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Regression based Experimental Investigation of Process Parameters on Burr Formation and Overcut during Drilling Process

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Abstract—*The main focus of this research is to analyze the burr height formation for different hole sizes i.e. by using drill bits of different diameters and by changing the depth of the hole and spindle speed on the vertical milling machine. In this paper the investigation was performed on a 15 mm aluminium plate and a dial gauge and digital Vernier caliper were used to measure the burr height and overcut respectively. The result showed a comparison between different parameters for different drilling combinations. It assisted in the analysis of burr height formation for different parameters and concluded the best possible way to reduce the burr height so that the demand of the uniform appearance of drilled holes was fulfilled as well as high productivity achieved at a low manufacturing cost. Such optimization also reduces the total cost of production.*

Keywords*: Drilling, Aluminium, Dial indicator, Measurement, Burr height, Ovality.*

1. INTRODUCTION

Drilling is one of the most common machining operation and most of workpieces are subject to hole-drilling before they leave a machine shop but during the drilling process in metals, Burr forms which may cause many major problems in assembly lines and and handling of the workpeice and cause small injuries of assembly workers and therefore a deburring operation is used for removal of burr from the metal surface which includes an additional cost which can be anywhere near about 25-30% of the entire manufacturing cost for high precision components so by reducing the burr height we are increasing the dimensional accuracy and thus deburring cost would be less and thus reducing the overall cost of the product. The holes of a uniform appearance is the requirement of a well optimized production process, This demand is of utmost importance when a single workpeice contains many numbers of drilled holes in that case the design will be inadequate if any defect in the hole quality is present then the design would be non-permissible, thus burr height should be reduced for proper dimensional accuracy and precision of the final product [1-5]. When the drilling depth increases, the deformation accumulated at the bottom of the hole also increases. When this value is enough to reach the tension of rupture (failure stress) of the material, the fracture begins at the point of greater deformation. The fracture also depends on the geometry of the drill, because drills with large chisel edge tend to increase the axial force in the centre of the hole. Explain the mechanisms of burr formation in drilling [6-7]. A great deal of research has focused on the development of more efficient deburring techniques to reduce the cost of deburring. In contrast, only a few studies have been carried out on the mechanisms of burr formation and the influence of cutting parameters to assist in the reduction of burrs and the production of burr-free components [8]. The machining burrs is identified into four specific types based on the mechanism of their formation: poisson burr, rollover burr, tear burr, and cutoff burr [9]. The dependence of burr formation on the stress field in machining is discussed, In order to clarify the effects of tool and workpiece geometry on burr formation, it is desirable to simulate these types of stress fields along the workpiece edge for various tool and workpiece geometry combinations [10]. A quantitative model of burr formation is proposed for ductile materials in orthogonal machining [11]. Later, a new model is proposed that caters for both ductile and brittle materials in orthogonal cutting [12]. The model was extended and a new model of burr formation with more realistic machining operations and cutting conditions. According to his observation, four different types of burrs—knifeedge, curl, wave, and secondary burr—were formed with variations in depth of cut and in-plane exit angle [13]. Development of a 3D finite element model for drilling with two sets of backup materials to investigate mechanisms of drilling burr minimization and predict cutting forces [14]. Developed the finite element model of the burr formation in 2D orthogonal cutting with a plane strain assumption and investigated the influences of various process parameters. The four stages of burr formation, that is, initiation, initial development, pivoting point, and final development stages, are investigated based on the stress and strain contours with the progressive change of geometry at the edge of the workpiece. In addition, the characteristics of thick and thin burrs are clarified along with the negative deformation zone formed in front of the tool edge in the final development stage [15]. Investigation using finite element simulation is conducted to investigate mechanisms of burr minimization by backup material and concluded that the burr can be effectively minimized by this way [16]. A general finite element model for burr formation in metals is presented and these simulation tools show excellent correlation with experimental results. The advantage of the simulation approach is that a wide range of parameters can be evaluated relatively quickly [17]. A finite element model of burr formation is developed to address the limitations of classical models of burr formation in drilling [18]. A model of the burr formation mechanism when burrs are formed in the feed direction during turning operation. Two cases have been considered in this study: continuous burr development, when the burr grows uninterruptedly, and discontinuous development, when the burr being formed is cut off and is renewed with each revolution of the workpiece. The model allows predicting burr height and thickness and is able to simulate burr development [19]. A coupled thermo-mechanical model of plane strain orthogonal metal cutting including burr formation is presented using the commercial finite element code. A simulation procedure based on Normalized Cockroft-Latham damage criterion is proposed for the purpose of better understanding the burr formation mechanism and obtaining a quantitative analysis of burrs near the exit of orthogonal cutting [20]. The effects of tool geometry and flank wear upon burr formation in face milling of a cast aluminum alloy. 3D face milling simulations were conducted to investigate more realistic chip flow and burr generation. Comparisons were made for burrs produced from 3D simulations with a sharp tool, 3D simulations with a worn tool, and face milling experiments. Some recommendations for cutting tool design were made to reduce burr formation in face milling [21].

2. EXPERIMENTAL DETAILS

2.1 Materials

In the present investigation aluminium alloy 6063 was selected. It a medium strength alloy commonly referred to as an architectural alloy used in intricate extrusions. It has good surface finish, high corrosion resistance, is readily suitable for welding applications. This grade of aluminium finds use in extrusions, window frames, doors, shop fittings, irrigation tubing, and hydroformed tube for chassis. The composition of Al 6063 is given in the Table 1.

Table 1: Elemental Composition of Al 6063.

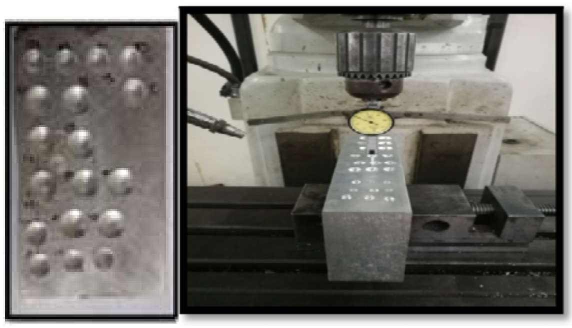
Element	Wt. %	Element	Wt. %
Al	Max 97.5	Mn	Max 0.1
Cr	Max 0.1	Si	0.2-0.6
Cu	Max 0.1	Ti	Max 0.1
Fe	Max 0.35	Zn	Max 0.1
Mg	0.45-0.9	Other	Max 0.2

2.2 Experimental Approach

A design of experiments was formulated with three factors at three levels viz. low, medium and high. The selection pf parameters was based on the previous research and the machine constraints. The parameters were drill bit diameter, cutting speed (spindle speed) and depth of cut. Experiments were conducted on a vertical milling machine under dry conditions (no lubrication was used). Low alloy steel drill bits were selected for the conduction of the experiments with the diameters as 6 mm, 9 mm, and 12 mm.

Figure 1: Experimental Set Up.

2.2.1 Burr Height (Exit). Drilling process is usually associated with a machining defect known as burr formation. This defect needs to be controlled in order to lower the cost incurred after the drilling process that is the surface finishing process. A puppy dial gauge with least count 0.01mm was used to measure the burr height. The gauge is secured in place of the drill bit and the work is moved around the gauge. The probe of the gauge is moved around the edges of the holes whose deflection is indicated on the dial.



(a) (b)

Figure 2: (a) Drilled Workpiece; (b) Burr Height Measurement.

2.2.2 Overcut. *Overcuts are used as an index to measure the dimensional accuracy, surface wear and the tool wear. These can be measured with the help of digital vernier caliper. The jaw ends were inserted in the drilled hole and the indicated reading was noted down. The value of overcut was obtained after the subtraction of the nominal diameter of the drill bit from the measured vernier reading.*

The following table displays the result of the recorded values of the output parameters.

2.3 Mathematical Modelling

Regression analysis is a statistical process for estimating the relationships among variables. Regression equations developed for the dependent variables i.e. Overcut, and Burr height, (Y) and the independent variables (X) i.e. drill diameter, spindle speed, and depth of cut.

The values of unknown parameters (β) which are dependent on x_1, x_2 and x_3 were calculated using general regression technique which are given below:

Burr height = - 10.9 + 1.70 Drill diameter - 0.000258 Speed + 0.428 DOC

Overcut = - 0.936 + 1.07 Drill diameter + 0.000153 Speed + 0.0244

These equations helped in identifying the optimized combination of input parameters where burr height can be minimized and the overcut can be controlled to maintain the overall dimensional accuracy of the drilled hole.

The following table displays the result of the recorded values of the output parameters.

Table 2: Experimental Values of the Output Parameters.

Independent Variables				Experimental Values	
S. No.	Drill Dia. (mm)	Spindle Speed (rpm)	Depth of Cut (mm)	Burr Height (µm)	Overcut (mm)
1	6	660	3	0.63	5.73
2	6	660	6	1.43	5.81
3	6	660	9	1.87	5.69
4	6	1110	3	0.54	5.66
5	6	1110	6	1.64	5.74
6	6	1110	9	2.12	5.79
7	6	1750	3	0.51	5.81
8	6	1750	6	1.53	5.86
9	6	1750	9	1.92	5.91
10	9	660	3	4.01	8.96
11	9	660	6	6.38	9.01
12	9	660	9	11.56	9.11
13	9	1110	3	4.53	8.81
14	9	1110	6	6.87	9.13
15	9	1110	9	10.83	9.21
16	9	1750	3	4.63	9.09
17	9	1750	6	5.93	9.3
18	9	1750	9	10.43	9.2
19	12	660	3	11.92	12.12
20	12	660	6	13.5	12.05
21	12	660	9	12.43	12.23
22	12	1110	3	9.02	12.16
23	12	1110	6	11.42	12.01
24	12	1110	9	10.23	12.24
25	12	1750	3	12.32	12.19
26	12	1750	6	13.53	12.32
27	12	1750	9	9.62	12.47

3. RESULTS AND DISCUSSION

From the present work with 6 mm, 9 mm, and 12 mm diameter twist drills for drilling holes in aluminium specimens, the following graphs were generated using Minitab 16 software representing the relationship between input parameters viz. depth of cut, drill diameter and spindle speed; and output parameters viz. burr height and overcut.

3.1 Burr Height (Exit)

The predictive analysis identified that diameter of drill bit and depth of cut plays a significant role in the formation of burr on the periphery of the drilled hole. The least value obtained of burr height is at high spindle speed, low depth of cut and small drill diameter i.e. 0.51µm. The cutting speed (spindle speed) have very low effect on the burr height formation.

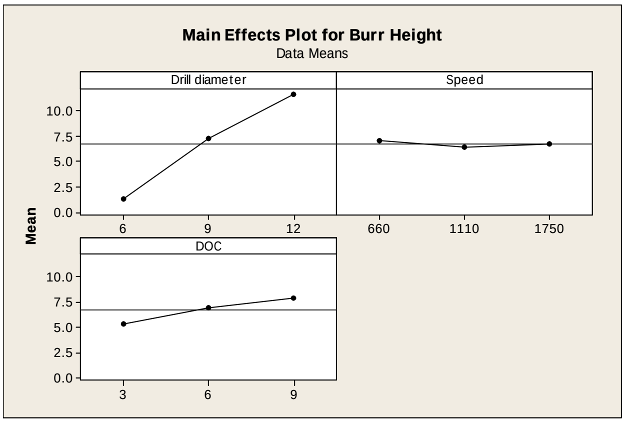


Figure 3: Input parameters vs Burr Height

3.2 Overcut

The regression analysis showed drill diameter as the most significant factor that affects the overcut during drilling process while depth of cut and spindle speed had very less effect on the overcut output parameter.

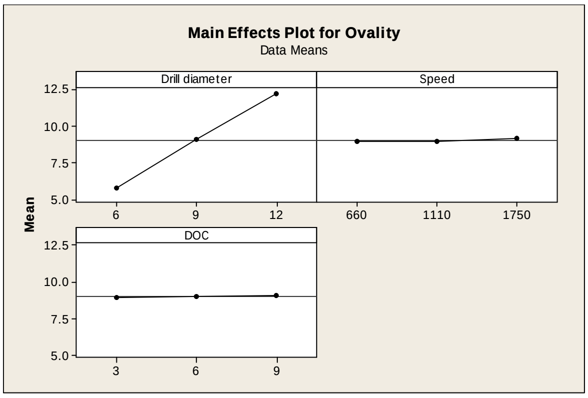


Figure 4: Input parameters vs Overcut (Ovality)

4. CONFIRMATORY EXPERIMENTS

The set of confirmation experiments were conducted at the optimum setting of the selected process parameters. The burr height was recorded minimum at high cutting speed and depth of cut while the drill diameter was minimum. Similarly the overcut was recorded minimum at minimum drill diameter. The overcut was minimized at high depth of cut.

5. CONCLUSIONS

The experimental investigation carried out on the aluminium alloy Al6063 concluded that there are certain parameters which significantly influence the drilling process. By performing the experimental investigation, the following conclusions were drawn:

1. An increase in burr formation is observed with the increase in drill diameter under dry conditions. The probable controlling factor can be lubrication during drilling process.
2. Increase in depth of cut leads to high burr height as the material removed in single pass is more and due to temperature rise at the cutting zone, the accumulation of chips occurs which increases the burr height.
3. The drill diameter plays a significant role in burr formation as well as overcut thereby governing the dimensional accuracy of the drilled hole.
4. Reduction in burr height and overcut will cut down the after machining costs and the overall cost of the component.

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