J. Mater. Environ. Sci. 6 (5) (2015) 1638-1645
ISSN : 2028-2508
CODEN: JMESCN

Assessment of factors influencing burr height on the machining of particle reinforced hybrid composites

A. Saravanakumar [1], P. Sasikumar [2*]

[1 & 2] *Department of Mechanical Engineering, KPR Institute of Engineering &Technology, Coimbatore, India..*

Received 12 Nov 2014, Revised 13 Mar 2015, Accepted 13 Mar 2015
[*]*Corresponding Author. E-mail: sasi_me75@yahoo.com*

Abstract
The present work is aimed at analysing the burr height at exit of the holes during drilling of hybrid aluminium matrix composite using TiN coated Solid carbide twist drills. The exit burr in drilling affects quality of the hole and so, it is necessary to study influence of input variables such as speed, feed, drill diameter and graphite on burr height. For experimentation, design of experiment - full factorial design concept was used. In this research work, a mathematical model has been developed using regression analysis to predict the burr height and analysis of variance (ANOVA) in order to study the main effects of machining parameters on burr height.

Keywords: Drilling, Burr height, Regression analysis, hybrid composite, Design of experiment.

1. Introduction
Aluminium matrix composites (AMCs) have received substantial attention because of their high strength and attractive tribological properties. Conventional materials are rapidly replaced with particle-reinforced aluminium alloy composites in various engineering applications from automotive to aircraft components [1, 2].Due to presence of hard particles such as aluminium oxide (Al_2O_3) and silicon carbide (SiC) particles, AMCs are extremely difficult for machining. Abrasive properties of Al_2O_3 and SiC particles in the aluminium alloy lead to rapid wear of the cutting tools leading to high tool cost [3]. Drilling is carried out for all mechanical parts and needed for joining the various parts together. So for most of the applications, holes act as stress concentrate location. During drilling, burrs are generated at the hole edges which degrade the performance in precision part and affect the reliability of the assembled product. Hence, it is essential to minimize burr size at the production stage itself to reduce the debarring cost [4].

Yahya Altunpak et al.[5] investigated the drilling of Al/20%SiC/5%Gr and Al/20%SiC/10%Gr hybrid composites with diamond-like carbon coated cutting tools on cutting force and surface roughness and found that inclusion of graphite as an additional reinforcement in Al/SiCp reinforced composite reduces the cutting force. Basavarajappa et al.[6] analyzed the influence of cutting parameters on thrust force, surface finish, and burr formation in drilling of Al2219/15SiCp and Al2219/15SiCp-3Gr composites. Result showed that graphitic composite exhibit better performance than non-graphitic composite and observed that addition of graphite to Al2219/15SiCp helps in the material to shear easily and form discontinuous chips during the drilling of the composites which leads to minimise the burr height.

MetinKok [7] studied the machining of 2024Al alloy composites reinforced with Al_2O_3 particles, based on Taguchi method with different Spindle speeds using coated carbide tools, K10 and TP30. It was concluded that surface roughness decreased with increasing size and volume fraction of particles and increased with increasing the Spindle speed. Rajmohan et al.[8] used solid carbide tool for the study of minimization of burr height in drilling of Al356/SiC/Mica hybrid composites and found that feed rate is the most influencing factor followed by spindle speed. Further in that paper, response surface methodology is used for modelling the cutting parameters in drilling of Al356/SiC/Mica. Songmene and Balazinzki [9] reported that graphitic aluminum MMC reinforced with alumina is easier to machine than those reinforced with other hard particles. Sharma et al.[10] reported that graphitic composite required less amount of energy for drilling the composite compared to the base alloy, since graphite being solid lubricant reduces the friction

ISSN : 2028-2508
CODEN: JMESCN

at tool–work interface. Experiments were conducted with HSS drill bit and concluded that tool life increased more while machining the graphite reinforced composite than base alloy.

In this research work, the effect of drilling process parameters such as speed, feed, drill diameter and wt-% of graphite were analyzed on the burr height of the AA 6063-6 wt-% Al_2O_3-x wt-% Gr (x = 0 and 1 wt-%) composites which was produced by stir casting method. Multiple regression models were established to describe the correlation between the cutting parameters and the burr height.

2. Experimental procedure

2.1 Materials and Manufacturing methods:

In this research, AA 6063 was used as a matrix alloy and Alumina (Al_2O_3) particles of size 20 µm, Graphite particles of average size 80µm were used as the reinforcement materials for fabrication of hybrid composite. The fact that used Al_2O_3 particles are α-Al_2O_3 and graphite particles are commercial graphite was established by X-ray diffraction (XRD) test. The hybrid composites of AA 6063-6 wt-% Al_2O_3-x wt-% Gr (x = 0 and 1 wt-%) were manufactured by stir casting method. The alloy which was in the form of rod was cut into small pieces to keep in the graphite crucible and melted using Induction electric resistance furnace. Reinforcements Al_2O_3 and Gr particles were kept in smaller crucible and preheated at 450^0C. Then it is added with molten metal of Al alloy at 800°C and stirred continuously. The degassing tablets of Hexa-Chloro Ehane (C_2Cl_6) were added over the melt for removing the unwanted gases entrapped in the melt. The stirring was done at 465 rpm for 7 minutes. Then, the molten alloy and hybrid composites in crucible were tilted and poured into the preheated permanent steel mould and allowed to cool in atmospheric air.

2.2 Experimental design

Drilling operation was conducted on FEELER FV-800A machining centre. TiN Coated solid Carbide tool (parallel shank) twist drill bit of 10mm and 6mm diameter was used for drilling. The samples were prepared in the form of 125 mm×25mm×10mm blocks for each material. The tests were performed at dry condition for different Spindle speeds, wt-% of Graphite (Gr) and feed rates. The lower and upper limits of the identified factors for this research work are given in Table1. In this experimental scheme, full factorial design of experiment concept was used and all possible combinations of levels (2^n refers to the number of factors and 2 represents number of levels i.e., 2^4 = 16 trials) were included which is shown in Table 2 along with measured burr height. Burr height of each hole was measured at the exit side of the hole by using SP-300 SIPCON profile projector machine which was connected to computer controlled software. Figure 3 shows the SEM images of AA 6063-6wt-% Al_2O_3-1wt-% Gr which confirms the uniform distribution of reinforcement.

Table1: Upper and Lower limit of parameters

Levels	Speed(A)(rpm) (rpm)	Feed(B)(mm/min) (mm/min)	Gr(C) wt-% (%)	Diameter(D)(mm)
I	1000	50	0	6
II	3000	150	1	10

Figure 1: Vertical machining centre and drilling setup

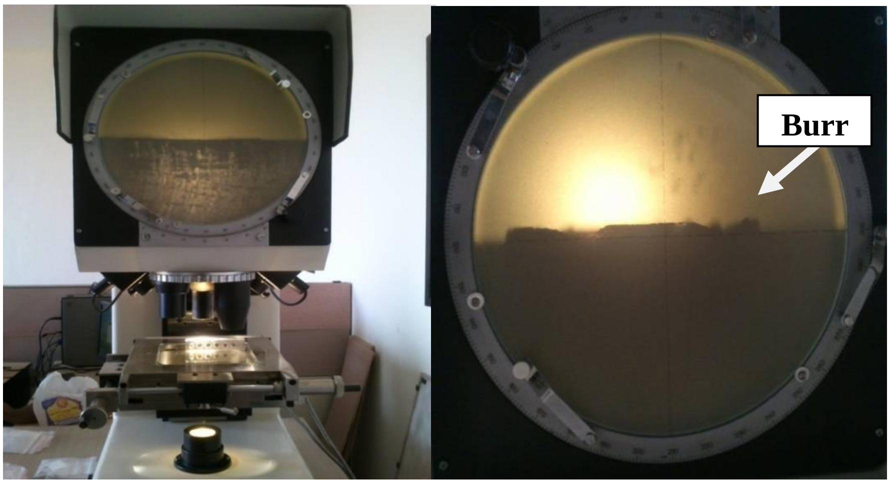

Figure 2: SP-300 SIPCON profile projector and burr height

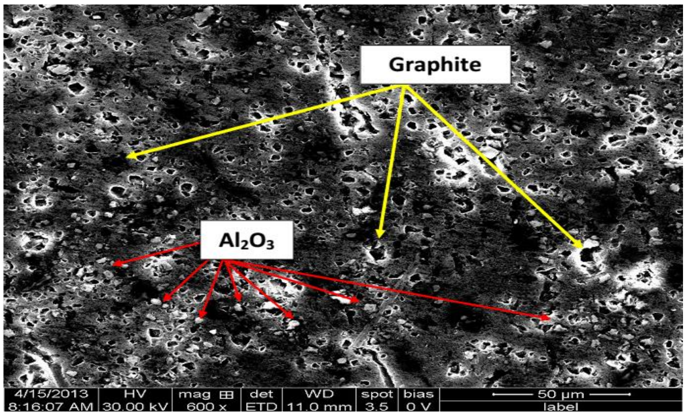

Figure 3: SEM image of AA 6063-6wt-% Al_2O_3-1wt-% Gr

Table 2: Experimental results of burr height

StdOrder	RunOrder	Speed(A)	Feed(B)	Graphite(C)	Diameter(D)	Burr height (BH) (mm)
12	1	3000	150	0	10	0.69
2	2	3000	50	0	6	0.395
5	3	1000	50	1	6	0.265
10	4	3000	50	0	10	0.42
9	5	1000	50	0	10	0.52
4	6	3000	150	0	6	0.505
16	7	3000	150	1	10	0.225
3	8	1000	150	0	6	0.675
13	9	1000	50	1	10	0.311
14	10	3000	50	1	10	0.15
15	11	1000	150	1	10	0.59
8	12	3000	150	1	6	0.195
7	13	1000	150	1	6	0.47
11	14	1000	150	0	10	0.755
6	15	3000	50	1	6	0.123
1	16	1000	50	0	6	0.49

3. Results and discussion

Analysis of the factors and its effects on burr height of AA 6063/6 wt-%Al_2O_3/-x wt-% Gr (x = 0 and 1 wt-%) composites machining process has been carried out through: (i) Main effects and interaction effect graph, (ii) Pareto chart and normal probability plot (iii) analysis of variance (ANOVA) technique with the use of MINTTAB 16 software and (iv) Chip morphology.

3.1 Main effects and interaction effect

In Fig.4, each factor Spindle speed, feed, percentage of graphite and diameter of drill and their level's effect on the formation of the average burr height are shown. When Speed and Graphite level changes from lower limit to upper limit, drastically, it reduces the average burr height which is very useful during machining operation. When the feed parameter changes from 50 to 150 mm/min, it increases the burr height and the same effect has been observed when diameter changes from 6 to 10 mm.

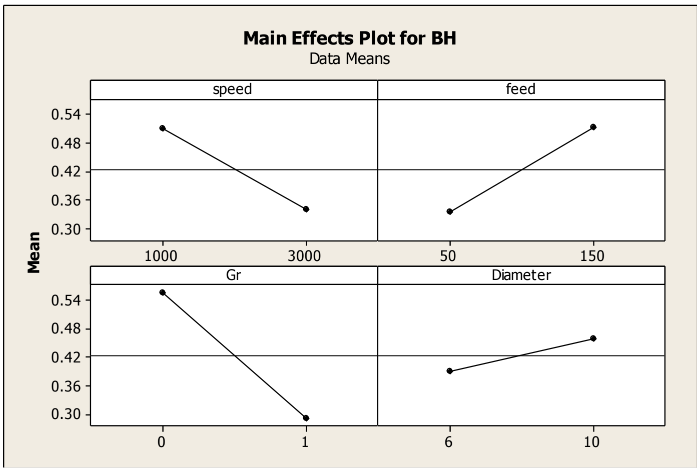

Figure 4: Main effects plot for Burr Height

The average values of the burr height are calculated for all the combinations. By using the values, interaction graphs are drawn for each combination of levels shown in Fig. 5. The interaction effects of burr height plot shows that interaction of feed and graphite (BC), speed and graphite (AC) are considerable than other combination. It is observed that for all the combination, burr height is minimised at higher Spindle speed(3000 rpm),low feed rate(50 mm/min), small diameter(6) and 1wt-% of graphite. The lowest burr height value is observed at highest spindle speed (3000 rpm), lowest feed rate (50 mm/rev) and 6wt-% of Alumina particles while drilling with 6mm diameter drill bit.

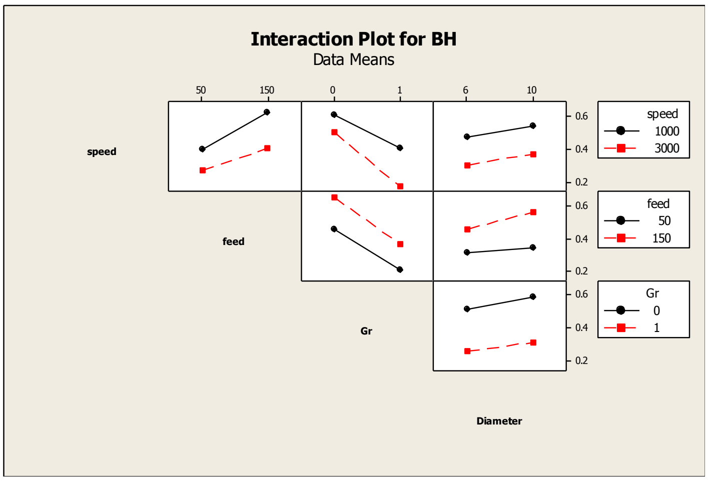

Figure 5: Interaction plot for Burr Height

3.2 Pareto chart and normal probability plot

In the above analysis, it was found that graphite, feed and Spindle speed greatly influences the burr height than diameter of the drill tool. To find the magnitude and the importance of each factor effect on burr height of exit hole, Pareto chart was employed. This chart displays the absolute value of the effects and a reference line on the chart is drawn. Any effect that extends past this line is potentially important [11].

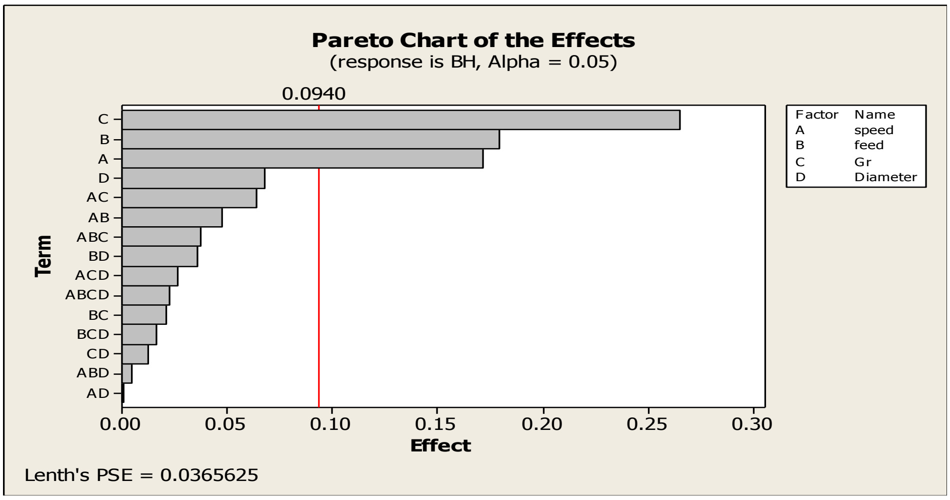

Figure 6: Pareto chart for Burr Height

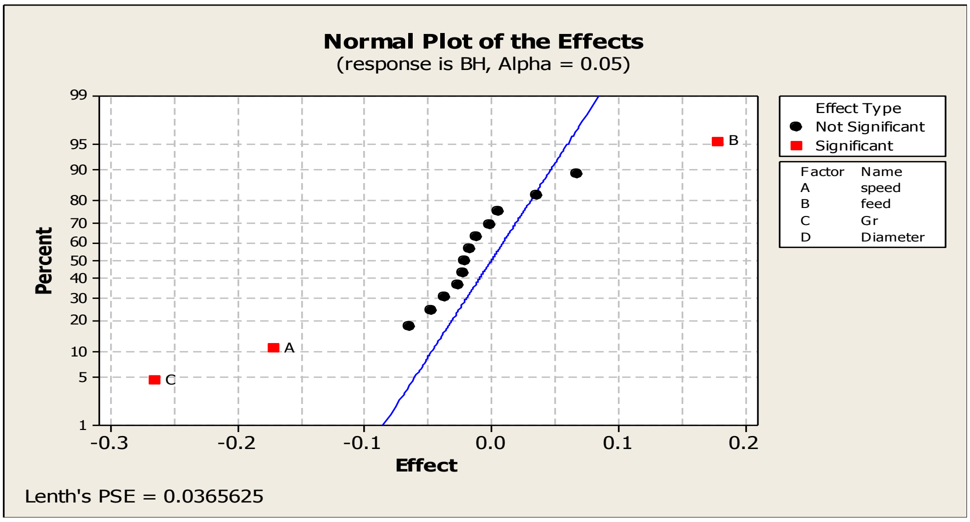

Figure 7: Normal probability chart for Burr Height

The effects of different parameters on burr height can be analysed by using standardized Pareto chart and normal probability plot. Fig. 6 shows the Pareto chart of the standardized effects. This chart displays the absolute value of the effects, and draws a reference line on the chart. Any effect that extends past this line is potentially important. Fig.7 shows the normal probability plot of the standardized effects of each parameter on burr height. Normal plot is a graphical technique based on ''Central limit theorem'' [12]. As per the normal probability plot, points which are close to a line fitted to the middle group of points represent estimated factors which do not demonstrate any significant effect on the burr height. On the other hand, the points which appear to be far away from the straight line are likely to represent the 'real' factor effects on the burr height. Based on observations, from Figs. 5 and 6, it can be concluded that the factors C, B and A are considered to be significant at 95% confidence level.

3.3 Analysis of Variance

Analysis of variance was performed for a level of significance of 5 % to study the contribution of the drilling process parameters on burr height with the help of MINITAB16. In the ANOVA table, when the P-value for each independent parameter is less than 0.05, then corresponding parameter can be considered as highly significant. It was observed that the Graphite, feed and Spindle speed was less than 0.05, which means that these parameters are highly significant at 95 % confidence level. The last column of the Table 3 shows the percentage contribution (Pc %) of each variable in the total variation indicating their degree of influence on the burr height of the composites. It was observed that the graphite (47.68 %) was the major contributing parameter followed by feed (21.70 %) and speed (19.98 %) influencing the burr height of the Al–Al_2O_3 - Gr composite.

Table 3: Analysis of Variance for burr height

Source	DF	SS	MS	F	P	Pc
A	1	0.11782	0.11782	29.22	0.000	19.98
B	1	0.12799	0.12799	31.74	0.000	21.70
C	1	0.28117	0.28117	69.74	0.000	47.68
D	1	0.01843	0.01843	4.57	0.056	3.14
Error	11	0.04435	0.00403			7.5
Total	15	0.58975				

DF - Degrees of Freedom; Seq.SS - Sequential sums of squares; Adj.MS-Adjusted sums of squares; Pc-Percentage of contribution.

3.4 Chip morphology

While drilling Al/Al_2O_3 composite, continuous and curling chips were formed and it gets curled within the tool work interface and needs to be removed at short interval. At the same time, the chips produced in graphitic composite material gets break off at regular interval leading to better surface finish and less affecting the tool work interface. The above factors are shown in Fig. 8 and Fig. 9. Microscopic analysis was made on the edges of the chips shown in Fig.10. From that, it is observed that, localization of plastic flow occurs at the edges of graphitic composite due to shear periodically [9]. The graphite content causes the breaking of the chips at regular interval easily, whereas this does not happen in Non-Graphite composite. Inclusion of graphite particles with Al/Al_2O_3 composite helps the material to shear easily leading to discontinuous chip and formation of burr is restricted during the drilling of the Al/Al_2O_3/Gr composites [6].

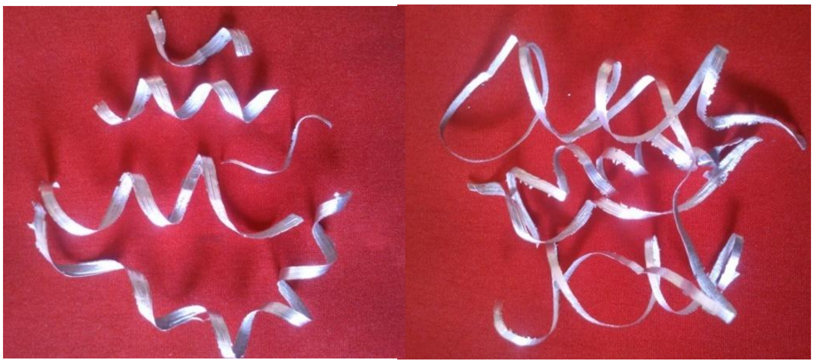

Figure 8: Chip formed in Non-Graphite composite at 3000 rpm, 50 mm/min and 6mm

Figure 9: Chip formed in Graphite reinforced composite at 3000 rpm, 50 mm/min and 6mm

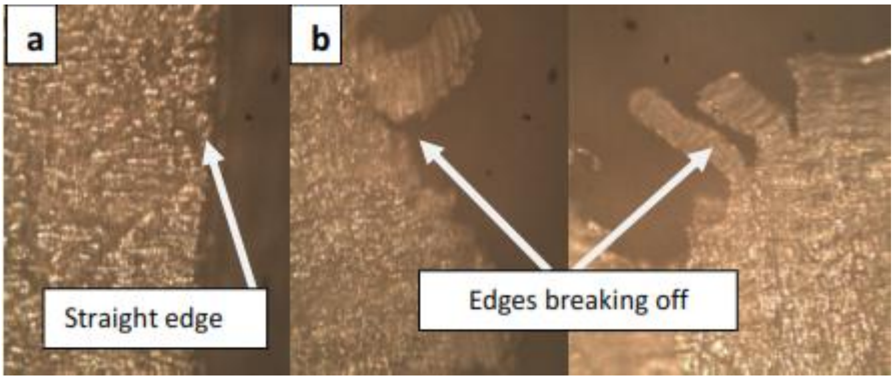

Figure 10: Chip edges formed in (a) Non-Graphite composite (b) Graphite reinforced composite

4. Modelling and confirmation study

4.1 Regression equation

To find the correlation among the drilling process parameters, multiple linear regression equation was developed on the response variable of burr height. The competence of the developed model can be verified by using R^2 value. It can be noted that regression coefficient for the model is 0.956, because of which data were not scattered. Since the values are reasonably close to unity, models provide reasonably good explanation of the relationship between the independent drilling process parameters and the burr height.

The regression equation developed for burr height is

$$BH = 0.328 - 0.000054\,A + 0.00200\,B - 0.0946\,C + 0.0170\,D - 0.000423BC - 0.000064\,CA \quad ... (2)$$

Where, BH = Burr height; A- speed, rpm; B- feed, mm/min; C-graphite wt-%; D-Diameter, mm.

From the regression equation, it is noted that the coefficient associated with graphite (C) is negative. It indicates that burr height of the composite decreases with increasing graphite content and also same effect is observed in Spindle speed (A). But in the case of feed (B), it is observed that positive coefficient which indicates that burr height of the composite decreases with increasing feed.

4.2. Confirmation test

Final step of the design of experiment process is confirmation test. In this experiment, unusual observations are noted for two tests. So it is necessary to conduct the conformation test to validate the model. Two set of confirmation experiments were conducted with different feed conditions and results are presented in the Table 4 and Table 5, respectively. The calculated values from the regression equation are nearly equal to experimental values with least error (± 8 %). Further these errors can be reduced, if numbers of observation of performance characteristics are increased. However, the validity of the regression equation is limited to the range of factors considered for the experimentation.

Table 4: Parameters used in the confirmation test

Test	Speed(A) (rpm)	Feed(B) (mm/min)	Graphite(C) wt-%	Diameter(D) (mm)
I	2000	100	1	6
II	2000	50	1	6

Table 5: Result of confirmation tests

Material	Burr height					
	Test-I			Test-II		
	Model equation	Expt.	Error, %	Model equation	Expt.	Error, %
$Al\text{-}Al_2O_3\text{-}Gr$	0.2564	0.246	4.22	0.178	0.165	8.0

ISSN : 2028-2508
CODEN: JMESCN

Conclusion

In the Design of experiment, 2 level full factorial design was adopted and ANOVA analysis was performed to investigate the effects of spindle speed, feed, drill diameter and weight fraction of graphite on the burr height in the drilling of Al6063/Al_2O_3 composite. The following conclusions were drawn from this experimental work:

- Burr height is greatly influenced by the graphite particle added in small amount as a second reinforcement with Al/ Al_2O_3. It was observed from ANOVA table that graphite particle (47.68 %) is the most significant factor followed by feed and spindle speed.
- The chip formed in drilling Al6063/ Al_2O_3-Gr composite is discontinuous and shorter in length making it easier for chip disposal, hence it leads to better machinablity and improvement in hole quality.
- The burr height decreases with increase in Spindle speed but increases with increase in feed rate for both the composites. The graphitic composite shows less burr height than Al_2O_{3p} reinforced composite.
- The results indicate that developed model for burr height is found to be satisfactory and can be used to estimate the characteristics within the experimental range.

References

1. Ibrahim I.A., Mohamed F.A., Lavernia E.J., *J. Mater. Sci.* 26 (1991) 1137.
2. Haque S., Ansari A.H., Bharti P. K., *J. Mater. Environ. Sci.* 5 (2014) 1485.
3. Sahin Y., Kok M., Celik H ., *J. Mater. Process. Technol*. 128 (2002) 280.
4. Gaitonde V. N., Karnik S. R., *J. Intell. Manuf*. 23-5 (2012) 1783.
5. Yahya Altunpak., Mustafa Ay., Serdar Aslan., *Int. J. Adv. Manuf. Technol*. 60-5 (2012) 513.
6. Basavarajappa S., Chandramohan G., Davim JP., *J. Mater. Process. Technol*. 196 (2008) 332.
7. MetinKök., *Int. J. Adv. Manuf. Technol*. 55 (2011) 911.
8. Rajmohan T., Palanikumar K., Madhavan Harish G., *Procedia. Eng*. 38 (2012) 56.
9. Songmene A.V., Balazinzki M., *CIRP.* 48 (1999) 77.
10. Sharma S.C., Girish B.M., Kulkarni R.S., Kamath R., *NML Tech. J*. 38 -3 (1996) 107.
11. Palanikumar K., Karthikeyan R., *Mater.Des.* 28 (2007) 1584.
12. Lochner RH, Mater JE. Designing for quality. London: Chapman &Hall; ISBN. 0412400200 (1990) 77.

(2015) ; http://www.jmaterenvironsci.com