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Optimization of Performance Parameters in Drilling Process for Minimizing the Burr Formation

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***Abstract* - Presently a-days precision manufacturing has picked up its significance in all assembling industries. The best product dimensions at low cost with minimum time become a measure of concern. The drilling process imparts more than 30% of all the metal removing operations done on a job or assembly. The burr is a plastically deformed material, generated during drilling is unnecessary output and reduces the product acceptability, often lowers the surface quality of the product requires deburring which increases the cost of product. Burr is caused due to improper machining, tooling and environmental parameters. Total elimination of burrs during drilling process is a difficult task but using proper process parameters it can be minimized. In the present experimental study, the optimization of process parameters for minimization of burr formation in drilling process has been carried out for Al6082 plate. The tool type (coated/uncoated), spindle speed, feed rate, and drill diameters were used as the process parameters. Taguchi's L18 orthogonal has been applied for DOE and drilling of Al6082 plates has been performed using ply-board as a backup support and without using any backup support on CNC drilling machine. The burr height and surface roughness were analyzed and optimized using S/N ratio and ANOVA and the optimum combinations for burr height and surface roughness has been found from S/N plots. The most influencing factors for burr height and surface roughness have been found from ANOVA tables.**
***Keywords:* Drilling, Burr Height, Surface Roughness, Taguchi Method**

I. INTRODUCTION

Drilling process is a basic metal cutting process in which a circular hole is created in solid materials. The tool used in drilling is a multi-point cutting tool which is rotated and gradually pressed into the work-piece and the hole is created. There are several drill tool materials and are chosen depending upon the work-piece material, the finishing required etc. There are many process parameters which effect the drilling responses like feed rate spindle speed, point angle, helix angle, drill diameter, material of tool and work-piece and machining environment etc. The use of improper machininig parameters may leads to increase in surface roughness and burr formation. Burr refers to the raised edge on a metal part generated during cutting or punching. It is a real time industrial problem and considered to be intolerable when the shape or size hinders the function of the part. Drilling burr has three types uniform, transient and crown burr categorized on the behalf of its shape and size. The formation of any type of burr mainly depends upon the work-piece material and the mahining parameters. Burr formation can't be eliminated completely but can be minimize using optimum machining parameters.

II. LITERATURE REVIEW

Luka s Pilny *et al* (2012) concentrate on optimization of cutting data, clamping conditions, and drill geometry for drilling process to minimize the burr formation while drilling the sheets of wroughtaluminium alloy and concluded that burr reduction takes place at increased speed with reduced feed rate and with properly constructed clamping system [1]. Mr. Dhanke V.D. *et al* (2013) concentrates on the analysis and optimization of input parameters Speed, feed, drill diameter and point angle to minimize the burr formation using taguchi and response surface methodology for drilling of AISI 1015 steel. Minimum burr height was obtained at higher cutting speed, lowest feed rate [2].

Sanjib Kundua *et al* (2014) used the application of Taguchi's L27 orthogonal array to minimize drilling burr formation for an aluminium alloy using HSS drill. Parameters used were cutting velocity, feed and machining environment using a back-up support. It has been found that moderate cutting velocity, low feed and wet condition with water cooling minimize burr height using a back-up support and the most significant factor is the machining environment [3]. M. Varatharajulu *et al* (2015) performed drilling on duplex stainless steel with solid carbide twist drill using feed rate and cutting speed as performance parameters to observe the effect of machining parameters on burr height and burr thickness formed. RSM was used for optimizing the performance parameters. It has been concluded that the increase in speed decreases burr height and increase in feed increases burr height [4].

Dr. S. Sathiyamurthy *et al* (2016) used finite elements modeling for dynamic analysis of drilling burr formation process. Simulation is performed using ANSYS software to calculate the stress distribution of the work-piece with various feed values. It has been found that the use of backup support is the best way to minimize burr formation, due to the fact that it does not allow any room for a burr to form [5]. Sangeetha.M. *et al* (2017) used taguchi's L27 orthogonal array to optimize the drilling parameters to minimize the burr formation for the drilling of aluminum alloy (Al356) reinforced with coated Silicon Carbide Particle. Spindle speed, feed rate and drill diameter were chosen as drilling parameters with solid carbide drill bit. It has been concluded that feed is the most significant factor which affect the burr height followed by drill diameter and spindle speed. The minimum burr height is achieved at high spindle speed, low feed and low drill diameter [6]. Alper Uysal (2018) optimized the drilling parameters to minimize the burr formation and surface roughness when drilling carbon black reinforced high-density polyethylene. Taguchi and analysis of variance statistical methods were used. It has been concluded that minimum burr dimension was found at low feed, low point angle and at high cutting speed. The most influencing factor for surface roughness was drill diameter and the least influencing was feed [7].

III. EXPERIMENTAL WORK

To comply with the objectives of the research, the work-piece specimens (Al6082 plates) were taken in dimensions of 915mm x 50mm x 6mm.

Fig.1 Al6082 plates

The spectroscopy test was performed and the chemical composition found is given in table I.

TABLE I CHEMICAL COMPOSITION FOR AL6082

El	Si	Cu	Fe	Mn	Mg	Zn	Ti	Cr	Al
%age	.79	.01	.07	.42	.22	.05	.03	.07	Bal

Spindle speed, feed rate, drill diameter and tool type were used as the process parameters. Simple HSS twist drills and TiN coated HSS twist drills (Addison tools) used for the experiments are shown in fig.2.

Fig. 2 Simple HSS and TiN coated HSS twist drill

The levels of each parameters used for the experiment is as shown in table II.

TABLE II PARAMETERS USED WITH THEIR LIMITS

S. No.	Parameter	Lower limit	Middle limit	Upper limit
1	Type of tool	HSS twist drill		TiN coated HSS twist drill
2	Cutting speed(RPM)	1600	2050	2500
3	Feed rate (mm/rev)	0.16	0.19	0.22
4	Drill dia (mm)	8	10	12

The experiment was performed on CNC drilling machine (as shown in fig.3)using the parameters value obtained from taguchi's L18 orthogonal array (MINITAB18) using ply board as the backup support and without using any backup support. The burr obtained is shown in fig. 4.

Fig. 3 Drilling of Al6082 plate on CNC machine

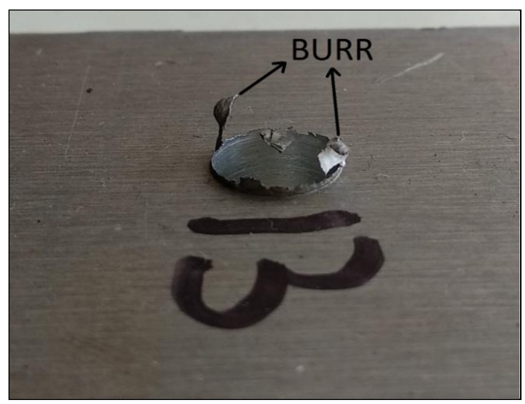

Fig. 4 Burr at the exit surface of Al6082 plate after drilling

The burr heights were measured with the help of digital height gauge (Mitutoyo) having 0.01mm least count and the surface roughness tests were performed for each hole with surface roughness tester (fig.5) of 'MITUTOYO' (Model-SJ-201P) having 0.01µm accuracy.

The values of burr height and surface roughness has been compared for both the cases of drilling (using backup support and without using backup support) after experiment and it has been found that the burr height values were less and surface roughness was more in case when backup support was used and the cost of drilling become high in this case so the optimzation of process parameters has been done for the case where no back up support was used.

Fig. 5 Measurements of burr height and surface roughness

For the optimization of process parameters to minimize the burr height and surface roughness, the signal to noise ratio & mean has been calculated and graphs were ploted for S/N ratio and means. The ANOVA has been employed for investigating the most influencing factor.

IV. RESULTS AND DISCUSSION

The main effect plot for means of burr height shows that the coated tool produces fewer burrs than uncoated tool because the TiN coating makes the tool harder which results more cutting without deformation. But the difference of burr height formed for coated and uncoated tool is very small.

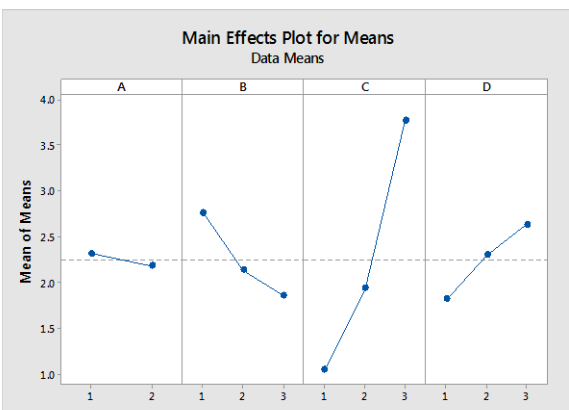

Fig. 6 Main effect plot for means of burr height

By increasing the spindle speed the burr height decreases. Because when the spindle speed the heat generation at the increase interface of tool and work-piece increases which increases the plasticity of Al6082. the increased spindle speed results more outward force which in turn cut the material without deforming it that lead to decrease the burr height. As the feed rate increases the burr height increases. This is due to the fact that the 'cap' is formed at the exit surface while drilling and at low feed rate the fracture occurs at the periphery of deformed cap and small burr height. But as the feed rate increases the fracture occurs at the centre of cap and the remaining portion of cap due to the axial force of tool deforms along the periphery and form large burr. As the drill diameter increases the burr height increase. This is due to the fact that as the drill diameter increases the cutting velocity increases for same RPM which creates the huge outward force which cause the increase in burr formation.

It can be seen from the ANOVA table that feed rate (C) is the most influencing factor in burr formation and the second most influencing factor is spindle speed (B).

TABLE III ANALYSIS OF VARIANCE FOR SN RATIO OF BURR HEIGHT

Source	DF	Seq SS	Adj SS	Adj MS	F	P	Pc
A	1	1.14	1.14	1.14	0.65	0.466	0.21
B	2	54.85	54.85	27.42	15.55	0.013[a]	10.19[II]
C	2	40.72	268.52	134.26	76.13	0.001[a]	75.93[I]
D	2	28.90	9.90	4.95	2.81	0.173	5.37
A*B	2	4.49	4.49	2.24	1.27	0.373	0.83
A*C	2	20.40	20.40	10.20	5.79	0.066	3.79
A*D	2	12.68	12.68	6.34	3.6	0.128	2.36
Res. Error	4	7.05	7.05	1.76			1.31
Total	17	538.26					100.0

Feed rate shows the major contribution of 76% in burr formation as shown in fig7.

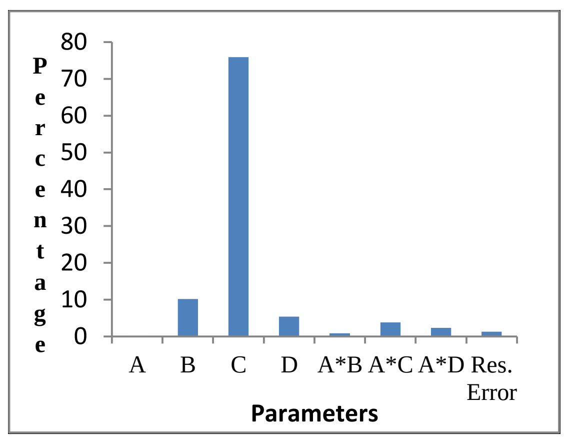

Fig. 7 Percentage contribution graph from S/N ratio of burr height

Regression equation for burr height = 0.77 - 0.67A - 0.661B + 1.263C + 0.084D + 0.195A*B - 0.019A*C + 0.120A*D - 0.011B*C - 0.019B*D + 0.086C*D

The main effect plot for S/N ratio of surface roughness shows that the TiN coated tool reduces the surface roughness because the TiN coating reduces the friction coefficient of tool and increase the wear resistance that allow the tool to drill the work piece smoothly. But the difference for surface roughness formed for both coated and uncoated tool is very small.

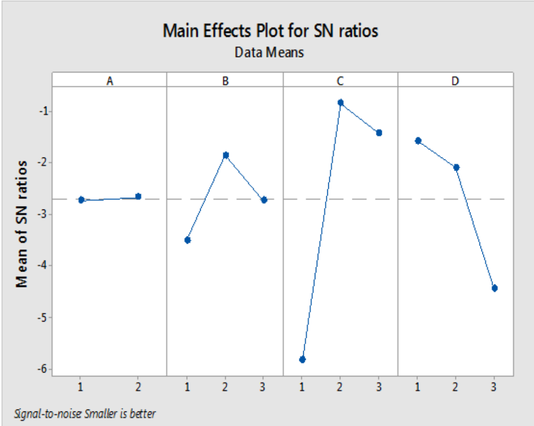

Fig. 8 Main effect plot for S/N ratio of surface roughness

At low spindle speed surface roughness is high because chips do not flow properly out from the cutting zone. The chips continuously rotates with the tool and scratches the profile of hole. When the spindle speed increases the flow of chip become better. But further increasing the speed again increases the surface roughness because of BUE formation due to high temperature. At very low feed rate the surface roughness is found to be high because the tool rub the job again and again at same place cause high surface roughness as feed increases to some particular value the cutting forces are sufficient to cut the material with greater accuracy which cause the decrease of surface roughness but by further increasing the value of feed rate, the chip thickness increase. Increased chip thickness with its high volume cause small increase of the surface roughness. As the diameter increases width of hole increase and large volume of material has to be cut for same feed rate and cutting speed which results high cutting forces. High cutting forces with high volume of chips cause the increase of surface roughness.

It can be seen from ANOVA table for surface roughness that the most influencing parameter which affect the surface roughness is feed (C) and the second most influencing factor is drill diameter. Feed rate shows the major contribution of 65.5% in surface roughness as shown in fig.9.

TABLE IV ANALYSIS OF VARIANCE FOR S/N RATIO OF SURFACE ROUGHNESS

Source	**DF**	**Seq SS**	**Adj SS**	**Adj MS**	**F**	**P**	**Pc**
A	1	0.017	0.017	0.02	0.06	0.825	0.01
B	2	8.152	8.15	4.07	13.1	0.018[a]	5.94[III]
C	2	89.953	55.82	27.91	89.74	0[a]	65.5[I]
D	2	28.012	21.33	10.66	34.29	0.003[a]	20.4[II]
A*B	2	1.02	1.01	0.51	1.64	0.302	0.74
A*C	2	2.536	2.53	1.267	4.08	0.108	1.85
A*D	2	6.407	6.40	3.20	10.3	0.026	4.67
Res. Error	4	1.244	1.24	0.31			0.91
Total	17	137.34					100

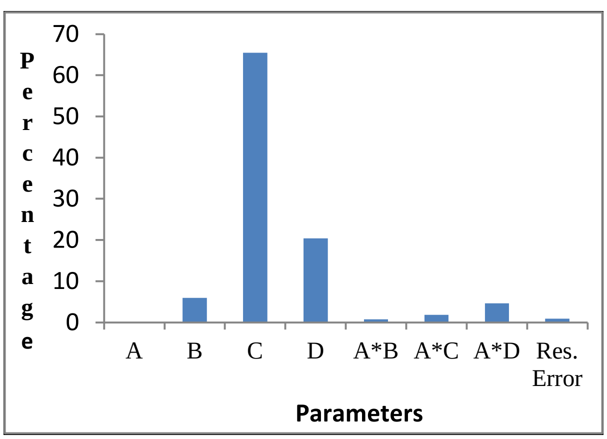

Fig. 9 Percentage contribution for S/N ratio of surface roughness

Regression equation for surface roughness =
1.36-0.51 A+ 0.361 B- 0.285 C+ 0.641 D-0.079 A*B+ 0.107A*C+0.203 A*D+ 0.004 B*C-0.179 B*D- 0.148 C*D

IV. CONCLUSION

Based on the above discussions the following conclusions can be drawn.

1. The most influencing factor which affect the burr height and surface roughness was feed rate
2. The use of back up support helps to reduce the burr height.
3. The second level of A, third level of B, first level of the C and first level of D results in minimum value of burr height.
4. The second level of A, second level of B, second level of the C and first level of D results in minimum value of surface roughness.

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