Selection of optimum Drilling Parameter in Drilling of commercial Acrylic sheet to achieve minimum Hole Expansion by using Taguchi Approach.

IRFAN KHAN[1]
Ganpati Institute of Engineering and Technology, Yamuna Nagar, Haryana

DHEERAJ LUTHRA[2] MUKESH VERMA[3] , SARABJOT SINGH[4],
[2] Maharishi Ved Vyas Engineering College, Jagadhri, Haryana
[3, 4] Sri Sukhmani Institute of Engg. And Technology, Derabassi, Punjab
[1] Correspondence Author, Email:er.irfankhan@gmail.com, Mob. 09729293786

Abstract
Drilling and Milling are the two most important machining processes. In drilling process, we make a hole in a work piece. In many engineering applications, it becomes very important to drill a precise hole. Accuracy of the hole depends upon the various factors such as cutting speed, feed, tool geometry, work material and thickness of the work piece to be drilled. During the drilling operation heat is generated at tool work interface which tends to decrease the accuracy of the hole. This phenomenon becomes extremely important in the drilling of plastics.
This investigation presents the use of Taguchi method to achieve the minimum hole size expansion in drilling of acrylic sheet. The purpose of this paper is to investigate the effect of cutting parameters, such as cutting speed and feed rate, and point angle on hole size(without considering the thermal effect)..
Keywords: Taguchi Method, Acrylic Sheet, Hole size expansion, Drilling

Introduction

Acrylic belongs to the family of man made or synthetic plastics. These plastics have excellent mechanical properties and provide an easy replacement of glass. Acrylic has a wide range of application in engineering, medical and domestic fields for example aquariums, sandals, in furniture, aircraft windows, motor bike visors etc.
During the drilling process, heat is generated at tool work interface which depend upon the various factors such as speed feed and tool geometry. This heat changes the dimensions of the drilled hole which cause the trouble during assembly and poor surface finish. This problem is commonly faced in case of acrylic parts which need to be drilled.

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.. 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.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.

Research methodology

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 and signal-to-noise ratio were employed to investigate the optimal drilling parameters.

Methods of analysis

Taguchi Method has been used for the minimizing the hole expansion 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

Our target is to achieve minimum hole expansion so 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.

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 graphical analysis of the obtained data.

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

Table 1 Drilling parameter and their levels

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.

Property	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 2 Mechanical properties

Property	Value
Thermal expansion	50-90 μ^{-6}/K
Thermal conductivity	0.167 - 0.25W/m.K
Refractive index	1.492
Glass transition temp	105°C
Density	1170 - 1200 kg/m^3
Friction co-efficient	0.54

Table 3 Physical properties

The drilling tests were carried out to determine the hole expansion under various drilling parameters. HSS drills (5-mm dia.) were used for drilling purpose. Drilling was done on a Radial drilling machine shown in fig.1 and hole size was measured by Universal Measuring Microscope shown in fig 2.

Fig 1 Drill machine

Fig 2 Microscope

Results and discussion

In machining operation, achieving proper hole size is an important criterion which becomes significant in case of plastics. The hole size expansion in drilling primarily depends upon the tool geometry, cutting parameters, and work piece materials. 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 hole expansion of acrylic sheet. Experimental results of the hole expansion for drilling with various drilling parameters are tabulated in Table 5 which also gives S/N ratio. The S/N ratio for each experiment of L_9 (3**3) was calculated by applying lower is best equation written above.

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 4 Showing actual design of experiment

Sr.no	v(in rpm)	f (in mm/rev)	(in degree)	E_1(mm)	E_2 (mm)	E (avg.)	s/n for Hole Quality
1	660	0.04	90	0.28	0.24	0.26	-11.700533
2	660	0.08	118	0.16	0.2	0.18	-14.8945499
3	660	0.15	140	0.12	0.18	0.15	-16.4781748
4	1115	0.04	118	0.08	0.1	0.09	-20.9151498
5	1115	0.08	140	0.078	0.08	0.079	-22.0474582
6	1115	0.15	90	0.058	0.056	0.057	-24.8825029
7	1750	0.04	140	0.04	0.044	0.042	-27.5350142
8	1750	0.08	90	0.03	0.04	0.035	-29.1186391
9	1750	0.15	118	0.028	0.02	0.024	-32.3957752

Table 5 Showing average value and S/N ratio for hole size expansion (Source: R & D Lab, Ludhiana)

Table 6 shows average effect response tables. Average effect response value and average S/N response ratios for hole expansion were calculated by utilizing experiment results. Fig 3a, 3b and 3c shows plot between S/N ratio vs. speed, feed and tool angle respectively.

As stated earlier, this 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 6 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 hole expansion are shown in fig 3 (a, b, and c).

level	speed	mean HE	S/N Ratio		feed	mean HE	S/N Ratio		angle	mean HE	S/N Ratio
1	660	0.196	-14.3577		0.04	0.1283	-20.0502		90	0.1173	-21.9005
2	1115	0.075	-22.6150		0.08	0.098	-22.0202		118	0.098	-22.7351
3	1750	0.0336	-29.6831		0.15	0.077	-24.5854		140	0.0903	-22.0202

Table 6 Average experimental results and S/N response table for hole expansion

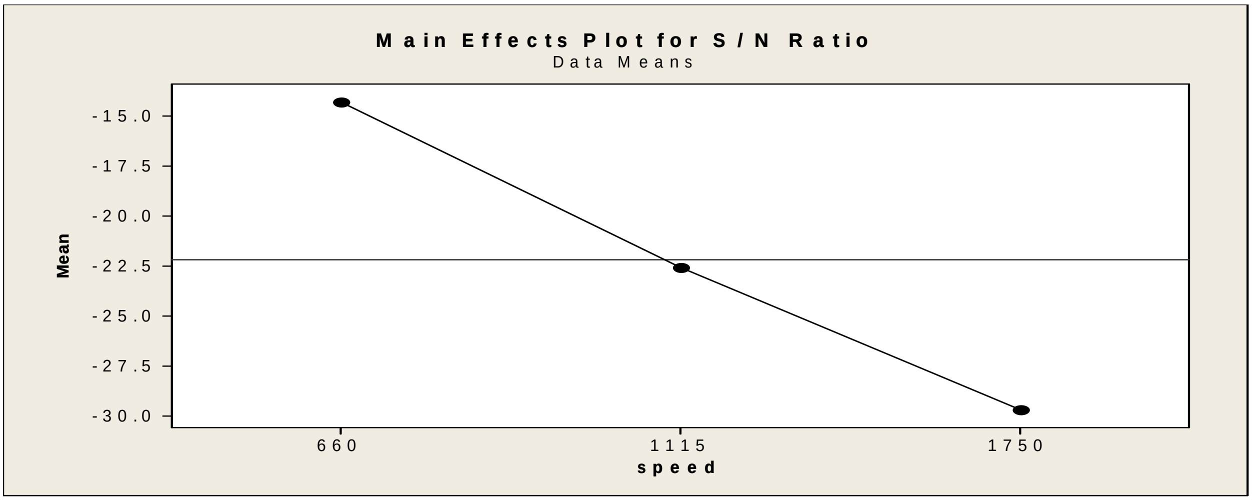

Fig 3a: Plot between speed and S/N Ratio

From the graph (3a) it is clear that S/N Ratio decrease as the speed of the spindle increase which corresponds to a lower hole expansion in the acrylic.

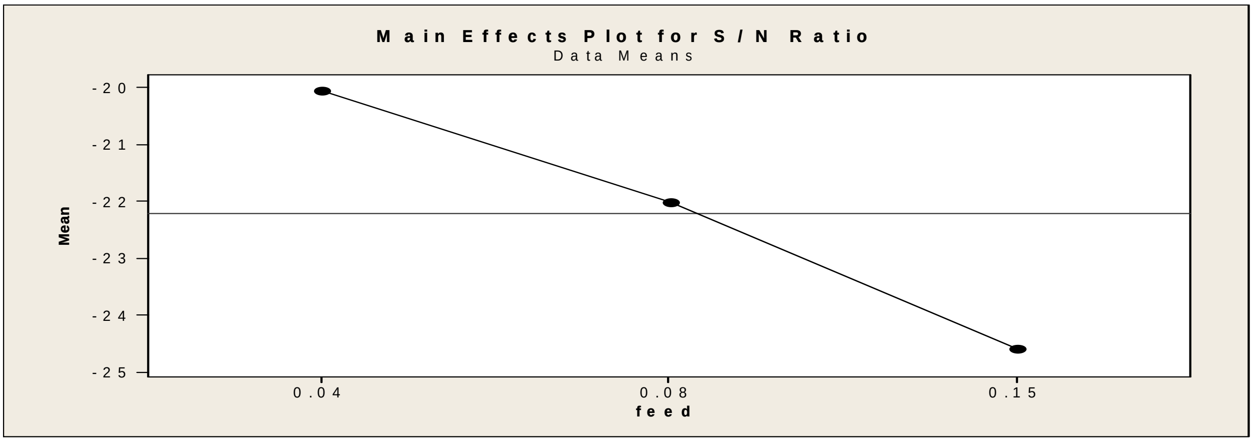

Fig 3b: Plot between feed and S/N Ratio

Plot between feed and S/N ratio (3b) indicate that with increase in feed rate a slight decrease in the hole expansion has been reported.

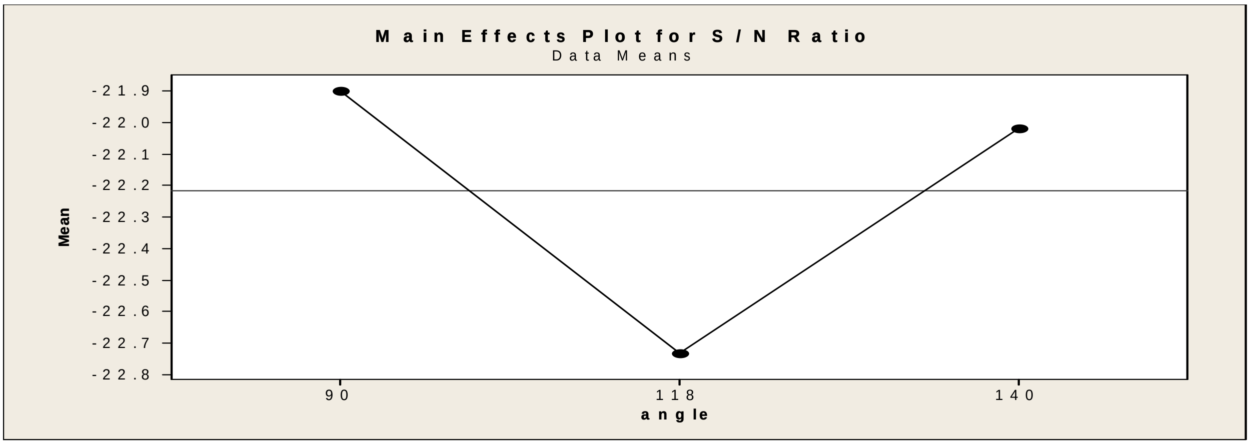

Fig 3c: Plot between tool angle and S/N Ratio

No significant result can be drawn in case of tool angle but graph indicate that hole expansion is higher in case of standard tool angle i.e.118^0 and lower when drilling with non-standard tool angles.

Conclusions

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

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 hole expansion was determined. It was found that cutting speed is the major factor on which hole size expansion depends. It is lower with higher cutting speed. Feed is another important factor which causes hole expansion but its dependence is lesser as compared to the speed. Tool angle is the most complex factor regarding which significant results could not be drawn, however it could be said that expansion is higher with standard angle and decrease with non-standard angle. So it is suggested that for achieving minimum hole expansion on the Acrylic always higher feed rates and higher cutting speeds are preferred with non-standard angles.

References

[1] V Krishna Raj, S Vijyanarayan, G Suresh (2005) *High speed drilling of GFRP*. IJMES 12, 189-195.
[2] V N Giantode (2006) *Taguchi approach with multiple performance characteristic for burr size minimization* JSIR 65, 977-981.
[3] Kovasevic and Sercovic (2007*) Laser PMMA interaction and stresses*. ISCOM07, Belgrade, Serbia, 112.
[4] Murugan and Dasaradan (2008*) influence of lateral deformation on fibrous assembly*. IJFTR 33, 258-263.
[5] M. M Noor and Kadirgama(2008*) Prediction modeling of surface roughness for laser beam cutting on acrylic sheets* International conference on advanced material processing tech.2008 Behrain.
[6] Paulina and Maria (2008) *Evaluation of cutting forces in orthogonal cutting of composites* Nonconventional Technologies Review – no. 3 / 2008.
[7] Frederico Ozanan Neves, and Gregório Christo Nocelli in 2011.*Evaluation of hole quality for hardened steel in high speed drilling using different cooling system*. Hindawi pub. 36.307-352.
[8] Jinan A. Abdulnabi, Thaier A. Tawfiq,Anwaar(2008) *Precise hole drilling in PMMA using 1064 nm diode laser cnc machine*. Hindawi pub 10.1155/2011/137407.
[9] Aggarwal and Parmar (2008) *Surface morphology of PMMA using SEM and X-ray diffraction techniques* IJPAP 45,193-197.
[10] K john and M Reddy (2008) *Refractive index of PMMA in formic acid* IJPAP 46,209-211
[11] P Singh and P Kumar (2010) *Optical, chemical and structural response of PMMA by carbon ion irradiation* IJPAP 48, 321-325.