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Burr Dimension Analysis on Various Materials for Convenantionally and CNC Drilled Holes

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This work reveals the burr dimensions at entry and exit of the drilled holes on copper, brass and stainless steel. Furthermore, the effect of spindle speed and feed rate on the burr dimensions are considered and reported. Burr size minimization is one of the key problems in drilling operation. The main aim of this research is evaluated the burr dimesion occurrences of drilling on conventionally drilled holes and CNC drilled holes. The burrs produced by conventional machine and CNC machine were compared and presented.

Keywords: drilling operation, burr dimension, copper, brass, stainless steel.

1. Introduction

In current years, there has been an increasing amount of attention in the determination of burr dimensions in machining operations such as turning, milling, drilling and grinding. However, lot of work has been started towards the investigation of cutting parameter for minimization of burr dimensions in drilling operation. In response to that there is no investigation carried out on burr dimensions in copper, brass and stainless steel in drilling operation. The goal of this work is to first plan a experiments as spindle speed and feed rate are input parameters; experimental investigation about effect of process parameters on burr dimensions on various materials.

1.1. *Problem formulation*

Drilling is one of the versatile machining processes. However, the drilling process generates higher burrs than other oblique cutting processes. A burr refers to the raised edge on a metal part. It may be presented in the form of a fine wire on the edge of a freshly sharpened tool or as a raised portion on a surface. These are undesirable projections of materials beyond the edge of the work–piece arising because of plastic deformation during drilling. The burr is an "the entry and exit perimeter of a hole diameter as burred if it has an extend beyond greater than boundary of hole faces" [1]. The burr formation in drilling primarily depends upon the cutting parameters and work piece materials [2]. The exit burr size is a performance indicator of the drilling process that decided the quality of the finished product [3]. These are the quality deviation and affect the efficiency of the assembled parts. Reducing the burr is very important in drilling process, because of the deburring cost and assembling tolerance. The burr formation is the result of a combination of larger forces and less resistance in the work piece material with plastic deformation fracture [4]. Generally the exit burrs are larger than entry burrs. Larger feed rate does not produce larger entry burr. Higher feed rates are help to reduce the size of the entry burr as well as exit burr. Due to high temperature generated at high spindle speed, the accumulation of molten chip remains takes place during the chip evacuation which results in the melting of the work material surrounding the entry edge [5]. The increase of temperature, cutting speed and feed are results easy flow of materials that causing the larger burr size. A lower feed generates thinner burrs. And also the authors stated that the drilling parameter influences with respect to the burr height and thickness are cutting speed, feed and tool geometry. Cutting speed does not have much impact on burr height and burr thickness. But smaller variation occurs compared with other parameters. Low feed and high feed gives greater burr height, comparatively higher feed gives higher burr height as well as lower feed. Higher feed gives smaller burr thickness compared with lower feed [6]. The selection of drilling parameters for minimizing the burr height and burr thickness are difficult task [7]. However this work examines the burr dimensions on various materials with conventional and CNC machines.

2. Experimental procedure

The response in this investigation is burr dimension and the parameters are spindle speed and feed rate. A drill diameter 6mm was used with 118° point angle two flutes. The work piece materials were copper, brass and stainless steel. The specimen size was used for drilling operation is 100 X 70 X 10 mm plates. The chemical compositions of the used work piece are listed in Tab. 1.

Alto make conventional milling machine and Lead well CNC milling machine are used for conventional drilling and CNC drilling respectively as shown in Fig. 1 (a) and 1 (b). Burr dimension measured by four different categories. These are i) Entry Burr Height, ii) Exit Burr Height, iii) Entry Burr Thickness and iv) Exit Burr Thickness. The burr height is measured by using mechanical comparator. The burr thickness is measured by using Tool Maker's Microscope.

a)

b)

Figure 1 a) Leadwell make CNC vertical machining center with the range of spindle speed from 12 – 6000 rpm with the work volume of 550 X 350 X 300 mm, b) Alto make conventional milling machine with power feed mechanism (limited to three different feed rate – 0.038, 0.076 and 0.203 mm/rev) and the spindle speed range of 80 – 4540 rpm, the table size 1270 X 252 X 500 mm.

Table 1 Chemical composition of Brass, Copper and Stainless Steel

Chemical composition							
Brass							
Elements	Cu	Lead	iron	Zn			
%	61.4	0.28	0.062	36.8			
Copper							
Elements	Bi	Cu	Lead				
%	0.002	99.91	0.003				
Stainless Steel							
Elements	C	Cr	Mn	Ni	P	S	Si
%	0.104	15.14	10.66	0.161	0.0262	0.0314	0.453

Table 2 Experimental run and ranges of parameter

Sl no	Copper and brass		Stainless steel	
	Spindle speed [rpm]	Feed rate [mm/rev]	Spindle speed [rpm]	Feed rate [mm/rev]
1	1860	0.038	270	0.038
2		0.076		0.076
3		0.203		0.203
4	2270	0.038	350	0.038
5		0.076		0.076
6		0.203		0.203
7	4540	0.038	540	0.038
8		0.076		0.076
9		0.203		0.203

The numbers of experiments are designed by using 3^2 factorial design. The ranges of input parameter are shown in Tab. 2. The experimental input parameter ranges were selected based on tool manufacturer recommendation and machine tool specification.

3. Results and discussion

A wide range of cutting conditions were used to conduct the drilling experiments. In this study, the spindle speed varied with three incrementals for each materials and feed rate are in three steps. The various combinations of spindle speed, feed rate and work piece materials were used to perform 27 experiments. For each of these drilling operation the burr dimensions were measured using the mechanical comparamer and tool makers microscope.

3.1. *Entry burr thickness*

Generally burr dimensions are classified into four types; that are entry burr height and entry burr thickness, these are the burr dimensions at entry of the hole. Similarly the exit burr height and exit burr thickness are the exit burr dimensions. In this work, burr dimensions are measured for conventional and CNC machined components. From Fig. 2 (a) & (b), conventional drilling operation produced the higher entry burr thickness. In that entry burr thickness higher in stainless steel of 1.6 mm occurs at spindle speed of 350 rpm and feed rate of 0.203 mm/rev, next brass and copper has lesser entry burr thickness than other materials. For copper high level spindle speed of 4540 rpm and high level feed rate of 0.203 mm/rev produces lesser entry burr thickness of 0.1 mm.

For brass lower spindle speed of 1860 rpm and higher feed rate of 0.203 mm/rev produces lesser burr thickness of 0.18 mm. For stainless steel higher spindle speed of 540 rpm and high level feed rate of 0.203 mm/rev produces the lesser burr thickness of 0.2 mm. In CNC drilling, the mid level spindle speed of 2270 rpm and with lower feed rate of 0.038 mm/rev generated lower burr thickness of 0.2 mm in copper. The lowest spindle speed of 1860 rpm and lower feed rate of 0.038 mm/rev produced the lower burr thickness of 0.18 mm in brass. The highest spindle speed of 540 rpm and higher feed rate of 0.203 mm/rev produced the lesser burr thickness of 0.18 mm in stainless steel.

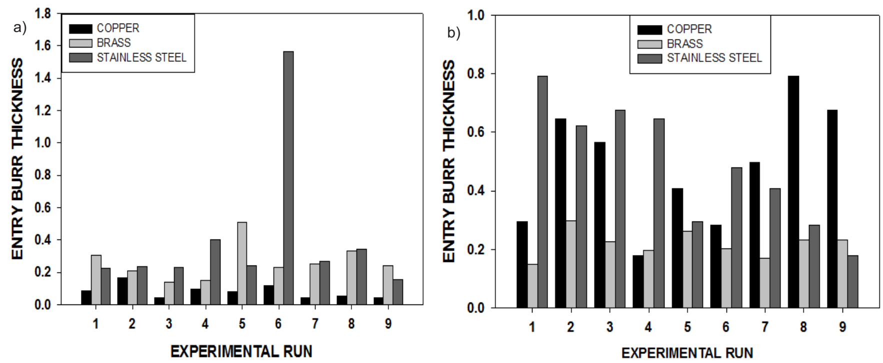

Figure 2 a) conventionally drillied hole entry burr thickness, b) CNC drilled hole entry burr thickness

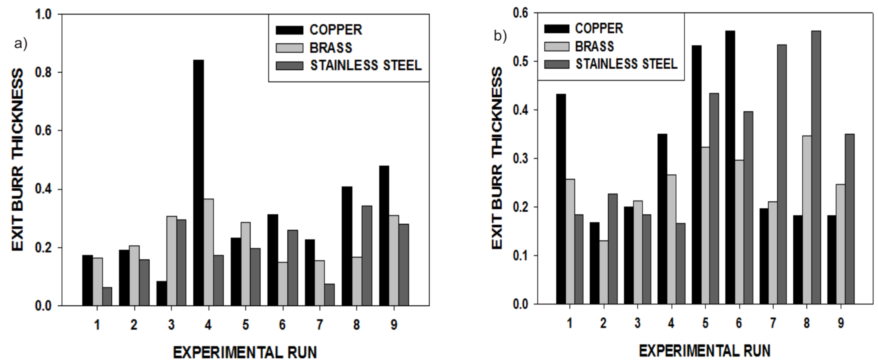

Figure 3 a) conventionally drillied hole exit burr thickness, b) CNC drilled hole exit burr thickness

3.2. *Exit burr thickness*

Comparatively exit burr thickness is lesser than entry burr thickness on both machines as shown in Fig. 3 (a) and (b). The exit burr thickness also larger in conventional drilled holes compared with CNC drilled holes. The lowest spindle speed with higher feed rate produces lesser exit burr thickness in copper. For CNC drilled holes, the lowest spindle speed of 1860 rpm with mid level feed rate of 0.076 mm/rev produced lesser burr thickness of 0.18 mm for copper. The higher spindle speed of 4540 rpm with lower level of feed rate of 0.038 mm/rev generates lesser burr thickness of 0.18 mm in brass conventionally drilled holes. In CNC drilled holes the lower level of spindle speed of 1860 rpm with mid level feed rate of 0.076 mm/rev produced lesser burr thickness in brass. For considering stainless steel and copper materials produces higher exit burr thickness of 0.56 mm than brass. The higher spindle speed of 540 rpm and lower feed rate of 0.038 mm/rev produced minimum burr thickness of 0.08 mm and 0.18 mm in conventionally and CNC drilled holes respectively on stainless steel.

3.3. *Entry burr height*

Entry burr height occurances is comparatively similar in conventionally and CNC drilled holes as shown in Fig. 4 (a) and (b). In copper, the highest spindle speed 4540 rpm with lower feed rate 0.038 mm/rev produced the minmum burr height of 0.16 mm in conventionally drilled holes. In CNC the mid level of spindle speed 2270 rpm with lower feed rate 0.038 mm/rev produces lesser burr height of 0.06 mm for copper work piece material. The lowest and highest spindle speed 1860 and 4540 rpm with mid level of feed rate 0.076 mm/rev generated minimum burr height of 0.02 mm for brass on both machines. The lowest spindle speed with higher feed rate generates minimum burr dimension on conventionally drilled holes. For CNC, the highest spindle speed with higher feed rate produced the lesser entry burr height on CNC drillied holes.

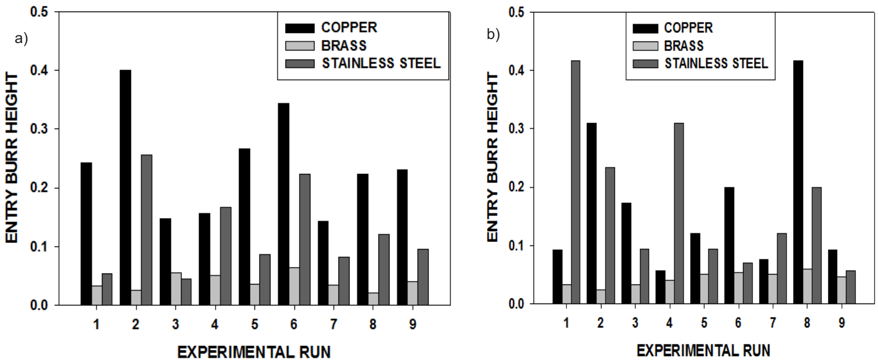

Figure 4 (a) conventionally drillied hole entry burr height, (b) CNC drilled hole entry burr height

3.4. *Exit burr height*

The exit burr height is larger in CNC drilled holes as compared to conventionally drilled holes and it is shown in Fig. 5a and b. The lower spindle speed of 1860 with higher feed rate of 0.203 mm/rev produces very minimum exit burr height in conventionally drilled holes on copper material. In CNC the lower spindle speed 1860 rpm with lower feed rate 0.038 mm/rev produced minimum burr height of 0.1 mm. For brass, the lowest spindle speed 1860 rpm with lowest feed rate 0.038 mm/rev produced lower burr height of 0.01 mm in conventionally drilled holes. In CNC, the highest spindle speed of 4540 rpm with higher feed rate of 0.203 mm/rev produced very minimum exit burr thickness of 0.01mm in brass material. The copper and stainless steel produced higher exit burr height of 2.2 mm than brass work piece material. In conventionally drilled holes, the lesser burr height of 0.1 mm occurs with mid level of spindle speed 350 rpm and high level of feed rate 0.203 mm/rev on stainless steel work piece material. The mid level of spindle speed 540 rpm with mid level of feed rate 0.076 mm/rev produces minimum exit burr height of 0.2 mm on CNC drilled holes in stainless steel material.

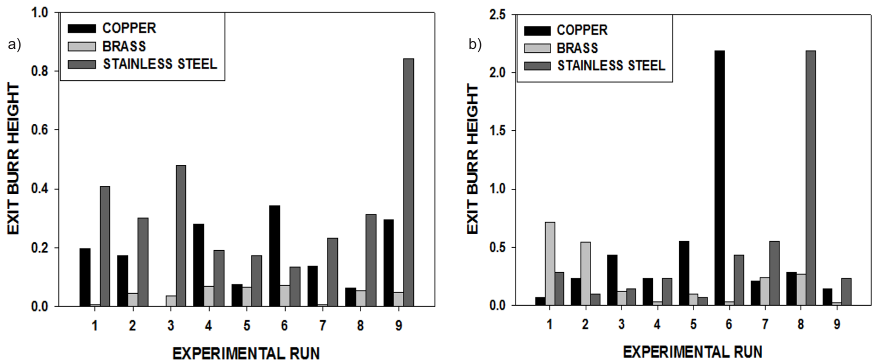

Figure 5 a) conventionally drillied hole exit burr height, b) CNC drilled hole exit burr height

4. Conclusions

The experiments were conducted bsed on design of experiment concepts and the standard point angle is fixed for all combination of spindle speed and feed rate. Based on experimintal investigation on various materials drawn the following conclusion;

- The conventional machines produces higher burr thickness than CNC machines, but the burr heights of entry and exit more on CNC than conventional machines for most of the spindle speed and feed rate combinations.
- Comparatively stainless steel material has higher burr dimensions than copper and brass.
- Copper has lesser burr thickness than other materials for most combination of spindle speed and feed rate.
- Brass has lesser entry burr height than copper and stainless steel materials.

- In conventional and CNC machines brass has less entry burr height for most combination of spindle speed and feed rate.
- The entry burr height is higher in CNC drilled holes than conventional drilled holes.
- Entry burr thickness is more in stainless steel material, copper material produced the higher exit burr thickness than other materials considered in this work.
- Copper material produced the higher entry burr and exit burr thickness due to ductility of copper.

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