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Effect of Drilling Parameters on Delamination Factor and Roughness of Aluminium 6061

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Abstract: The present experimental research on drilling studies the process parameters that are affecting the machining performance of CNC Drilling. A combined approach is used for the optimization of parameters and performance characteristics based on Taguchi method. The design of experiments is based on Taguchi's L9 orthogonal array. The response table and response graph for each level of machining parameters are obtained from Taguchi method to select the optimal levels of machining parameters. In the present work, the machining parameters are Spindle Speed and Feed Rate, which are optimized for minimum Delamination Factor and minimum Surface Roughness during drilling of Aluminium 6061. Analysis of Variance is also used to find out variable affecting the various responses mentioned above.
Keywords: Delamination factor, Roughness, Drilling, Aluminium 6061

I. INTRODUCTION

Drilling is one of the basic machining process of making holes and it is essentially for manufacturing industry like Aerospace industry, watch manufacturing industry, Automobile industry, medical industries and semiconductors. Especially Drilling is necessary in industries for assembly related to mechanical fasteners. Drilling is the process of generating circular hole in the work-piece by using a rotating cutting tool known as drill bit. Bits are attached in a tool called a drill which helps to rotate drill-bit and also gives torque and axial force to generate the cylindrical hole in work-piece material.

Conventional mechanical drilling of aluminium alloys has to face increasing physical limitation when hole diameter is decreased. Below some decisive dimension, friction exceeds the mechanical strength of the tool and machining is possible only by diamond, carbide coated tools which are having high modulus values. In this thesis, the thrust forces, delamination factor and roughness in deep hole drilling processes are optimized. The speed, feed and the depth of cut are used as process parameters to determine the optimum drilling conditions. For this purpose, Micro drilling on Alumnium 6061 bar are carried out based on DOE (Design of Experiments), and the resultant experimental data are studied using Taguchi method.

New industrial applications require materials with advanced properties for products particular requirements with reliable and economical manufacturing processes and higher productivity. These advanced engineering materials are used in automotive, aerospace, electronics, medical applications and others industries. The advanced and modified properties will improve the quality of these materials and help meet certain mechanical, electrical, or chemical requirements. Typical properties that are needed are tensile strength, hardness, thermal, conductivity, and corrosion and wear resistance.

Studies have been performed by various researchers in the domain of plain turning. The researchers have performed analysis for providing knowledge of current plain turning trend.

J Kopac and P Krajnik [1] both have discussed about optimization process of flank milling 3 level parameters as coolant application, no of flute, cutting speed, feed per tooth, axial depth and radial depth. They optimize this experiment by grey relational analysis using L_{18} orthogonal array of design. They concluded that reducing feed rate improves the performance and the tool life. M M Okasha and P T Mativenga [2] tested upon sequential laser mechanical drilling process on aerospace material of inconel 718 alloy. The performance of the twist drill improved by this operation and also helps in reducing burr size and increasing of tool life. They introduced Laser-Pilot-Mech technique for minimization of thrust force and torque value.

Tsai Chih-Hung et al [3] created a vendor evaluation factors model on characteristics of demand of raw materials of an enterprise by using grey theory. In this optimization method they concluded that the ranking order changes with the different value of weighs in each evaluation factor. Ashish B. Chaudhari et al [4] found that noticeable reduction of entry delamination with increase of feed rate was observed. Cutting speed has less effect on entry and exit DF. After comparing the experimental results with the predicted results it is found that the root means square error (RMS) at DF at entry and exit are1.4732% and 2.9277% respectively. Faramarz et al [5] from their research indicated that the delamination factor increased at low and high values of the parameters within the considered experimental range of the parameters. At the end, the optimum values of parameters were determined in order to minimize delamination.

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Anurag et al [6] came to conclusion that the optimum delamination factor was obtained when spindle speed and feed rate are at their initial level. The optimum parameters for obtaining lower delamination factor are spindle speed and feed are in drilling a hole as 1000 rpm and 150mm/min respectively. R. Vimal et. al [7] has Modeled and analyzed the Thrust force and Torque in drilling GFRP composites by multifaceted drill using fuzzy logic .The research has been made by taking Glass Fibre Reinforced Plastic using 8 facet solid carbide tool. 3 parameters such as spindle speed; feed rate and drill diameter with each having 3 levels using Taguchi L27 was used. Machine used was ARIX-CNC Machine centre. Thrust force and torque were taken as judging criteria for optimization of input parameters. Fuzzy rule based model was developed to indicate thrust force and torque in drilling of GFRP composites. The results suggested that the model can be effectively used for predicting the response variable by means of which delimitation can be controlled.

Yu Teng Liang et al. [8] has investigated the various Micro Machining Cutting Parameters of PMMA Polymer Material Using Taguchi’s Method and applied Grey-Taguchi method to optimize the micro-drilling of PMMA polymer with multiple performance indices. The four machining parameters were taken as coating layer, feed rate, spindle speed, and depth of cut. The performance of the drilling process was evaluated by two judging criteria, namely drill wear and surface roughness. The orthogonal array, grey relational analysis, and analysis of variance were used to study the two judging indices. The optimal combination of parameters was determined by using the grey relational grade, a performance index formed by combining the two performance characteristics. P.F. Zhang [9] made a review on mechanical drilling process for titanium alloy which was based on micro drilling using different tools of diameter ranging from 0.05mm to 10mm with w/p material as Ti alloy. The paper presented a complete thorough review on conventional drilling processes for Titanium, namely, twist drilling, vibration assisted twist drilling, ultrasonic machining, and rotary ultrasonic machining. It discusses cutting force, cutting temperature, tool wear and tool life, hole diameter, cylindricity, surface roughness, burr and chip type as judging criteria while drilling of Ti using the mentioned processes.

II. EXPERIMENTAL DETAILS

1) *Work piece:* The material used for the present work is Aluminium 6061 with specification of 20mm diameter.

TABLE I: SHOWING COMPONENTS OF ALUMINIUM 6061

Component	Weight %
Aluminium Al	97.36%
Chromium Cr	0.21%
Copper Cu	0.15%
Iron Fe	0.5%
Magnesium Mg	0.9%
Mangenese Mn	0.15%
Silicon Si	0.4%
Titanium Ti	0.13%
Zinc Zn	0.20%

2) *Machine:* Surya VF-30 CNC VS Machine available at Central Institute of Plastic Engineering & Technology, Lucknow.

The present investigation is performed by varying spindle speed and feed in order to analyze the Delamination factor and surface roughness.

Fig. 1: Drilled Specimens

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Table III: Showing Parameters Used For Experimentation On Drilling Machine

S.No.	Parameters	Units	Level 1	Level 2	Level 3
1	Spindle Speed	RPM	1000	2000	3000
2	Feed	mm/min	150	200	250

Table IIIII: Showing Experimental Values Of Delamination Factor And Surface Roughness

Exp. No	Spindle Speed	Feed	Maximum Diameter D_{max} (mm)	Diameter of drill bit d (mm)	Delamination Factor (mm)	Surface Roughness (Ra)
1	1000	150	5.25	5	1.05	4.1
2	1000	200	5.7	5	1.14	4.43
3	1000	250	6.2	5	1.24	3.98
4	2000	150	5.45	5	1.09	4.14
5	2000	200	5.3	5	1.06	4.17
6	2000	250	5.85	5	1.17	3.71
7	3000	150	5.35	5	1.07	3.42
8	3000	200	5.65	5	1.13	3.64
9	3000	250	6.35	5	1.27	3.14

III.RESULTS AND DISCUSSION

A. *Influence of parameters on Delamination Factor*

The damage zone that develops due to drilling hole was measured with the help of scanning electron microscopy (SEM). The delamination factor was determined by equation.

$$F_d = \frac{D_{max}}{d}$$

Where F_d is the delamination factor, D_{max} is maximum diameter of drill damage zone and d is the diameter of drill bit. For present set of experiments, drill bit diameter is 5mm.

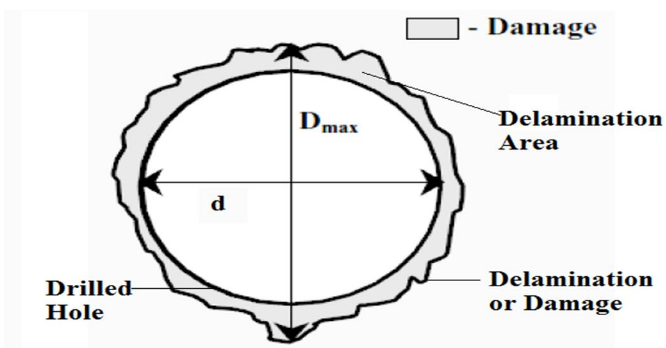

Fig. 2: Delamination Factor

The following table IV shows the analysis of variance for delamination factor of drilled specimens. It shows that feed is the most crucial factor for delamination factor with a contribution of 80.12% while spindle speed has negligible influence and has a contribution of 8.10%. Spindle speed is the least influencing parameter for delamination factor .

Table IVV: Anova Table Of Delamination Factor Of Drilled Specimens

Source	DOF	SS	Adj MS	F Value	Contribution
Speed	2	0.004022	0.002011	1.38	8.10%
Feed	2	0.039756	0.019878	13.60	80.12%
Error	4	0.005844	0.001461		11.78%
Total	8	0.049622			100%

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Figure 3 shows main effect plot for Delamination Factor. While considering it is clear that as we increase the spindle speed, the delamination factor tends to decrease initially till 2000 RPM. As the spindle speed is further increased, the delamination factor of the drilled hole start increasing. This is due to the fact that at higher spindle speed, the thermal gradients and drill speed make the drilled hole a bit larger than required. The feed is the most significant factor for delamination factor. Delamination factor increases with increase in feed and it shows that delamination factor follows an increasing trend with feed. As we increase the feed, the thickness of material to be removed increases. This increases the delamination effect and hence increased size holes are obtained. Minimum Delamination Factor is obtained at 2000 RPM spindle speed and 150 mm/min feed rate.

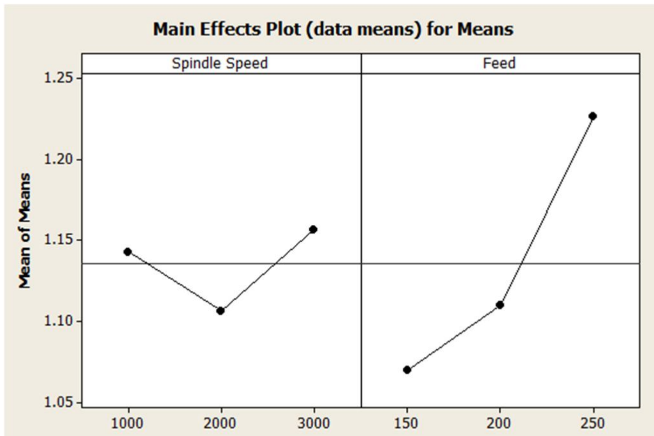

Fig. 3: Main effect plot for Delamination Factor

The figure 4 below shows the SEM image of sample 1 taken to assess the delamination factor of the sample due to drilling process. SEM images of all the drilled holes were taken and later analyzed.

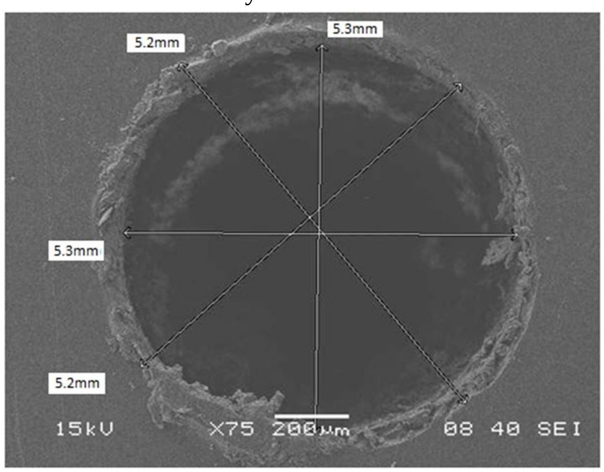

Fig. 4: SEM image of drilled sample 1

B. Influence of parameters on Surface Roughness

The following table V shows the analysis of variance for surface roughness of drilled holes. It depicts that spindle speed is the crucial drilling parameter for the roughness of the surface machined and contributes 72.92% towards it. Feed rate is found to be the least influencing parameter with only 24.72% contribution towards surface roughness.

TABLE V: ANOVA TABLE OF SURFACE ROUGHNESS

Source	DOF	SS	Adj MS	F Value	Contribution
Spindle Speed	2	0.98762	0.49381	62.03	72.92%
Feed	2	0.33482	0.16741	21.03	24.72%
Error	4	0.03184	0.00796		2.36%
Total	8	1.35429			100%

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Following figure 5 shows the main effect plot of drilling parameters for surface roughness. From the graphs it is seen that the surface finish improves with increasing the level of machining parameters. By increasing the spindle speed, the surface roughness increases and the surface finish starts to improve. A finished surface is generated as we increase the spindle speed to the higher levels. Spindle speed is the most crucial factor for surface roughness and ANOVA also shows that it contributes 72.92% towards surface roughness. In case of feed rate, it also affects the surface roughness in similar fashion. The surface initially degrades with the increase in feed rate upto 200 mm/min. But with further increase in the value of feed rate, surface finish start to improve. Feed rate has a contribution of 24.72% towards surface roughness. Lowest surface roughness is obtained at 3000 RPM spindle speed and 250 mm/min feed rate.

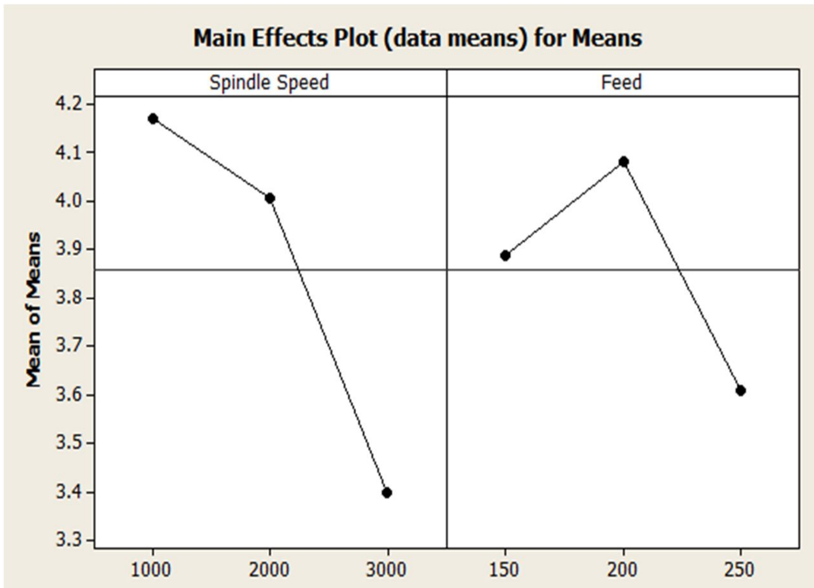

Fig. 5: Main effect plot for Surface Roughness

IV. CONCLUSIONS

This experimental study described the optimization of input machining parameters of drilling machine viz. spindle speed and feed rate during drilling of Aluminium 6061 using HSS tool with Taguchi method for designing the experiments. Factors with different levels were found to play significant role in drilling operation for minimization of Delamination Factor and Surface Roughness. Based on above work following conclusions are made:

A. As we increase the spindle speed, the Delamination Factor tends to decrease initially till 2000 RPM. As the spindle speed is further increased, the delamination factor of the drilled hole start increasing. This is due to the fact that at higher spindle speed, the thermal gradients and drill speed make the drilled hole a bit larger than required.
B. The feed is the most significant factor for delamination factor. Delamination factor increases with increase in feed and it shows that delamination factor follows an increasing trend with feed.
C. As we increase the feed, the thickness of material to be removed increases. This increases the delamination effect and hence increased size holes are obtained.
D. Minimum Delamination Factor is obtained at 2000 RPM spindle speed and 150 mm/min feed rate.
E. The surface finish improves with increasing the level of machining parameters. By increasing the spindle speed, the surface roughness increases and the surface finish starts to improve. A finished surface is generated as we increase the spindle speed to the higher levels. Spindle speed is the most crucial factor for surface roughness and ANOVA also shows that it contributes 72.92% towards surface roughness.
F. In case of feed rate, it also affects the surface roughness in similar fashion. The surface initially degrades with the increase in feed rate upto 200 mm/min. But with further increase in the value of feed rate, surface finish start to improve. Feed rate has a contribution of 24.72% towards surface roughness.
G. Lowest surface roughness is obtained at 3000 RPM spindle speed and 250 mm/min feed rate.

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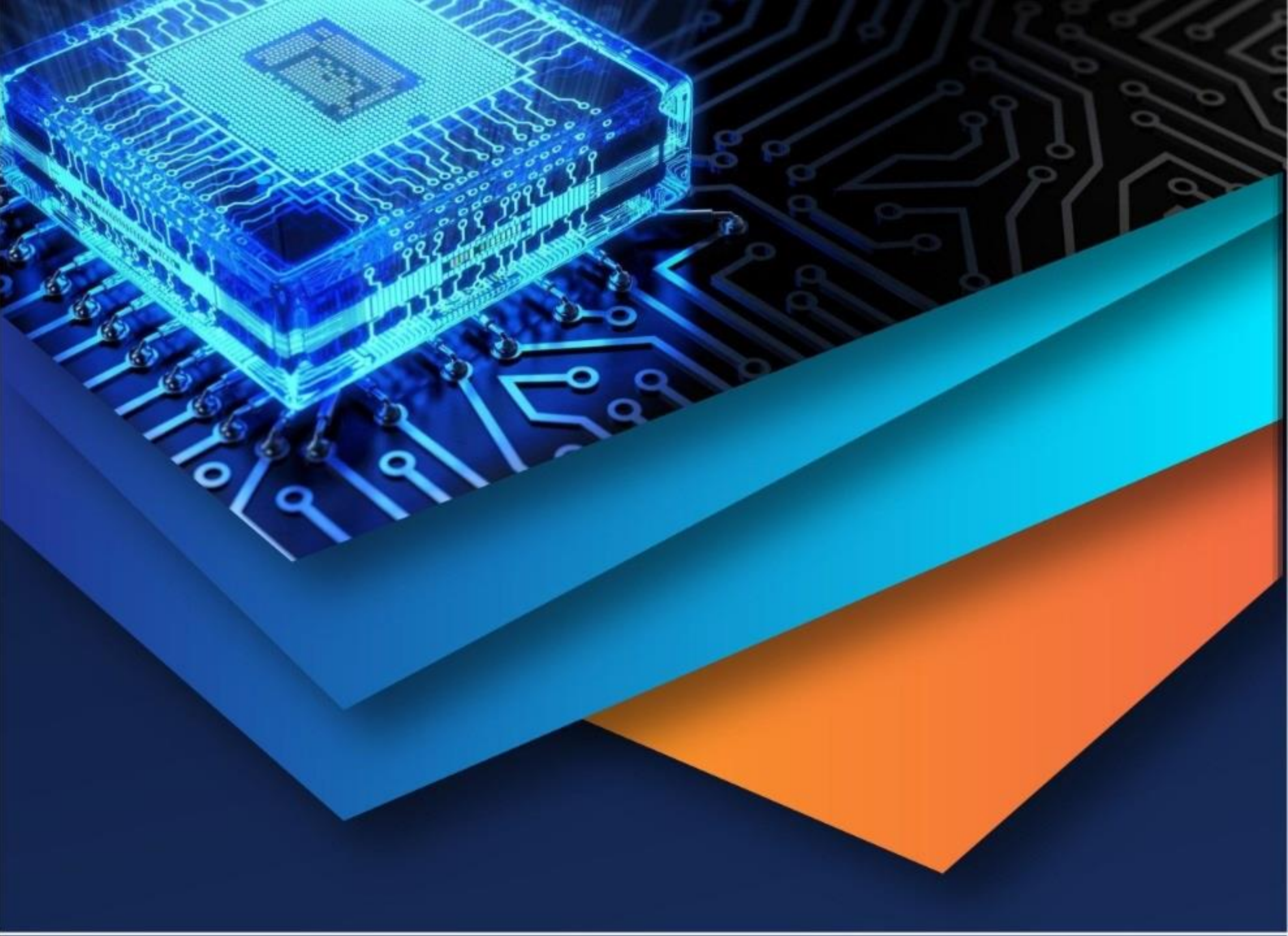

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