materials and in addition to reducing the structural integrity of the material, it also leads to poor assembly tolerances and has the potential for long-term performance deterioration. Drilling-induced delamination occurs both at the entrance and the exit planes of the workpiece. Investigators have studied analytically and experimentally cases in which delamination in drilling have been correlated to the thrust force during exit of the drill. Davim and Reis [16] also presented a similar approach using Taguchi’s method and the analysis of variance (ANOVA) to establish a correlation between cutting velocity and feed rate with the delamination in a CFRP laminate. A significant amount of research was carried out to find the influence of machining parameters on the delamination of composite laminates using Taguchi and analysis of variance techniques [17–20].

In this work, process parameters are optimized in drilling of hybrid composites using Taguchi technique for design of experiment and the results are analyzed using ANOVA technique to know the significance of each parameter on thrust force, roundness, cylindricity and surface roughness of the hole in hybrid composites. In the present work, the statistical analysis software MINITAB 17 is used for evaluation of drilling parameters.

2. EXPERIMENTAL PROCEDURE

2.1. Specimen Preparation and Drilling Test

In this study, hybrid composite laminate specimens with 50% fiber volume ratio were prepared with T300 carbon fiber and E- glass fiber using epoxy resin by hand lay-up process. The work piece material specimen size of 250 × 35 × 10 mm was cut from a laminate. The drilling experiments were conducted according to Taguchi’s L9 orthogonal array as shown in Table. 2. on hybrid composite laminates with 8 mm diameter Solid carbide drill of double point angles 120^0 , 180^0 and helix angle of $20^{\,0}$. Each experiment was carried out twice to minimize the experimental error. A computer numerical control (CNC) vertical machining (VMC) was used for conducting experiments. A digital drilling tool dynamometer was used to measure the axial thrust force. The experimental setup used for drilling operation is shown

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in Fig. 1. The roundness and cylindricity errors of the drilled holes were measured using Coordinate Measuring Machine (CMM) as shown in Fig. 2.

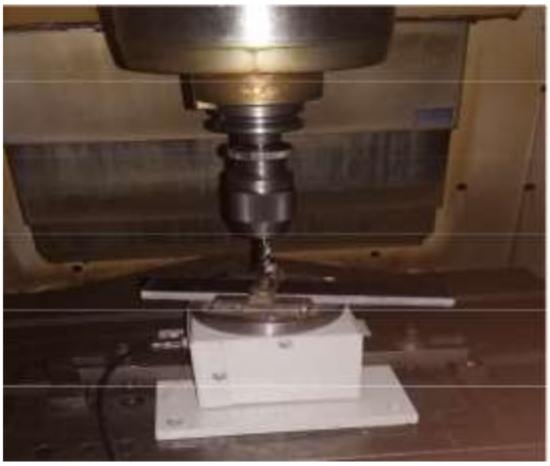

Figure 1 Experimental set-up

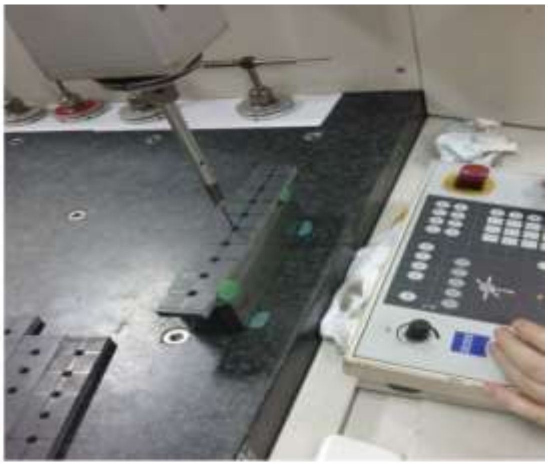

Figure 2 Roundness and Cylindricity measurement

After conducting experiments, the quality of drilled holes was measured in terms of the end surface of the hole using a Mitutoyo surface roughness tester (SJ301) . For each test 3 measurements over drilling surfaces were made. Considering the number of measurements to be carried out, a programmable technique was used, by previously selecting a roughness profile, the cut-off (0.8 mm) and the roughness evaluator parameter (Ra), according to ISO.

2.2. Plan of Experiments

For the elaboration of the plan of experiments the method of Taguchi for two factors at three levels was used. Table. 1. indicates the factors to be studied and the assignment of the corresponding levels. By levels we mean the values taken by the factors. The array chosen was the L9 (2^4), which has 9 rows corresponding to the number of tests (8 degrees of freedom) with 2 columns at three levels, as shown in Table. 2. The factors and the interactions are assigned to the columns. The plan of experiments is made of 9 tests (array rows) where the first column was assigned to the Spindle speed and the second column to the feed rate and the remaining were assigned to the interactions. The outputs to be studied are the thrust force (Fz), roundness, cylindricity, and surface roughness.

Table 1 Experimental factors and their levels

Levels	Spindle speed (rpm)	Feed rate (mm/rev)
1	640	0.08
2	1120	0.13
3	1760	0.20

Table 2 Orthogonal array L9 (2^4) of Taguchi

Experiment No.	1	2	3	4
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

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2.3. Taguchi Method

Taguchi has envisaged a new method of conducting the design of experiments which are based on well-defined guidelines. Taguchi techniques employ a special design of orthogonal arrays to analyze the variables and their interactions using minimum number of experiments. It provides a simple efficient and systematic approach to optimize design for performance, quality and cost. Taguchi parameter design optimizes the performance characteristics by setting the design parameters and reduces the sensitivity of the system performance to the source of variation. The crux of the orthogonal arrays method lies in choosing the level combinations of the input design variables for each experiment. The experimental results are then transformed into a signal-to-noise (S/N) ratio. It uses the S/N ratio as a measure of quality characteristics deviating from or nearing to the desired values. There are three categories of quality characteristics in the analysis of the S/N ratio, i.e. the lower the better, the higher the better, and the nominal the better.

Table 3 Response table for S/N ratios for Thrust force**. Table 4** Response table for S/N ratios for Roundness

Level	Spindle speed	Feed rate
1	-27.65	-25.16
2	-27.09	-27.04
3	-27.12	-29.67
Delta	0.55	4.51
Rank	2	1

Level	Spindle speed	Feed rate
1	44.68	51.37
2	44.92	45.57
3	41.94	41.11
Delta	2.98	10.26
Rank	2	1

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5 Response table for S/N ratios for Cylindricity **Table 6** Response table for S/N ratios for Surface roughness

Level	Spindle speed	Feed rate
1	43.69	41.43
2	42.24	40.39
3	41.80	45.92
Delta	1.88	5.53
Rank	2	1

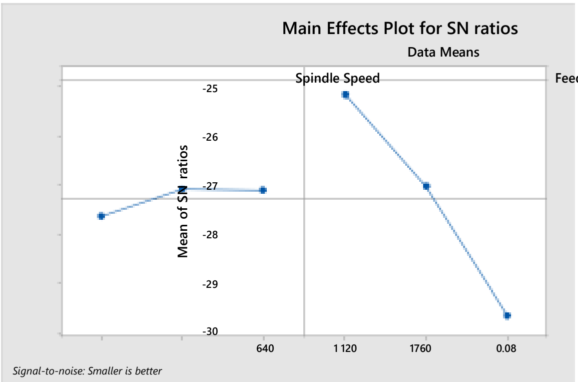
Level	Spindle speed	Feed rate
1	-8.076	-18.324
2	-16.710	-9.348
3	-18.070	-15.186
Delta	9.994	8.976
Rank	1	2

2.4. Analysis of Variance (ANOVA)

ANOVA is a statistical technique for determining the degree of difference or similarity between two or more groups of data. It is based on the comparison of the average value of a common component. In this paper ANOVA was used to determine the optimum combination of process parameter more accurately by investigating the relative importance of process parameters. The Pareto ANOVA technique does not need *F*-test. This technique identifies the important parameters and calculates the percentage influence of each parameter on different quality characteristics.

3. RESULTS AND DISCUSSION

The results of thrust force, roundness, cylindricity and surface roughness are shown in Table 7. The experimental results were transformed into S/N ratios using Taguchi method. The S/N ratio values for all responses are presented in Tables 3–6. The main effect for mean and S/N ratio is plotted in Figs. 3–6, respectively.



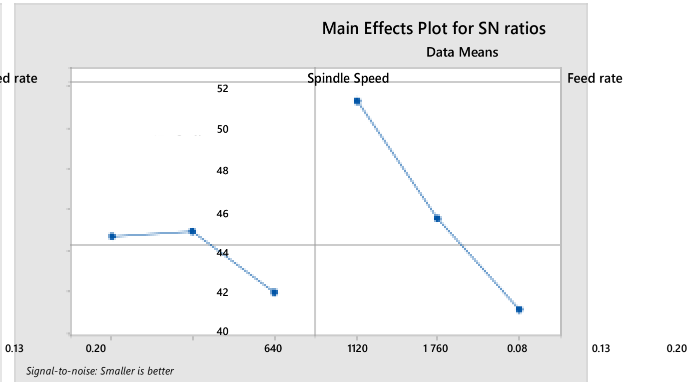
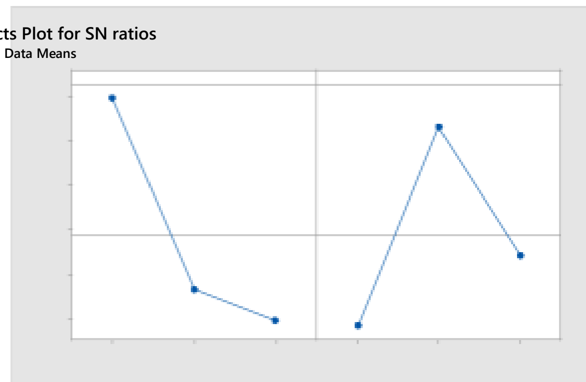


Figure 3 Main effects plot for S/N ratio (thrust force) **Figure 4** Main effects plot for S/N ratio (roundness)



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640 1120 1760 0.08 0.1 3 0.20

Signal-to-noise: Smaller is better

Main Effects Plot for SN ratios
Data Means

Spindle Speed Feed rate

Mean of SN ratios

-8
-1 0
-1 2
-1 4
-1 6
-1 8

640 1 120 1760 0.08 0.13 0.20

Signal-to-noise: Smaller is better

Figure 5 Main effects plot for S/N ratio (cylindricity) **Figure 6** Main effects plot for S/N ratio (surface roughness**)**

Table. 3. and Fig. 3. shows the influence of process parameters on the thrust force. The optimum process parameters on the thrust force are obtained as speed at level 1 (640 rpm), feed at level 3 (0.20 mm/rev). Table. 4.and Fig. 4. shows the effect of process parameters on roundness. The optimum process parameters on roundness are obtained as speed at level 3 (1760 rpm), feed at level 3 (0.20 mm/rev) . Table. 5. and Fig. 5. shows the influence of process parameters on cylindricity. The optimum process parameters on the cylindricity are obtained as speed at level 3 (1760 rpm), feed at level 2 (0.13 mm/rev). Table. 6. and Fig. 6. shows the effect of process parameters on surface roughness. The optimum process parameters on the surface roughness are obtained as speed at level 3 (1760 rpm), feed at level 1 (0.08 mm/rev).

Table 7 ANOVA for thrust force

Source	**DF**	**Adj SS**	**Adj MS**	**F-Value**	**P-Value**
Spindle Speed	2	14.22	7.111	0.37	0.715
Feed rate	2	234.89	117.444	6.04	0.062
Error	4	77.78	19.444		
Total	8	326.89			

Table 8 ANOVA for roundness

Source	**DF**	**Adj SS**	**Adj MS**	**F-Value**	**P-Value**
Spindle Speed	2	0.000025	0.000012	4.88	0.084
Feed rate	2	0.000097	0.000048	19.27	0.009
Error	4	0.000010	0.000003		
Total	8	0.000132			

Table 9 ANOVA for cylindricity

Source	**DF**	**Adj SS**	**Adj MS**	**F-Value**	**P-Value**
Spindle Speed	2	0.000014	0.000007	0.55	0.613
Feed rate	2	0.000041	0.000020	1.57	0.314
Error	4	0.000052	0.000013		
Total	8	0.000107			

Table 10 ANOVA for surface roughness

Source	**DF**	**Adj SS**	**Adj MS**	**F-Value**	**P-Value**
Spindle Speed	2	92.40	46.20	1.25	0.379
Feed rate	2	38.28	19.14	0.52	0.631
Error	4	147.91	36.98		
Total	8	278.59			

The ANOVA results for all the responses are presented in Tables 7-10 respectively. It is observed from the ANOVA results that feed is the significant factor followed by speed for all the responses except for surface roughness for which speed is the significant factor. The model adequacy checking was conducted after performing an ANOVA analysis to verify the normality assumption of the residual. Figs. 7–10 show normal probability plots of the residuals and these figures reveal that almost all the residuals follow a straight line pattern and this agrees well with the results reported by Davidson et al. [21].

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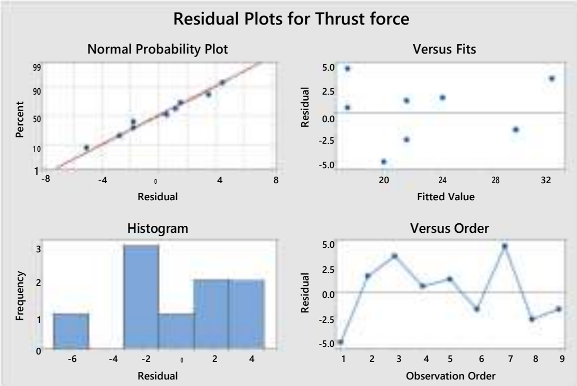

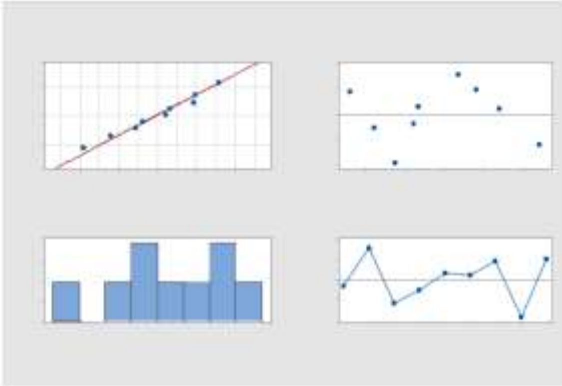

Figure 7 Residual Plots for thrust force

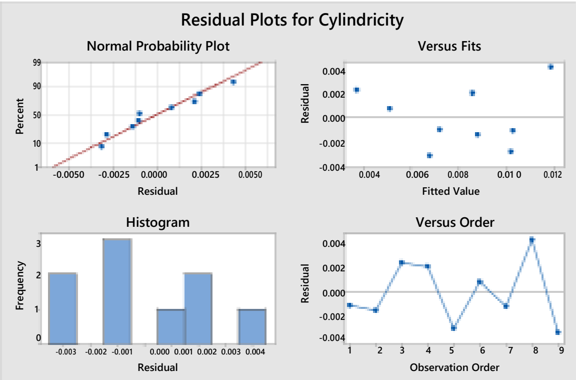

Figure 9 Residual Plots for cylindricity

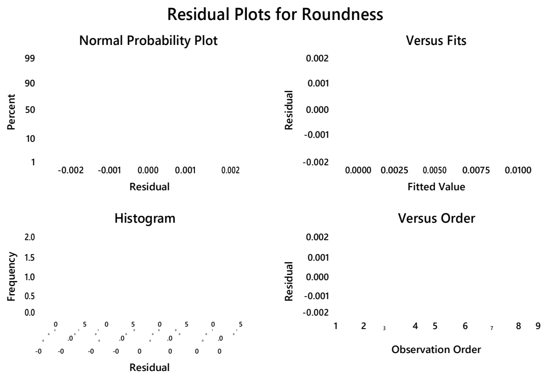

Figure 8 Residual Plots for roundness

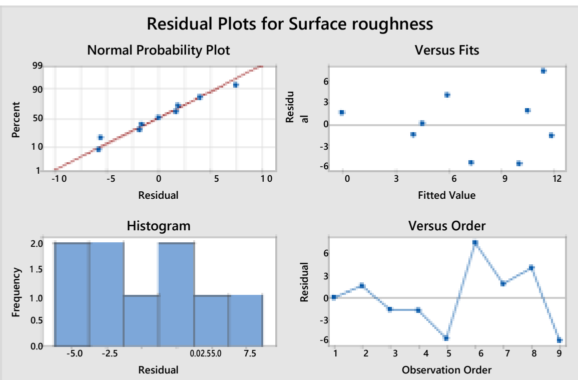

Figure 10 Residual Plots for surface roughness

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4. CONCLUSIONS

Based on the experimental results presented, the conclusions are:

It is observed that the feed rate is the most significant parameter that affects the quality of the drilled hole.

The optimum process parameters for thrust force for drilling are speed of 640 rpm, feed rate at 0.20 mm/rev.

In the similar way for roundness, the optimum process parameters are speed of 1760 rpm, feed rate at 0.20 mm/rev.

For cylindricity, the optimum process parameters are speed of 1760 rpm, feed rate at 0.13 mm/rev.

For surface roughness, the optimum process parameters are speed of 1760 rpm, feed rate at 0.08 mm/rev.

REFERENCES

[1] J.P. Davim, Pedro Reis “Study of delamination in drilling carbon fiber reinforced plastics (CFRP) using design experiments”, Composite Structures 59 (2003) pp. 481–487

[2] Vijayan Krishnaraj, A. Prabukarthi , Arun Ramanathan , N. Elanghovan , M. Senthil Kumar. “Optimization of machining parameters at high speed drilling of carbon fiber reinforced plastic (CFRP) laminates”, Composites: Part B 43 (2012) pp.1791–1799

[3] A. Krishnamoorthy, S. Rajendra Boopathy, K. Palanikumar, J. Paulo Davim. “Application of grey fuzzy logic for the optimization of drilling parameters for CFRP composites with multiple performance characteristics”, Measurement 45 (2012) pp.1286 – 1296

Sy

[4] PK Rakesh, I Singh, D Kumar, Drilling of composite laminates with solid and hollow drill point geometries, Journal of Composite Materials, vol. 46, 25: pp. 3173-3180., December 2012.

[5] UA Khashaba, A El-Sonbaty, AI Selmy, AA Megahed, Drilling analysis of woven glass fiber-reinforced/epoxy composites, Journal of Composite Materials, vol. 47, 2: pp. 191-205., January 2013.

[6] Manna A, Bhattacharyya B. Taguchi method based optimization of cutting tool flank wear during turning of PR-Al/20 vol.% SiC-MMC. International Journal of Machining and Machinability of Materials 2006;14:488–99.

[7] Abrao AM, Faria PE, Campos Rubio JC, Paulo Davim J. Drilling of fiber reinforced plastics: A review. Journal of Material Processing & Technology 2007;186:1–7.

[8] Gopalsamy B, Mondal B, Ghosh S. Taguchi method and ANOVA. An approach for process parameters optimization of hard machining while machining hardened steel. Journal of Scientific Industrial Research 2009;68:686–95.

[9] L.H. Miner, Cutting and machining Kevlar aramid composites, Kevlar Composites Symposium El Segundo California, Society of Plastics Engineers, 1980, pp. 85–93.

[10] B.A. Mackey, How to drill precision holes in reinforced plastics in a hurry, Plastic Engineering 2 (1980) 22–24.

[11] A. Koplev, Cutting of CFRP with single edge tool, Proceedings of the 3rd ICCM, Paris, France, 1980, pp. 1597–1605.

[12] Enemuoh, Ugo E., El-Gizawy Sherif A., Chukwujekwu Okafor A. An aproach for development of damage-free drilling of carbon fiber reinforced thermosets. International Journal of Machine Tools and Manufacture 2001;41(12):1795–814.

[13] Caprino G, Tagliaferri V. Damage development in drilling glass fibre reinforced plastics. International Journal of Machine Tools and Manufacture 1995;35(6):817–29.

[14] Taguchi G. Introduction to quality engineering, Asian Productivity Organization. Dearborn, MI: Distributed by American Supplier Institute Inc.; 1986.

[15] Phadke SM. Quality engineering using robust design. Englewood Cliffs, N.J: Prentice Hall; 1989.

[16] J.P. Davim, P. Reis, Study of delamination in drilling carbon fiber reinforced plastics (CFRP) using design experiments, Composite Structure 59 (2003) 481–487.

[17] Bagci E, Ozcelik B. Analysis of temperature changes on the twist drill under different drilling conditions based on Taguchi method during dry drilling of Al7075-T651. Journal of Advanced Manufacturing & Technol ogy 2006;29:629–36.

[18] Abrao AM, Campos Rubio JC, Faria PE, Davim JP. The effect of cutting tool geometry on thrust force and delamination when drilling glass fibre reinforced plastic composite. Journal of Materials Design 2008;29:508–13.

[19] Rubio JC, Abrao A, Faria P, Esteves Correia A, Davim JP. Effects of high speed in the drilling of glass fibre reinforced plastic: evolution of the delamination factor. International Journal of Machine Tools & Manufacturing 2008;48:715–20.

[20] Abrao AM, Campus Rubio J, Faria PE, Davim JP. The effect of cutting tool geometry on thrust force and delamination when drilling glass fibre reinforced plastic composite. Journal of Material Design 2008;29:508–13.

[21] Davidson MJ, Balasubramanian K, Tagore GRN. Surface roughness prediction of flow-formed AA6061 alloy by design of experiments. J Mater Process Technol 2008;202:41–6.