Optimization of burr height in drilling of commercial Acrylic sheet using Taguchi method.

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1. Abstract

This investigation presents the use of Taguchi method for minimizing the burr height in drilling of acrylic sheet. The purpose of this paper is to investigate the influence of cutting parameters, such as cutting speed and feed rate, and point angle on burr height produced when drilling acrylic sheet. A plan of experiments, based on L_9 Taguchi design method, was made and drilling was done with the selected cutting parameters. All tests were run at cutting speeds of 660, 1115 and 1750 r.p.m. and feed 0.04, 0.08, and 0.15 mm/rev and point angle of 90°, 118°, and 140°. The orthogonal array, signal-to-noise ratio, and analysis of variance (ANOVA) were employed to investigate the optimal drilling parameters. It was found that higher cutting speeds and higher feed rate produces better results with higher tool angle (140^0).

Keywords: Taguchi Method, Acrylic Sheet, Burr Height, Drilling, ANOVA

2. Introduction

Acrylic sheets are lighter in weight and much stronger than the glass and hence provide an easy replacement for glass. They have a wide range of applications such as constructing aquariums, in motorcycle helmet visors, aircraft windows, and infra-red receptors tamper-proof.

Drilling is one of the most commonly used machining processes in the shaping of acrylic. This process produces burrs on the surface when the tool exits the work piece. The burr is the material extending off the exit surface of the work piece. Burr formation affects work piece accuracy and quality in several ways such as dimensional accuracy, challenges to assembly and handling caused by burrs in sensitive locations on the work piece.

3. Literature review

Enough literature has been studied regarding the drilling operation, acrylic and its properties and Taguchi Method.V Krishna Raj, S Vijyanarayan and G Suresh (2005) studied high speed drilling of glass fiber reinforced plastic and concluded that zero point drill and multi faced drills can be used at higher spindle speed and produces less thrust force. V N Giantode (2006) apply Taguchi approach for the investigation of bur height in AISI 316 stainless steel and found that 134^o angle provides better results. . Kovasevic and Sercovic (2007) works on the thermal effect of laser affect on the acrylic sheet and found that thermal damage were more in thick sheets as compared to thin sheets. Murugan and Dasaradan (2008) in their study compare the influence of lateral deformation on fibrous assembly in different resin such as acrylic, polyester and epoxy etc. M. M Noor and Kadirgama(2008) predicts the surface roughness for laser cutting of acrylic sheets using Taguchi and estimated optimum tip distance Paulina and Maria (2008) in their studied orthogonal cutting of acrylic composites Lincoln Cardoso Brandão, Frederico Ozanan Neves, and Gregório Christo Nocelli in 2011 studied hole quality of mild steel with high speed drilling by using different cooling system. They concluded that the best hole quality is produced with a higher cutting speed using flooded or minimum lubrication quantity independent of drill wear. Jinan A. Abdulnabi, Thaier A. Tawfiq,Anwaar A. Al-Dergazly etc(2011) studied the precise hole drilling in PMMA using 1064 nm diode laser CNC machine and concluded that gas pressure, time of exposure and power affect the surface finish.

Beside this, researcher from the field of chemical engineering and chemistry has done a lot of work on the chemical properties of acrylic. Some of these are:

Tanwar and Gupta (2006) works on the dielectric relaxation of PMMA in dilute solutions. Salvakumar and Krishana bhatt (2008) studied the miscibility of PMMA in dimethyl formaldehyde with temperature effects.. Aggarwal and Parmar (2008) investigated the surface morphology of PMMA using SEM and X-ray diffraction techniques. K john and M Reddy (2008) studied the refractive index of PMMA in formic acid. P Singh and P Kumar (2010) studied the optical, chemical and structural response of PMMA by carbon ion irradiation.

4. Methods of analysis

Taguchi Method has been used for the minimizing the burr height in the drilling of acrylic sheet Taguchi recommends analyzing the mean response for each run in the inner array, and he also suggests analyzing variation using an appropriately chosen signal-to-noise ratio (S/N). These S/N ratios are derived from the quadratic loss function, and three of them are considered to be standard and widely applicable. These are:

(1) Lower is best, (2) Higher is best, (3) Average is best

In this study, we have used lower is best which is

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

There lower S/N ratio corresponds to a better performance. So, the optimal level of the process parameters is the level with the lowest S/N value. The statistical analysis of the data was performed by ANOVA to study the contribution of the factor.

5. Design of experiment

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 L_9 (3***3) orthogonal array based on Taguchi method. Minitab 16.1 software was used for regression and graphical analysis of the obtained data.

Table 1 Drilling parameter and their levels

Symbol	Parameter	Level 1	Level 2	Level 3
A	Spindle speed (in rpm)	660	1115	1750
B	Drill point angle	90	118	140
C	Feed rate (in mm/rev)	0.04	0.08	0.15

6. Experimental details

Acrylic sheet of 300x150x40 was used for the drilling experiments in the present study. The mechanical and physical properties of acrylic sheet can be seen in Tables 2 and 3, respectively

Table 2 Mechanical properties

.Quantity	Value
Young's modulus	1800 – 3100 Mpa
Shear modulus	1700 Mpa
Tensile strength	48-76 Mpa
Compressive strength	18-124 Mpa
Fatigue	11-12 Mpa
Bending strength	120-148
Impact strength	0.16-.18 J/cm

Table 3 Physical properties

.Quantity	Value
Thermal expansion	50-90 μ^{-6}/K
Thermal conductivity	0.167 - 0.25W/m.K
Specific heat	1466 J/kg.K
Glass transition temp	105°C
Density	1170 - 1200 kg/m^3
Shrinkage	0.3 - 0.8%
Friction co-efficient	0.54
Refractive index	1.492

The drilling tests were carried out to determine the bur height under various drilling parameters. HSS drills (5-mm dia.) were used for drilling purpose. Drilling was done on a vertical drilling machine shown in fig.1 and burr height was measured by burr height tester shown in fig 2.

Fig 1 drill machine

Fig 2 Burr height tester

7. Results and discussion

In machining operation, minimizing the burr height (H) is an important criterion. The burr formation in drilling primarily depends upon the tool geometry, cutting parameters, and workpiece materials. When the material has moderate ductility, the material tends to elongate to some extent during burr formation, resulting in a large burr height and burr volume. However, if the material is quite brittle, catastrophic fracture occurs as the feed rate and cutting speeds increase, resulting in regular burrs having several large chunks, lobes, or petals. Many factors affect the surface condition of a machined part, machining parameters such as cutting speed, feed rate, depth of cut, and work piece properties have a significant influence on the hole size expansion for a given machine tool and work piece setup.

A series of drilling tests was conducted to assess the influence of drilling parameters on burr height of acrylic sheet. Experimental results of the burr height for drilling with various drilling parameters are tabulated in Table 5 which also gives S/N ratio for burr height. The S/N ratio for each experiment of L_9 (3**3) was calculated by applying lower is best equation written above.

Table 4 showing actual design of experiment

spindle speed(in rpm)	feed rate (in mm/rev)	tool angle(in degree)
660	0.04	90
660	0.08	118
660	0.15	140
1115	0.04	118
1115	0.08	140
1115	0.15	90
1750	0.04	140
1750	0.08	90
1750	0.15	118

Table 5 Showing average value and S/N ratio for burr height and hole size expansion

Sr.no	v(in rpm)	f (in mm/rev)	Ө (in degree)	H (mm)	S/N for Burr Height
1	660	0.04	90	0.28	-11.0568394
2	660	0.08	118	0.245	-12.2166783
3	660	0.15	140	0.11	-19.1721463
4	1115	0.04	118	0.225	-12.9563496
5	1115	0.08	140	0.09	-20.9151498
6	1115	0.15	90	0.055	-25.1927462
7	1750	0.04	140	0.045	-26.9357497
8	1750	0.08	90	0.03	-30.4575749
9	1750	0.15	118	0.02	-33.9794001

Table 7 shows analysis of variance for burr height.

Table 7 ANOVA table for burr height

Source	ss	DOF	Variance	F Test	F critical	ss'	C %	F T > FC
Cutting Speed	0.048606	2	0.024303	143.3805	19	0.028317	34.89206	S
Feed Rate	0.022206	2	0.011103	65.50442	19	0.022206	27.36212	S
Point Angle	0.010006	2	0.005003	29.51622	19	-0.01028	-12.6707	S
Error	0.000339	2	0.00017					
Total	0.081156	8	0.010145					
E-pooled	0.081156	8	0.010145					

Table 8 shows average effect response tables. Average effect response value and average S/N response ratios for burr height were calculated by utilizing experiment results and computed values of the S/N ratios from table 6. Fig 3a, 3b and 3c shows plot between average burr height and S/N ratio vs speed, feed and tool angle respectively.

As stated earlier, our work is based on the lower is best s/n ratio so parameter having lowest s/n was selected as optimum parameter. Based on the results shown in table 7 the optimum level for spindle speed, feed rate and tool angle are 3,3 and 3 respectively i.e. v =1750 rpm, f =0.15, θ =118^o .This indicate that drilling of acrylic sheet will give better results when drilled with a tool of standard angle with higher speed and feed rate. Plot for cutting speed, feed rate and tool angle vs burr height are shown in fig 3 (a, b, and c).

Table 8 Average experimental results and S/N response table for burr height

level	speed	mean BH	S/N Ratio		feed	mean BH	S/N Ratio		parameter	mean BH	S/N Ratio
1	660	0.2117	-13.4856		0.04	0.1833	-14.7368		90	0.1217	-22.23
2	1115	0.1233	-18.1807		0.08	0.1217	-18.2942		118	0.1633	-19.71
3	1750	0.0317	-29.9788		0.15	0.0617	-24.1943		140	0.0793	-22.33

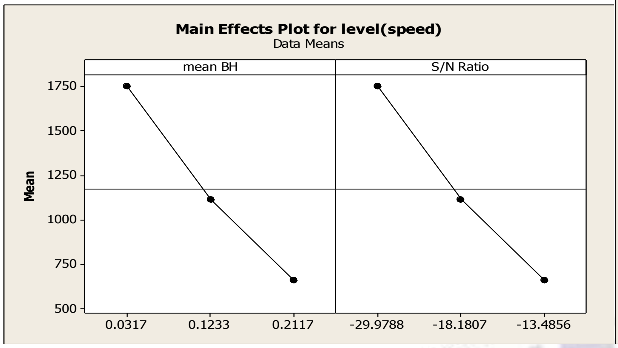

Fig 3a plot for average burr height, s/n ratio vs speed

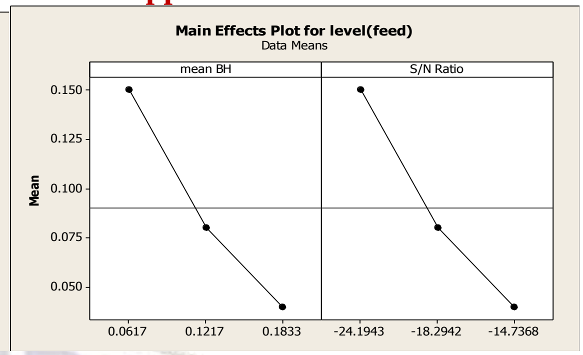

Fig 3b plot for average burr height, s/n ratio vs feed

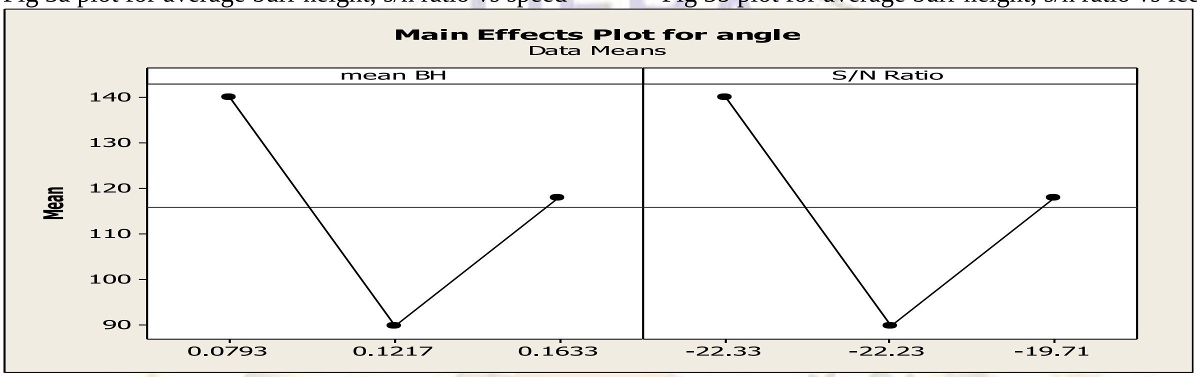

Fig 3c plot for average burr height, s/n ratio vs angle

8. Conclusions

This paper has presented an application of Taguchi method for selecting the optimum combination values of drilling parameters affecting the burr height in drilling of acrylic sheet. The conclusions of this present study were drawn as follows:

Taguchi method has been found as the successful technique to perform trend analysis of the burr height with respect to various combinations of drilling parameters. The analysis of experiments has shown that Taguchi method can successfully verify the optimum cutting parameters. The level of the best of the cutting parameters on the burr height is determined using ANOVA. The results of ANOVA reveal that spindle speed is main cutting parameters, which has greater influence on the burr height. The lowest burr height occurs at higher feed rates, high cutting speed, and standard point angle. With this proposed optimum conditions using the Taguchi method and ANOVA, a lower burr height was obtained. The optimal levels for the controllable factors were cutting speed 1750 rpm, feed rate 0.15 mm/rev, and point angle 140°.

So it is suggested that for achieving minimum burr height on the Acrylic always higher feed rates and higher cutting speeds are preferred.

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