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Research Article

Optimization of Burr Height and Surface Roughness in the drilling of PU based babbar fibres reinforced composites using Taguchi Method

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Abstract

Now a days, composites are replacing a large number of metallic parts, because of advantages like light weight, low cost and their comparable strength. List of their applications in the industry is very long and it is still has a growing potential. During mechanical machining these composites undergoes many operations. Drilling and milling are among the common operations applied to them. This study presents the use of Taguchi Method to optimize the process parameters for minimizing burr height and surface roughness in the drilling of Polyurethane based randomly distributed babbar reinforced composites. Cutting speed, feed rate and tool angle each having three levels, were selected as control parameters and a plan of experiments based on L27 OA was performed drilling. ANOVA statistical tool and mean vs control factor were used to analyze the data obtained from the experiments.

Keywords: *Taguchi Method, Drilling, Composites, Polyurethane, Surface Roughness, Burr Height, ANOVA*

1. Introduction

A composite is made up of two or more than two materials. Composite has entirely different properties than the parent materials. It consists of a resin called matrix and reinforced fibres. Resin is used to bind the fibres within the composites. A variety of resin is available in the market which can be used to form composites. Some of them are Natural or Synthetic. Reinforcing material used are generally fibres, however some other materials such as minerals, bio waste etc also can be utilized. Main functions of the matrix are to provide equal stress distribution among the fibres and to prevent the fibres from environmental and mechanical damage whereas fibre carries the load along their longitudinal axis. Fibres can be arranged in various geometries inside the matrix. Some common geometries are aligned, woven and random distribution. Once the Composite is formed, it undergoes various machining processes, such as Cutting, Drilling, Milling, Turning etc.

Drilling in composites is one of those operations which are used to convert raw material into usable form. This process however produces burr which tends to damage the surface texture of the material. Height of these burr and surface roughness depends on various factors such as tool geometry, work material, process parameters and tool material etc. In the present study, Taguchi DOE has been used as quality tools. This approach is the focus on differentiating offline and online quality control method in the quality engineering systems. In Taguchi design, a measure of robustness used to identify control factors that reduce variability in a product or process by minimizing the effects of uncontrollable factors. Control factors are those design and process parameter that can be controlled, whereas Noise factors cannot be controlled during production.

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2. Experimental set up

2.1 Sample preparation

High density PU resin and babbar was purchased from the market.

Fig 1 Preparation of mould and mixture of babbar fibres and resin

Babbar fibres were cut in a length of 10-12 mm each. A homogeneous mixture of babbar fibre (randomly distributed) and PU containing 10% babbar fibres (Approximately 72gm) by weight was prepared in a beaker.

This mixture was then poured in a properly cleaned mild steel mould of dimensions 300x32x20 mm. Mixture was kept in sunlight for 48 hrs and allowed to set. After setting of composites material, piece was removed carefully from the mould and washed to remove the dirt, grease and other foreign particles.

2.2. Machinery used

A radial drilling machine was used for drilling purpose. It uses a stepped speed and feed rates. Spindle speed ranging 180-2250 rpm (5 steps) and feed ranging from 0.04-0.15 mm/rev were available in steps (3 steps). Height master with least count 0.001 micron was used to measure the burr height. Profile projector was used to measure of surface roughness.

2.3. Selection of drilling parameter and their level

In this study, three machining parameters were selected as control factors, and each parameter was designed to have three levels, denoted by 1, 2, and 3. The experimental design was based on L27 (3***3) orthogonal array based on Taguchi method. A set of experiments designed using the Taguchi method was conducted to investigate the relation between the process parameters and response factors. Minitab 16.1 software was used to study the linear relation and graphical analysis of the data obtained from experiments.

Table 1 Drilling parameters and their level

Parameter	Level 1	Level 2	Level 3
Spindle speed (in rpm)	660	1115	1750
Drill point angle (deg.)	90	118	135
Feed rate (in mm/rev)	0.04	0.08	0.15

2.3 Orthogonal Array

Orthogonal Arrays are selected based on the no of parameters, their level and degree of freedom. In the present study, 3 process parameters are used up to 3 levels. Total degree of freedom is 6 hence L_{27} OA is used. Experiments were designed according to the L_{27} orthogonal array of Taguchi method.

Table 2 Design of experiments

Sr.No	Spindle Speed(in rpm)	Feed Rate (in mm/rev)	Tool Angle(in degree)
1	660	0.04	90
2	660	0.04	118
3	660	0.04	135
4	660	0.08	90
5	660	0.08	118
6	660	0.08	135
7	660	0.15	90
8	660	0.15	118
9	660	0.15	135
10	1115	0.04	90
11	1115	0.04	118
12	1115	0.04	135
13	1115	0.08	90
14	1115	0.08	118
15	1115	0.08	135
16	1115	0.15	90
17	1115	0.15	118
18	1115	0.15	135
19	1750	0.04	90
20	1750	0.04	118
21	1750	0.04	135
22	1750	0.08	90
23	1750	0.08	118
24	1750	0.08	135
25	1750	0.15	90
26	1750	0.15	118
27	1750	0.15	135

2.4 Measurement of response variable and analysis of data

Burr height is measured using surface Height Master and Surface Roughness is measured using Profile Projector (both least count 0.001 micron). ANOVA statistical Technique, average vs Control factor, S/N ratio vs Control Factor are used to analyze the data obtained from experiments.

2.5 Results and discussion

Aim of the study is to minimize the response variable so smaller is better approach of the Taguchi has been used.

$$\frac{S}{N} = -10\log\left\{\frac{1}{n}\sum_{i=0}^{n} y2\right\}$$

3. Analysis and discussions for Burr Height

Table 3 BH and S/N ratio table

Sr.No	Spindle Speed(in rpm)	Feed Rate (in mm/rev)	Tool Angle(in degree)	BH (in mm)	S/N Ratio
1	660	0.04	90	0.572	-4.85207942
2	660	0.04	118	0.44	-7.13094647
3	660	0.04	135	0.682	-3.32431251
4	660	0.08	90	0.814	-1.7875119
5	660	0.08	118	0.858	-1.33025424
6	660	0.08	135	0.671	-3.4655496
7	660	0.15	90	1.034	0.29041078
8	660	0.15	118	0.99	-0.08729611
9	660	0.15	135	0.682	-3.32431251
10	1115	0.04	90	0.748	-2.52196804
11	1115	0.04	118	0.858	-1.33025424
12	1115	0.04	135	0.44	-7.13094647
13	1115	0.08	90	1.32	2.41147862
14	1115	0.08	118	1.265	2.04181051
15	1115	0.08	135	0.44	-7.13094647

16	1115	0.15	90	1.21	1.65570741
17	1115	0.15	118	1.045	0.38232581
18	1115	0.15	135	0.803	-1.90568909
19	1750	0.04	90	0.863	-1.27978409
20	1750	0.04	118	1.023	0.19751267
21	1750	0.04	135	0.462	-6.70716049
22	1750	0.08	90	1.133	1.0845982
23	1750	0.08	118	1.232	1.81221416
24	1750	0.08	135	0.715	-2.91387916
25	1750	0.15	90	1.32	2.41147862
26	1750	0.15	118	1.76	4.91025336
27	1750	0.15	135	0.99	-0.08729611

It is clear from the ANOVA table that feed rate has highest impact on burr height followed by point angle and cutting speed. An interaction plot between the burr height and process variable is shown in fig 2. This shows that a continuous increase in burr height has been noticed with increase in speed. So this indicates that decrease in spindle speed will provide better hole quality and optimum burr height. In case of feed rate, a continuous increase in burr height has been found with increase in feed rate. Also higher tool angle provides lesser burr and hence a better hole quality.

Table 4 ANOVA Table for burr height

Source	ss	DOF	Variance	F Test	F critical	ss'	C %	F T > FC
Cutting Speed	0.421673	2	0.210837	8.945738	4.46	0.267087	9.829801	s
Feed Rate	0.797152	2	0.398576	16.91148	4.46	0.797152	73.66699	S
Point Angle	0.846625	2	0.423313	17.96104	4.46	0.692039	25.46962	s
B*C	0.096403	4	0.024101	1.022589	3.84			NS
C*D	0.078348	4	0.019587	0.831071	3.84			NS
D*B	0.288365	4	0.072091	3.058813	3.84			NS
Error	0.188547	8	0.023568					
Total	2.717115	26	0.104504					
E-pooled	1.082102	14	0.077293					

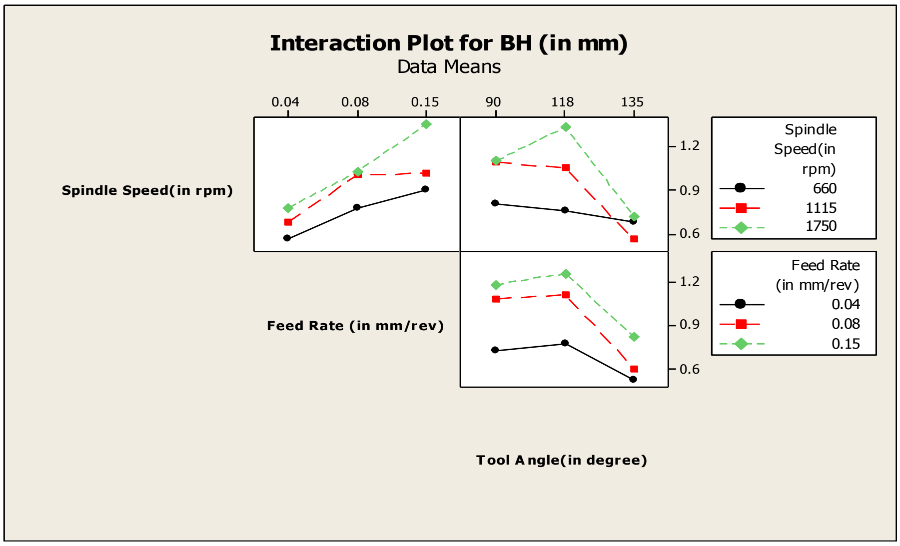

Fig 2 Interaction Plot between burr height and the process parameters

4. Analysis and discussions for surface roughness

Sr.No	Spindle Speed(rpm)	Feed Rate (mm/rev)	Tool Angle(degree)	SR(μmm)	S/N Ratio
1	660	0.04	90	3.113	9.86358241
2	660	0.04	118	3.047	9.67744908
3	660	0.04	135	2.651	8.46819456
4	660	0.08	90	3.388	10.598868
5	660	0.08	118	3.3	10.3702788
6	660	0.08	135	2.816	8.99265301
7	660	0.15	90	4.015	12.073711
8	660	0.15	118	3.97	11.9758101
9	660	0.15	135	3.41	10.6550876
10	1115	0.04	90	4.191	12.4463532
11	1115	0.04	118	4.092	12.2387125
12	1115	0.04	135	3.608	11.1453306
13	1115	0.08	90	4.51	13.0835308
14	1115	0.08	118	4.51	13.0835308
15	1115	0.08	135	3.795	11.5842356

16	1115	0.15	90	4.972	13.9306224
17	1115	0.15	118	4.84	13.6969072
18	1115	0.15	135	4.24	12.5473171
19	1750	0.04	90	5.61	14.9792572
20	1750	0.04	118	5.69	15.1022453
21	1750	0.04	135	4.84	13.6969072
22	1750	0.08	90	5.94	15.4757289
23	1750	0.08	118	6.028	15.6034649
24	1750	0.08	135	5.86	15.3579523
25	1750	0.15	90	6.38	16.0964136
26	1750	0.15	118	6.248	15.9148204
27	1750	0.15	135	5.39	14.6317753

Table 5 ANOVA table for surface roughness

Source	ss	DOF	Variance	F Test	F critical	ss'	C %	F T > FC
Speed	27.8914	2	13.9457	532.0248	4.46	27.525629	83.4249	S
Feed Rate	2.4369	2	1.21845	46.483548	4.46	2.0711286	6.277193	S
Point Angle	2.0988	2	1.0494	40.034335	4.46	2.0988	10.29791	S
A*B	0.2519	4	0.062975	2.4024797	3.84			NS
B*C	0.0806	4	0.02015	0.7687172	3.84			NS
C*A	0.0253	4	0.006325	0.2412971	3.84			NS
Error	0.2097	8	0.026212					
Total	32.9945	26	1.269019					
E-pooled	2.5604	14	0.182885					

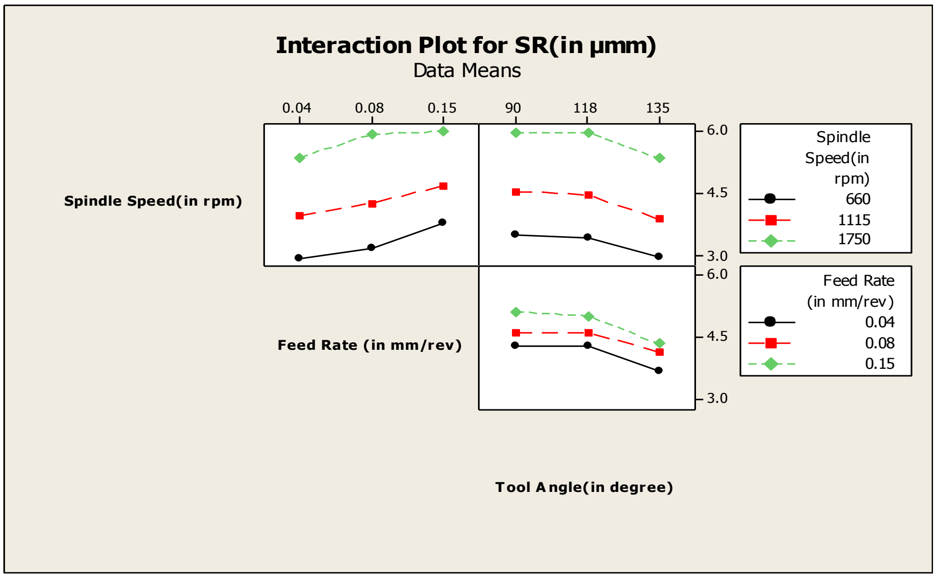

Fig 3 Interaction plot between SR and process Variables

It is clear from the ANOVA table that speed has highest impact on surface roughness followed by point angle and feed rate. An interaction plot between the surface roughness and process variable is shown in fig 3. This shows that a continuous increase in surface roughness with increase in speed and feed rate. So a lower value of these parameters will enhance the surface quality. In case of tool angle, better surface quality is obtained by higher tool angles.

Conclusion

This work presents the application of Taguchi method for selecting the optimum combination of drilling parameters affecting the burr height and surface roughness in drilling of PU based composites.

Taguchi method has been found as the most successful technique to perform trend analysis of the burr height and the surface roughness with respect to various combinations of drilling parameters. The analysis of experiments has shown that Taguchi method can successfully verify the optimum cutting parameters. It was suggested that for achieving minimum burr height and surface roughness on the PU based composites lower feed rates and cutting speeds should always be preferred with non-standard tool angles of higher degree.

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