Effect of Drilling Process Parameters on Brass Alloy 272 Through Experimental Techniques

Aqib Hussain†, Aamer Sharif*, Numan Habib‡, Sadiq Ali‡, Kareem Akhtar‡, Faraz Ahmad‡†, Muhammad Salman†, Waqar Ahmad‡, Irfan Ullah‡, Muhammad Ishaq‡‡

† Department of Mechanical Engineering, CECOS University of IT and Emerging Science, Peshawar, Pakistan
‡ Department of Mechanical Engineering, University of Engineering and Technology Peshawar, Pakistan
‡† Department of Mechanical Engineering, Air University Islamabad, Aerospace and Aviation Campus, Kamra, Pakistan
‡‡ Department of Software Engineering, Abasyn University Peshawar, Pakistan

*Corresponding Author email: aamer@cecos.edu.pk

ABSTRACT

Generally, parts are rejected during drilling operation due to low quality drilled holes and improper selection of process parameters such as feed rate and spindle speed. The current study is mainly focused on the drilling operation of brass alloy 272 having 13 mm thick sheet through vertical milling machine to study the effect of feed rate and spindle speed on Torque, Axial load, temperature and surface roughness. Thermal analysis is also carried out to predict temperature generation at tooltip during the drilling operation. Moreover, surface roughness analysis obtained during drilling of brass alloy 272 is also investigated in current study. The results show that the axial load and torque increases with increase in feed rate and decreases with increase in spindle speed. However, the temperature increases with increase in spindle speed and also increases with increase in feed rate but not significantly. Furthermore, surface roughness decreased with increase in spindle speed and increase with increase in feed rate. This study clearly reveals that the feed rate is more influential on axial load and torque as compared to spindle speed while the spindle speed is more influential on temperature.

KEYWORD

Drilling, feed rate, spindle speed, torque, axial load, temperature, surface roughness

INTRODUCTION

Drilling is the most prominent machining process mostly used in all manufacturing industries, where a large number of holes are required for assembly operation [1, 2]. There are many problems related with the drilling process such as cutting forces, including feed rate, cutting speed and surface roughness [3]. Generally, brass is the composition of two metals that is copper and zinc. Brass is known to be the very expensive material and golden colored [4]. Due to quality characteristics such as smooth surface, minimum resistance in deep drilling process, brass 272 is considered to be the best alloy for machining operations [5]. Due to gleaming and shining effects brass 272 is mainly used in gears, locks, bearings, valves and mostly used in traditional houses [6]. Specifically, brass alloys suggested for high thermal conductivity, excellent antibacterial properties and widely used in various enterprises like electric electronics and automotive industries [7].

In past literature little worked performed on the machining of Brass alloy 272. B. balout et al. [8] worked on the fine dust generated during machining which hazards to the environment and workers in industries. They observed that dust generation is affected by many factors such as material type, heat treatment process, and temperature and chip formation during machining. Bamidele et al. [9] analyzed the optimum process parameters needed for drilling of brass in order to investigate the response surface methodology. Various process variables such as feed rate, spindle speed and depth of cut are analyzed to overcome surface roughness of the brass. V.N Gaitunde et al. [10] worked on the minimum quality of lubrication (MQL) and process variables, aiming to improve machinability
for a desired work material. Azlan et al. [6] investigated the influence of cutting parameters such as feed rate, spindle speed and tool size on surface roughness and dimensional accuracy.

The claimed that the value of surface roughness is greatly influenced by spindle speed and feed rate. Nima et al. [11] investigated the dimensional accuracy and surface quality of lead free brass. They determined that the cutting tools have strong effect on microstructure and hardening of surface. S. Marichamy et al. [12] determined the machinability behavior of brass alloy through electrical discharge machine by conducting Taguchi technique through various process conditions. The results show that the peak value of SN ratio was significant factor to influence all the response. The above study indicates that there is still lack of research regarding drilling and thermal analysis of the Brass alloy 272, which needs further investigation. Therefore, this study focused on the drilling of Brass alloy 272 to comprehensively analyze the influence of process parameters on the hole quality, i.e., feed rate and spindle speed, on the axial load, torque, and temperature and surface roughness.

MATERIAL AND METHOD

In the current study, Brass Alloy 272 plate was used having length of 150 mm, width of 50 mm and thickness of 13 mm as shown in Figure 1 c. The experimentations were conducted on vertical milling machine (Model: Victoria-Elliott U2, London, UK). A square fixture with a center hole of 30 mm was used to hold the work piece on the dynamometer while vertical milling machine bed was used to mount the dynamometer as shown in the Figure 1 b. The feed rates were 0.12, 0.2 and 0.3 rev/min and spindle speeds were 330, 410, and 510 rpm for the current study. A Dormer HSS Jobber drill bit of 10 x 133 mm dimension and a point angle of 118°, and a helix angle of 30° were used for drilling operation. The experimentations were conducted in dry-cutting conditions without coolants due to environmental concerns [13]. The axial load or thrust force and torque induced during the cutting operation were measured through a piezoelectric dynamometer and data acquisition device was used to record the data as shown in figure 1 a.

The data analysis is carried out by using MATLAB to display real-time graphs and record the data. The temperature generated during cutting process was measured with an infrared thermal sensor (Model: OS-180-USB-LSTL, Omega, United Kingdom). The emissivity value for Brass alloy 272 was taken as 0.03. An infrared thermal sensor was mounted to the top of the lathe machine with the help of a magnetic stand, as shown in Figure 1 a. The laser gun was attached on a thermal sensor lens to point the infrared sensor accurately on a drilled hole for precise readings. In this study, the process parameters were feed rate and spindle speed, whereas the responses were torque, axial load, and temperature. The experimental conditions and equipment details are shown in Table 1.

Table 1. Equipment Details

<table>
<thead>
<tr>
<th>Work piece material</th>
<th>Brass Alloy 272 cylindrical work pieces having a size of 32 mm x 19 mm Length and diameter respectively.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drill bits</td>
<td>High speed steel (HSS) having a diameter of 10 mm helix angle 30° and point angle 118°. Length 133mm, Cutting length 87mm</td>
</tr>
<tr>
<td>Machine tool</td>
<td>Vertical Radial Drilling machine</td>
</tr>
<tr>
<td>Drilling condition</td>
<td>Dry conditions</td>
</tr>
<tr>
<td>Spindle speed (m/min)</td>
<td>330,410,510</td>
</tr>
<tr>
<td>Feed rate (mm/rev)</td>
<td>0.12,0.20,0.30</td>
</tr>
<tr>
<td>Thermal Sensor</td>
<td>Infrared type, min/max temp Measurement (450° – 842°) /(2000° – 3632°)</td>
</tr>
</tbody>
</table>
RESULTS AND DISCUSSIONS

Axial Load

The Axial load or thrust force acting on the work piece during drilling operation is considered as the most important parameter to determine the tool wear and hole quality [14]. Figure 2-7 shows the average axial load observed during experimentation. A gradual decrease in axial load can be seen with increasing spindle speed from 330 to 510 rpm. The temperature produced in a drilled hole area, reduces the hardness of the material, which results in minimum axial load [15]. Furthermore, the axial load decreases with increase in spindle speed due to increase in material ductility, resulted from increase in temperature at higher spindle speeds [16]. In addition to this, the mechanical properties likewise hardness, ultimate tensile strength and ductility may influence the thrust force [17].

It is observed that the axial load increases with increase in feed rate from 0.12 to 0.3 mm/rev as shown in Figure 5-7. The reason is that the drill penetration into the work piece increases due to increase in chip thickness [18]. This is due to the fact that with increasing feed rate, the chip thickness increases, and the material shows resistance against rupturing, which results in higher axial load [19]. The hardness of the material also influences the thrust force because of the maximum hardness of the studied material resulting in greater wear of the tool: hence produce more thrust forces [17]. However, the maximum material is removed at higher feed rate of 0.3 mm/rev which needs more power to obtain the machining process.
Figure 2. Axial load vs time graph at 0.12 mm/rev feed rate.

Figure 3. Axial load vs time graph at 0.2 mm/rev feed rate.

Figure 4. Axial load vs time graph at 0.3 mm/rev feed rate.
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Figure 5. Axial load vs time graph at 330 rpm spindle speed.

Figure 6. Axial load vs time graph at 410 rpm spindle speed.

Figure 7. Axial load vs time graph at 510 rpm spindle speed.

Torque
The measurement of torque acting on the work piece is greatly influenced by the feed rate and spindle speed. Figure 8-11 shows the behavior of torque with increasing feed rate from 0.12 mm/rev to 0.3 mm/rev. The torque is increased with increased in feed rate due to the continuous and faster penetration of the drill bit with higher...
feed rates which results in formation of larger chip thickness and material removal rate and hence increase the torque [20]. Moreover, maximum material is removed at 0.3 mm/rev which requires more power to achieve the machining process. The average value of the torque decreases from 15 N·m to 10 N·m with increased in spindle speed from 330 rpm to 510 rpm as shown in Figures 11-13. The rise in temperature results in the liquefaction of the material in nearby zones of the drilled hole. Moreover, the material become soft due to maximum temperature and a very little force is required for shearing layers to slip easily as related to hard material and low temperature [21]. The same phenomenon occurs in low torque values with high spindle speed.

**Figure 8.** Torque vs time graph at 0.12 mm/rev feed rate.

**Figure 9.** Torque vs time graph at 0.2 mm/rev feed rate.
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Figure 10. Torque vs time graph at 0.3 mm/rev feed rate.

Figure 11. Torque vs time graph at 330 rpm spindle speed.

Figure 12. Torque vs time graph at 410 rpm spindle speed.
Temperature

Brass alloy 272 is soft material which shows less resistance to the shearing process during drilling operation. Furthermore, the brass alloy 272 low resistance results in low fraction and producing low temperatures in the cutting zone as compared to mild steel and other alloys [4]. The temperature increase in drilling operation depends upon functional parameters such as spindle speed and feed rate. The variations in temperature are occurred due to many reasons such as that chip extraction, tool wear, chip profile and surface roughness [22]. The heat produced during drilling operation is dependent on the friction resulted from the drill tool and its speed. When the spindle speed increases the heat transfer and fractional heat flux also increases which eventually rise the work piece temperature [23]. The formation of continuous chips and higher feed rates increases the temperature at the tool tip [22]. When the feed rate increases the material removal rate also increases due to the tool depths of travel as shown in Figures 14 to 16. This phenomenon results in the rise of temperature [24]. The fluctuation at the beginning of the graph is due to the temperature of the tool and work piece was not brought to the room temperature for the coming experiment. Figure 17 to 19 shows the increasing trend of temperature with increase spindle speed. This rise in temperature is due to the high fraction between the work piece and the rotating tool. This could be related to the fact that fraction increases with increase in relative velocity between two contact surfaces, ultimately increasing the temperature in cutting zone [25].

Figure 13. Torque vs time graph at 510 rpm spindle speed.

Figure 14. Temperature vs time graph at 0.12 mm/rev feed rate.
Figure 15. Temperature vs time graph at 0.2 mm/rev feed rate.

Figure 16. Temperature vs time graph at 0.3 mm/rev feed rate.

Figure 17. Temperature vs time graph at 330 rpm spindle speed.
Surface Roughness

Surface roughness (Ra) is considered to be an important factor affecting machining performance of a work piece [26]. It also known to be the principal scale for investigating the function of a hole during drilling operation and have adverse effect on manufacturing process as well as manufacturing cost [27]. It is considered to be the most complex and dynamic during machining operation. Surface roughness is basically the irregularities or scratches produced during machining operation [28]. The geometry of the tool and vibrations induced on the work piece also has an influence on surface roughness [29]. Furthermore, greater value of the surface roughness causes severe corrosions and high fatigue which results in overcomes the machining performance [30]. The surface roughness value Ra is greatly influenced by the spindle speed and feed rate.

The Figure 20 shows the continuous decline in the direction of increasing spindle speed at various cutting conditions. This states that, the value of surface roughness is gradually decreases with increasing spindle speed. The maximum surface roughness value is measured at 330 rpm and minimum are observed at 510 rpm. It is observed that the value of Ra is increases with increase in feed rate. The maximum value is obtained at 2.4 um at 0.3 mm/rev and minimum value 1.9 um is obtained at 0.12 mm/rev. However, the value of the surface roughness is decreased with increase in spindle speed. This is due to the phenomenon that the tool tip comes in contact with chip for very short interval of time due to which the Ra value reduces. Secondly the temperature of the surface was increased, which results in softening of the material and reduces the resistance against the tool tip [31].

Figure 18. Temperature vs time graph at 410 rpm spindle speed.

Figure 19. Temperature vs time graph at 510 rpm spindle speed.
increase in ductility also increases the temperature which results in decrease of the Ra value [32]. However, the surface roughness value Ra increases with increase in feed rate due to the work piece material is lacerating due to high temperature. Moreover, the chips formed in a closed area due to which the severe vibrations produced which is called chattering phenomenon. The increase in feed rate also increases the material removal rate which results in poor hole quality surface [30]. In addition to this the chip volume increases with increase in feed rate during drilling operation, which results in low shear angle and high thrust force [33].

CONCLUSION

In the current study the experimental investigations has been conducted on Brass Alloy 272 to study the effect of feed rate and spindle speed on axial load, torque, temperature and surface roughness. The main conclusions drawn from the above study are as follows:

- It is observed that the axial load is more affected by the feed rate as compared to spindle speed while the spindle speed also affects the axial load but not significantly. Furthermore, the maximum values of axial load observed at 0.3 mm/rev and minimum spindle speed at 330 rpm which reveals that the axial load decreases with increase in spindle speed.

- The value of torque increases with increase in feed rate from 0.12 to 0.3 mm/rev at constant spindle speed. However, the torque value decreases with increase in spindle speed from 330 to 510 rpm at constant feed rate. The maximum torque is measured at 0.3 mm/rev and minimum torque is measured at 0.12 mm/rev. In addition to this, the torque decreases with increase in spindle speed due to rise in temperature.

- The rise in temperature is more influenced by the spindle speed as compared by the feed rate at various cutting conditions. Therefore, maximum temperature is observed at 510 rpm and minimum temperature is achieved at 330 rpm. Similarly, in case of increasing feed rates the temperature also increases but not significantly.

- The surface roughness decreased with increase in spindle speed and increase with increase in feed rate.

REFERENCES


