Chapter

Drilling of 7075 Aluminum Alloys

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Abstract

Aluminum alloy (Al 7075) has been increasingly used as structural components in automotive and aerospace industry due to their low density, high strength and good corrosion resistance compared with other metals. To manufacture and assemble the components, drilling operations are often conducted. However, Al 7075 is ductile and soft, which causes difficulty in drilling, resulting in material adhesion, high tool wear, short tool life and poor hole quality. As a result of the poor hole quality, there is a high percentage of part rejection, which can increase the manufacturing time and cost. This chapter discusses challenges and techniques to drill Al 7075 in terms of the cutting parameters and drilling conditions to prolong the tool life and achieve good hole quality. Drilling experiments on Al 7075-T6 (heat-treated) were conducted using carbide cutting tools at various cutting parameters. Reducing cutting speed and increasing feed rate resulted in reducing tool wear, whereas a reduction in surface roughness, hence improved machined surface finish, was found when both cutting speed and feed rate were reduced in drilling Al 7075-T6. Producing good hole quality is vital during the drilling process to ensure a good assembly and product service performance.

Keywords: drilling, Al 7075, tool wear, hole quality, surface roughness, burr

1. Introduction

Aluminum alloys (particularly 6000 and 7000 grades) are desirable in various industrial applications due to their high strength to weight ratio and good corrosion resistance. Aluminum has a low density of 2.7 g/cm^3 compared to 7.87 g/cm^3 for steels. It is generally lighter (about one to three times) than steel; however, its properties (i.e., Al 7075) in terms of specific strength and toughness are almost similar to some steel. In addition, aluminum alloys are relatively cost-effective and have good economic value [1]. Some industries that highly rely on aluminum alloys are aerospace, automotive, shipbuilding and rail companies. In the industries, machining operations, particularly drilling, are widely conducted to manufacture the components. Drilling of the components is usually performed at the end of manufacturing processes to produce holes for assembly of a final product using suitable fasteners. Some defects such as cracks, burr and surface deformation may be introduced during drilling operations which could lead to poor product performance and product failure. It is important for the dimension of the drilled holes to be within the tolerance and has minimum or no defect, so that the components can be assembled securely as a functional product.

Drilling efficiency is strongly dependent on the materials, tool geometry, cutting parameters and process conditions. Drilling aluminum alloy in a dry condition is challenging as it often results in poor drilled hole quality, which includes the formation of burr, high surface roughness and adhesion on the work material. After the drilling operation, the product will need additional finishing processes, such as reaming and deburring to achieve the required hole quality. To overcome such issues, drilling can be done with the presence of cutting fluid to reduce heat generation and hence reduce thermal softening and material adhesion. Nevertheless, it is important to note that the use of cutting fluid or lubricant during drilling is costly, could have a high environmental impact and requires high maintenance for disposal. Therefore, dry drilling is usually preferable, however, choosing appropriate cutting parameters is crucial to produce drilled holes with good quality for the product assembly.

2. Application of aluminum alloy 7075

The increasing application of Al 7075 in the automotive and aerospace industries generally contributes to the reduction of the total mass of the vehicle. In the aerospace industry, Al 7075 is commonly used to produce structural components of the airframe, including wing skins, empennage or tail, and fuselage. The high corrosion resistance, high strength, high crashworthiness and durability of Al 7075 make the material desirable for structural components applications [2]. Typical mechanical properties for Al 7075 are shown in **Table 1**.

The modulus elasticity of AI 7075 is 71.7 GPa and its shear modulus is 26.9 GPa, which makes it suitable for high-performance metal application. Moreover, AI 7075 has a good tensile yield strength which means it could resist up to 503 MPa of tension before being deformed and will not revert to its initial form. The main reason for the high strength of Al 7075 compared to pure Aluminum is due to the zinc content as its primary alloying element [1]. The weight reduction while maintaining the strength of the component is advantageous to reduce fuel consumption and reduce maintenance costs. These good properties show the benefit and the reasons for Al 7075 is increasingly being used in industries for structural components.

From the aspect of machinability, Al 7075 is more machinable than other high-performance metals such as steel, cast iron and titanium due to its better chip formation and can be sheared easily [3]. Compared to other high-performance alloys (e.g., steel and titanium), the cutting forces, cutting temperature and energy consumed in machining aluminum alloy are relatively low which makes them a good alternative for achieving high productivity [4]. However, producing good hole quality in Al 7075 in terms of dimensional accuracy and good machines surface

Mechanical properties	Values
Ultimate tensile strength	572 MPa (83,000 psi)
Tensile yield strength	503 MPa (73,000 psi)
Shear strength	331 MPa (48,000 psi)
Fatigue strength	159 MPa (23,000 psi)
Modulus of elasticity	71.7 MPa (10,400 ksi)

Table 1.
Typical mechanical properties of Al 7075 tempered [1].

finish can be challenging. The soft and ductile properties of aluminum alloy could lead to thermal softening on the material during the operation which causes built-up edge formation that accumulated at the tool edge and material adhesion on the machined surface. Consequently, this leads to poor machined surface finish and hole quality. Hence, this chapter discusses the crucial drilling parameters that need to be considered to produce the required good hole quality.

3. Cutting tools

Cutting tools in terms of the tool geometry and tool material are important factors that need to be determined before conducting drilling operations because they can affect the tool wear, tool life and hence surface finish of the Al 7075. Twist drill, as shown in **Figure 1** (the image of the tool was captured by the authors), is the common type of drill that has been used, especially in drilling Al 7075 because it has helical grooves to facilitate the chip evacuation along with the flutes. The helix angle is the angle that forms between the leading edge of the drill and drill axis [5]. The efficiency of the drilling operation can be improved by using a drill with a low helix angle since the tool strength is improved by reducing the helix angle. For drilling Al 7075, the common helix angle that has been used is 30°. The point angle, which is the angle form between cutting lips is also important to ensure drilling efficiency. The standard point angle that is normally used for general purpose drilling is 118°.

The selection of drill material is important because it determines the toughness, hardness, wear-resistance and thermal resistance of the drill during the drilling process. The drill materials that have been used in drilling Al 7075 are commonly made from high-speed steels (HSS) and tungsten carbide (WC). It has been stated that the HSS drill is often used due to the availability in a wide range, low cost and hardness; however, the HSS drill does not resist high cutting temperature well [6]. To manufacture high-performance components, tungsten carbide drills are preferable as they usually produce better hole quality due to their ability to resist high cutting temperature and maintain their toughness compared to HSS drills. Less material adhesion, less BUE, low tool wear and improved chip formation were reported when using carbide drills during drilling Al 7075 compared to HSS drills [7]. This is supported by previous research [8] which found that tungsten carbide drill has 20% longer tool life than HSS drill, and it also produces high-quality holes with good dimensional accuracy within a range of 6.04 to 6.12 mm when drilling with 6 mm drill diameter in dry condition. Therefore, a tungsten carbide drill is generally recommended for drilling Al 7075.

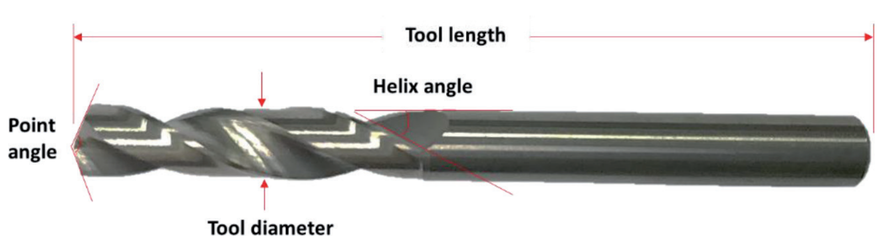

Figure 1.
Typical cutting tool for drilling aluminum alloys.

4. Cutting parameters

Cutting parameters are important in drilling operations because they have a significant influence in determining the rates of material removal, tool wear, and tool life which could affect the drilled hole quality. The important cutting parameters which need to be appropriately considered and selected in drilling operations are cutting speed and feed rate.

4.1 Cutting speed

A cutting speed is measured in terms of the rate at which the outside or periphery of the tool moves to the work being drilled. The range of cutting speeds that are normally used in drilling Al 7075 is within 50 to 250 m/min for 6 to 8 mm diameter cutting tools. It was reported that increasing cutting speed caused a reduction in the machined surface roughness due to the improved material shearing [9]. Based on [9], which conducted drilling experiments using 180, 200, 220, and 240 m/min of cutting speeds, it was found that the surface roughness of Al 7075 decreases by 5.49% when the cutting speed is increased from 180 to 240 m/min. However, an increase in cutting speeds could increase the tool chatter which affects the surface roughness of the machined surface. This view is supported by previous research [10], which also reported that increasing cutting speed could increase the tool vibration caused by the spindle rotation, which would lead to poor machined surface finish. To avoid the tool chatter and vibration due to high cutting speed during drilling, proper fixture and clamping of the work material, as well as a secured spindle head must be ensured before starting the drilling operation.

Furthermore, high cutting speed can also cause an increase in cutting temperatures between the tool and workpiece due to high heat generated during drilling operations which may lead to a higher tool wear rate. When the cutting speed is increased, the cutting temperature also increases which would result in the workpiece material sticking at cutting edges. This is supported by a previous study [11], which found that increasing cutting speed from 60 to 100 m/min caused the cutting temperature to increase from 195 to 240°C during drilling of Al 7075. Another previous study [9] shows that the flank wear increased from 0.08 to 0.19 mm due to an increase in cutting speeds from 180 to 240 m/min with 0.1 mm/rev feed rate which also resulted in decreased surface roughness from 4.015 to 3.619 μm. Although, higher cutting speed causes higher tool wear, using too low cutting speed is not recommended as it may cause the formation of Built-Up Edge (BUE) on the cutting edge which leads to high machined surface roughness and also cause low productivity. Based on [12], BUE formation was observed when drilling using a low cutting speed of 40 m/min with a cutting temperature of 160°C which resulted in surface roughness, Ra of 1.16 μm. Hence, using moderate cutting speeds within the range of 100 to 220 m/min is generally recommended when drilling Al 7075 to maintain good productivity.

4.2 Feed rate

Feed rate is a major factor that influences chip formation, cutting forces and hole quality. Feed rate is the distance that the drill moves into the workpiece for each complete turn of the cutting tool. The range of feed rates that are typically used in drilling operations of Al 7075 is within 0.01 to 0.10 mm/rev. A previous study [13] found that an increase in feed rate from 0.05 to 0.2 mm/rev at a constant cutting speed of 50 m/min caused the thrust force to increase from 825 to 1020 N and produce continuous chips which could entangle in the drill flutes hence causing poor machined surface finish. Another previous study [14] examined the effect of feed rate on drilled holes and found that at high feed rates, there is a deterioration in the shape of the holes. This is due to the high thrust forces caused by the thick chip formation. Generally, a low feed rate is recommended when drilling Al 7075 as it causes low thrust force, produces a good machined surface finish and prolongs the tool life.

5. Chip formation

Chips are formed during drilling operation as the aluminum alloy is removed by the cutting edges. Understanding the chip formation and morphology is important because it can influence the tool wear and hole quality. A drilling operation on Al 7075-T6 was conducted by the authors using 6.5 mm carbide drills at cutting speeds of 120 and 160 m/min as well as feed rates of 0.01 and 0.1 mm/rev. It was found that the chips produced are in the form of continuous, spiral, and discontinuous, as shown in **Figure 2a**.

The continuous chip in the form of a spiral or ribbon, as shown in **Figure 2b**, formed during drilling with increasing cutting speed. This is supported by previous research [15–17], which explained that the continuous chips formed due to material straining caused by thermal softening as a result of high cutting temperature. The material became more ductile, which led to the formation of continuous chips. Whereas, thinner continuous chips, as shown in **Figure 2c** are formed when the feed rate is decreasing. Continuous chips are typically undesirable because they could cause difficulty in chip evacuation as the chips entangle around the drill and jam in the flutes, which consequently could cause high surface roughness and poor drill hole quality [18]. In this case, a chip breaker is needed to break the chips into smaller pieces during drilling to facilitate chip evacuation from the drilled hole.

Based on [18], the chip becomes shorter as the drilling operation progresses as the resistance between the material and the drilling bit decreases. In addition, the chip produced unfolds due to the opposite of the torque of the friction to the chip rotation. The break-up of the chip into pieces is when the chip reaches its fracture point, whereas the continuous cone-shaped spiral chips break into smaller pieces when the chip exceeds the breaking torque between the tool and hole wall [18]. In addition, the use of chilled air during drilling Al 7075 with carbide drill could be favorable as it was found to result in shorter chips than dry drilling by 20 and 32.5% at cutting speeds of 120 and 160 m/min, respectively, as shown in **Figure 3**. The chip started to change into a segmented chip from a continuous chip due to the lower cutting temperature which lowered the thermal softening and material straining.

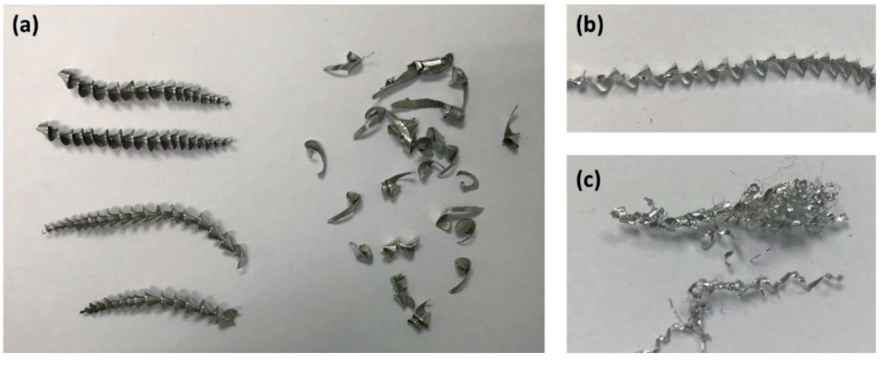

Figure 2.
Chip morphology of Al 7075-T6 during drilling operations (a) continuous, discontinuous and smaller pieces chips (b) cone-shaped spiral chips (c) thinner continuous chips.

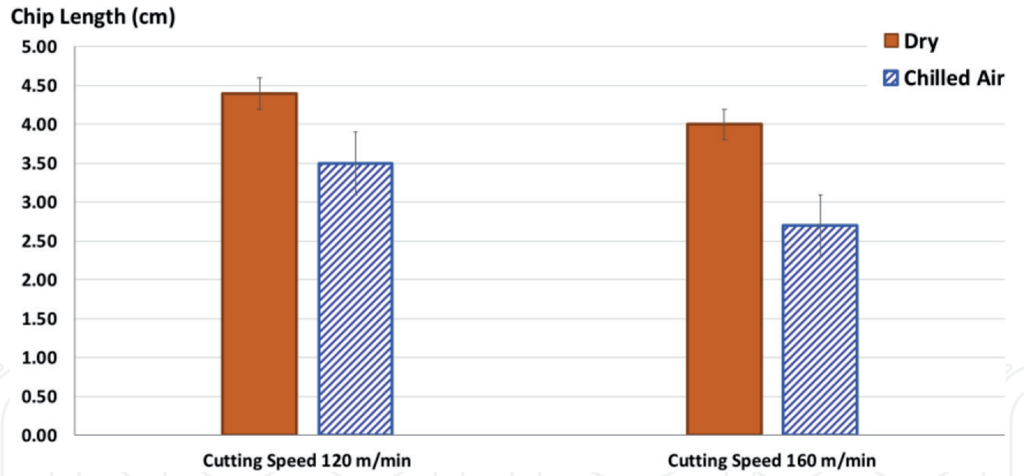

Figure 3.
Comparison of chip length when drilling Al 7075-T6 at cutting speeds of 120 and 160 m/min and a constant feed rate of 0.05 mm/rev.

6. Tool wear

Tool wear is an important element that can affect tool life, the machined surface finish of the drilled hole and hence hole quality. Tool wear is the change in the geometry and dimension, particularly at the cutting edges, which indicates the failure rate of the cutting tool due to drilling a significant number of holes. The tool wear mechanisms that typically occur in drilling Al 7075 are abrasive and adhesive wear, as shown in **Figure 4**, which was observed during experiments conducted by the authors**.** The abrasive wear, as shown in **Figure 4a**, occurs as the tool material (e.g., carbide and cobalt), especially at the cutting edges, were abraded due to the removing process of the harder workpiece material (e.g., Al7075) in the drilling process.

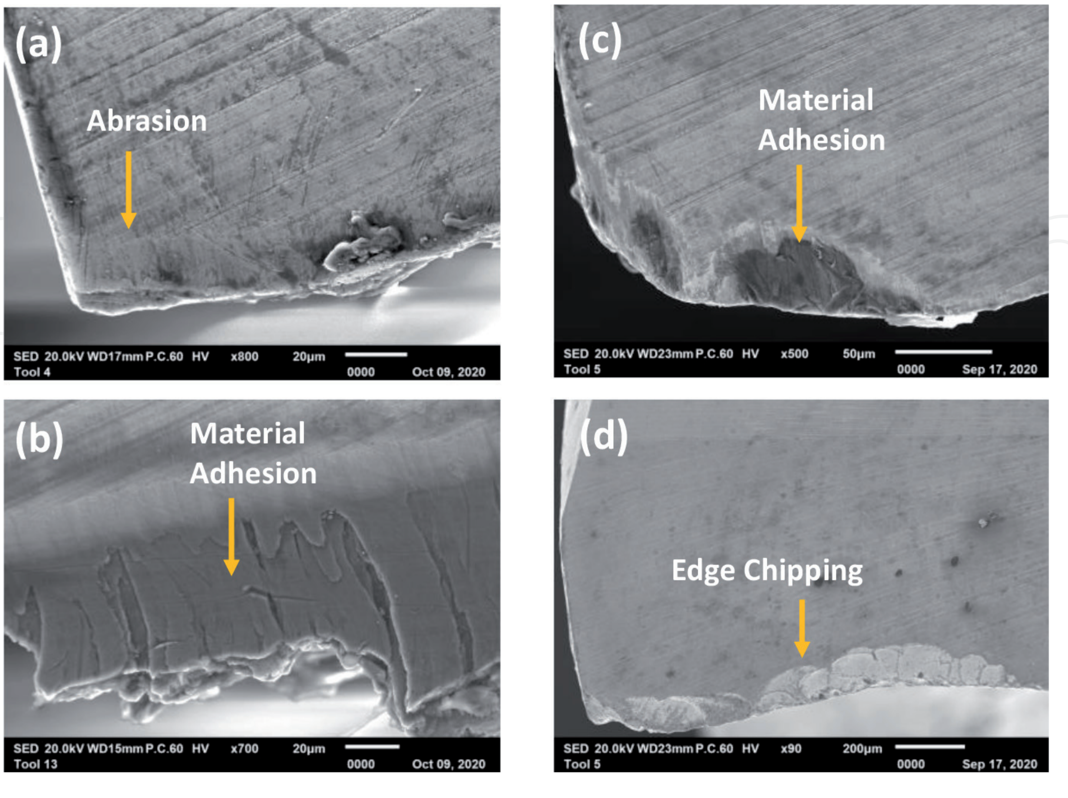

Figure 4.
Tool wear mechanism when drilling Al 7075-T6 (a) abrasive wear, (b, c) adhesion of material, and (d) chipping at the cutting edge of carbide drills.

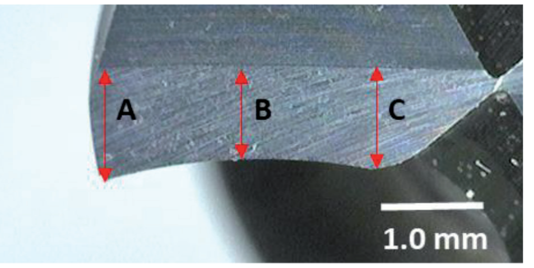

Figure 5.
Measurement of tool wear is taken as the change in flank length indicated by A, B, and C after drilling each 10th hole compared to the initial flank length.

Based on [19], scratches at the cutting edges parallel to the cutting direction will show the proof and region of abrasive wear. It was reported [20] that the abrasion mechanism occurs at a low cutting speed due to a low chip removal rate compared to drilling at a higher cutting speed. To minimize the abrasive wear, a cutting tool with a harder material than the workpiece material should be used in the drilling operation. Adhesive wear, as shown in **Figure 4b** and **c**, occurs when the chip or machined material adhere to the cutting edges due to high cutting temperature and pressure, which can cause edge chipping, as can be seen in **Figure 4d** when the adhered material breaks off [21, 22]. Previous studies [20, 23] reported that increasing cutting speed from 76 to 198 m/min in dry drilling resulted in material adhesion due to an increase in cutting temperature, thus will lead to higher tool wear.

The tool wear is typically affected by the cutting parameters and process conditions used. The authors experimented drilling Al 7075-T6 heat-treated using 6.5 mm carbide drills to investigate the effect of cutting speed and feed rate on tool wear. The tool wear was determined by measuring the change in the flank, as shown in **Figure 5**. This measurement follows ISO 3685:1993, which recommends that the end of tool life is reached when the flank wear is equivalent to 0.3 mm.

From the experiment conducted by the authors, it can be seen in **Figure 6** that increasing cutting speed from 80 to 120 and to 160 m/min at a constant feed rate of 0.05 mm/rev resulted in increasing tool wear. This is likely due to increasing heat generation, which caused weakening of the tool material as well as material adhesion on the cutting edges. Feed rate also has a significant effect on tool wear. As shown in **Figure 7**, increasing feed rate from 0.01 to 0.05 and to 0.1 mm/rev

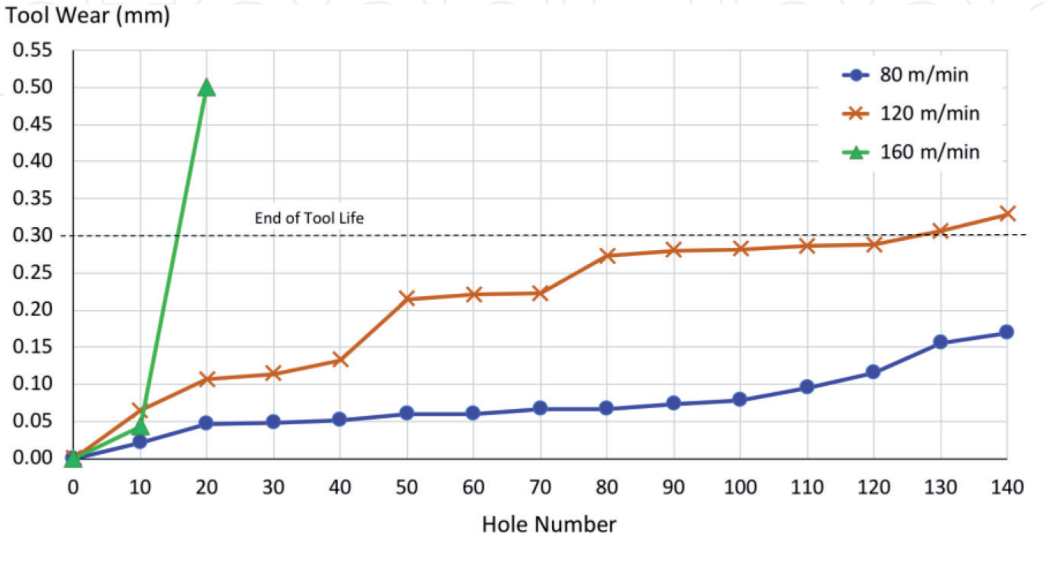

Figure 6.
Tool wear in drilling Al 7075-T6 (heat-treated) using 6.5 mm carbide drills at cutting speeds of 80, 120 and 160 m/min and a constant feed rate of 0.05 mm/rev.

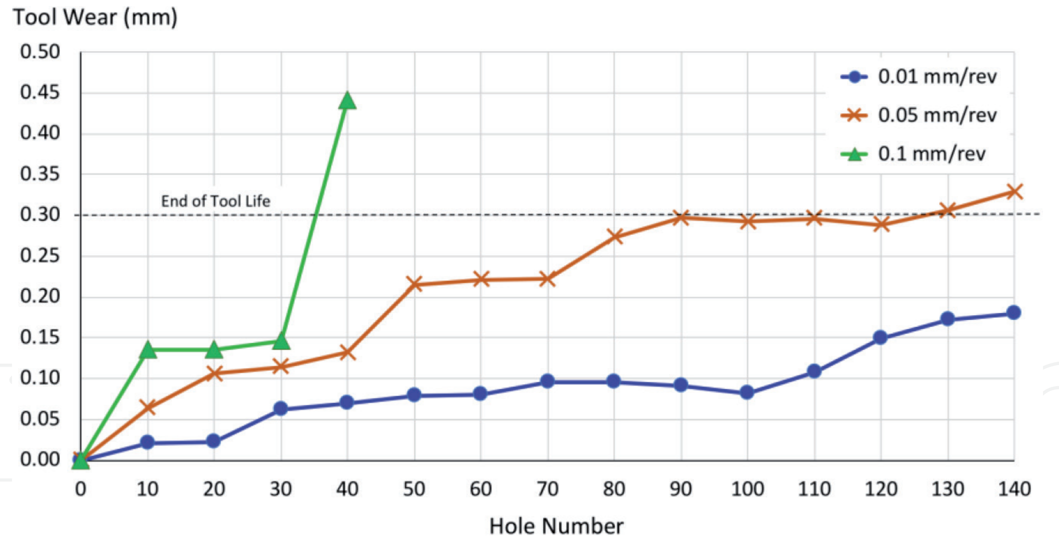

Figure 7.
Tool wear in drilling Al 7075-T6 (heat-treated) using 6.5 mm carbide drills at feed rates of 0.01, 0.05 and 0.1 mm/rev and a constant cutting speed of 120 m/min.

at a constant cutting speed of 120 m/min was found to increase tool wear. This is likely due to the increasing volume of material removed per tool rotation that could cause higher thrust force and weaken the cutting edges leading to higher tool wear. This indicates that a low cutting speed and low feed rate can produce low tool wear therefore a longer tool life.

Even though using a low cutting speed and a low feed rate can cause a lower tool wear rate in drilling Al 7075-T6, it is usually not preferable in the industry as this can lead to longer production time hence low productivity. Therefore, moderate cutting speed and feed rate could be used when productivity is a concern, although frequent tool change may be needed to ensure the tool wear does not affect the hole quality. Drilling in a dry condition typically results in high tool wear due to heat generated between workpiece material and cutting tool. Therefore, the presence of cutting fluid and chilled air during drilling Al 7075 could improve the tool wear. Referring to [24], chilled air can act as a coolant to reduce the temperature at the cutting zone, thus will result in low tool wear, hence longer tool life.

7. Hole quality

Ensuring that the holes are produced with good quality as required is important for component assembly hence the product functionality and service life. The drilled hole quality can be measured and assessed in terms of the hole diameter, roundness, machined surface roughness and burr formation.

7.1 Hole diameter and roundness

The diameter of drilled holes has been reported to increase when the cutting speed, feed rate and point angle increase [25]. The increase in cutting speed and feed rate leads to the increase in the oversized hole because of the vibrations that are induced at higher speed and feed rate [10, 26]. HSS drills have been reported to produce undersized holes compared to carbide drills [26]. Therefore, carbide drills are recommended for drilling the Al alloy to produce holes within the required tolerance. The authors conducted a drilling experiment on Al 7075-T6 (thickness of 13 mm) using 6.5 mm diameter carbide tools with two different feed rates of 0.01

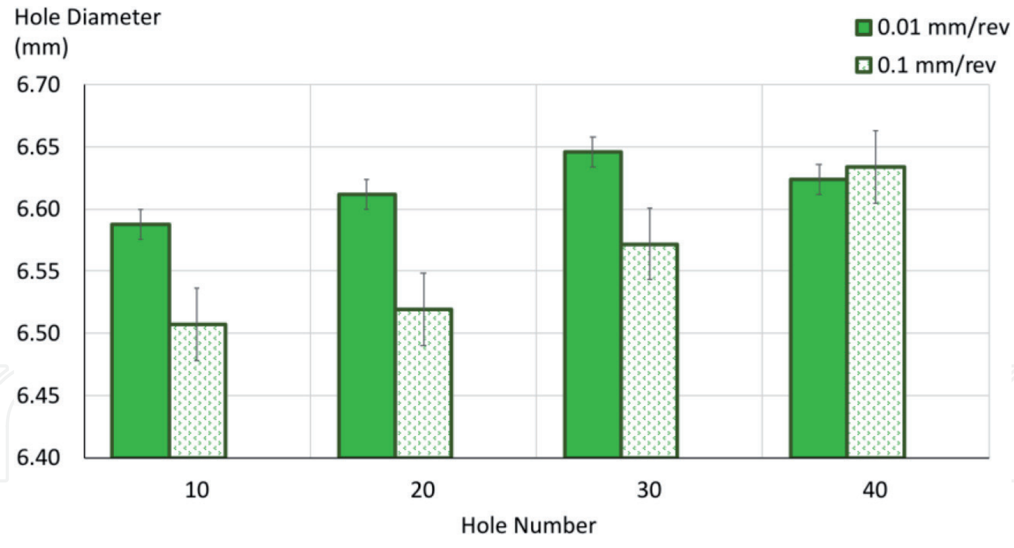

Figure 8.
The effect of feed rate on hole diameter in drilling Al 7075-T6 (heat-treated) at a constant cutting speed of 120 m/min and 6.5 mm diameter carbide cutting tools.

and 0.1 mm/rev at a constant cutting speed of 120 m/min. The drilled hole diameters were measured and results are shown in **Figure 8**. Increasing hole numbers resulted in increasing hole diameter, which is likely caused by the increased chip adhesion on the cutting tool. Generally, the use of a higher feed rate of 0.1 mm/rev resulted in more accurate hole diameters closer to the tool nominal diameter of 6.5 mm.

In addition, hole roundness is also an aspect that determines the drilled hole quality. The roundness of the hole is defined as how closely the hole matches a perfect circle, which can be determined by measuring the consistency of the hole diameters at various orientations. The hole roundness error has been reported to be significantly influenced by the feed rate [15]. Based on [15], which conducted experiments on drilling aluminum alloy using a 6 mm diameter drill, the hole roundness error was found to be lower (0.030–0.038 mm) when using a lower feed rate of 0.04 mm/rev compared to the higher feed rate of 0.08 mm/rev which causes higher roundness error (0.05–0.06 mm). However, no significant difference in the roundness error was observed when cutting speeds changed from 25 to 50 m/min [15]. Therefore, using a low feed rate is recommended to ensure the hole is produced with minimum dimensional error. However, as cutting speed is likely to have less effect on the hole diameter, a higher cutting speed is recommended to improve productivity. Nevertheless, the tool wear needs to be observed as the material adhesion could also affect the hole dimensional accuracy.

7.2 Surface roughness

The machined surface typically contains irregularities and deviations from the desired form due to the machining operations, cutting parameters, and cutting conditions used. These deviations are normally assessed as roughness. The surface roughness acts as an indicator to determine the quality of the holes and surface finish. Cutting parameters are seen to be the most critical factor that could affect the surface roughness. The authors conducted a drilling experiment on Al7075-T6 in two different conditions (dry and with chilled air) and different cutting parameters to determine their effects on the machined surface roughness (Ra). The pressure and flow rate of the chilled air that was used during the drilling were 14 m/s and 6.9 bar, respectively. The surface roughness results, which were measured in terms of Ra are shown in **Figure 9**.

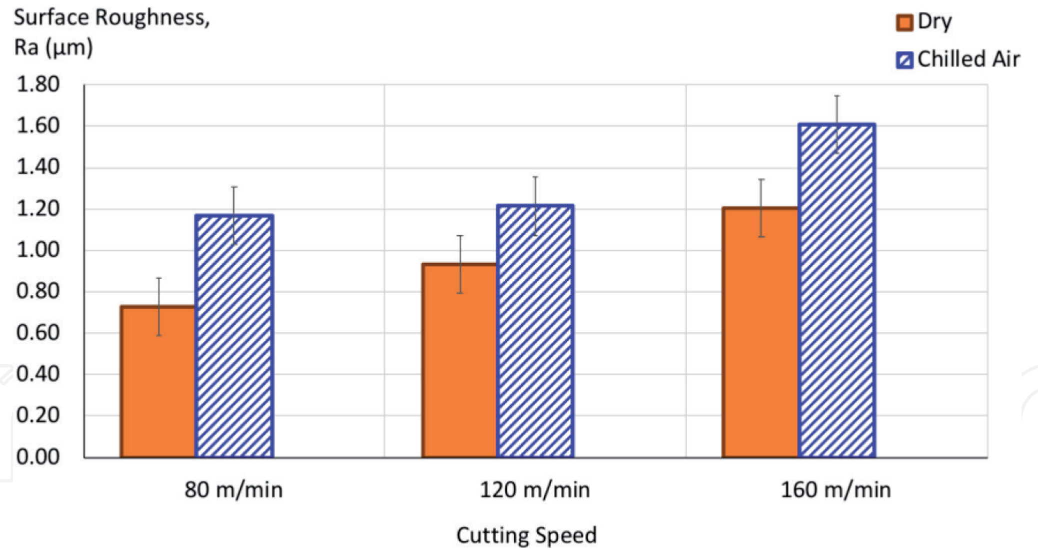

Figure 9.
The effect of cutting speed and condition on surface roughness (Ra) in drilling Al 7075-T6 (heat-treated) using cutting speeds of 80, 120 and 160 m/min at a constant feed rate of 0.05 mm/rev and 6.5 mm diameter carbide drills.

Increasing cutting speed from 80 to 120 and to 160 m/min resulted in increasing surface roughness by the values as shown in **Figure 9**. This is supported by a previous study [12], which also conducted drilling of Al 7075 alloy with three parameters which are cutting speeds (within range of 40 to 120 m/min), feed rates (within range of 0.05 to 0.15 mm/rev), and point angle (within range of 120 to 140°). It was found that an increase in cutting speeds from 40 to 120 m/min at a constant feed rate of 0.05 mm/rev and point angle of 140° resulted in increased surface roughness value, Ra from 0.5 to 1.16 µm. During drilling operation at higher cutting speeds, the ductility properties of aluminum alloy will increase because of the higher heat generated that is caused by, the higher spindle speed and energy. The higher cutting temperature causes thermal

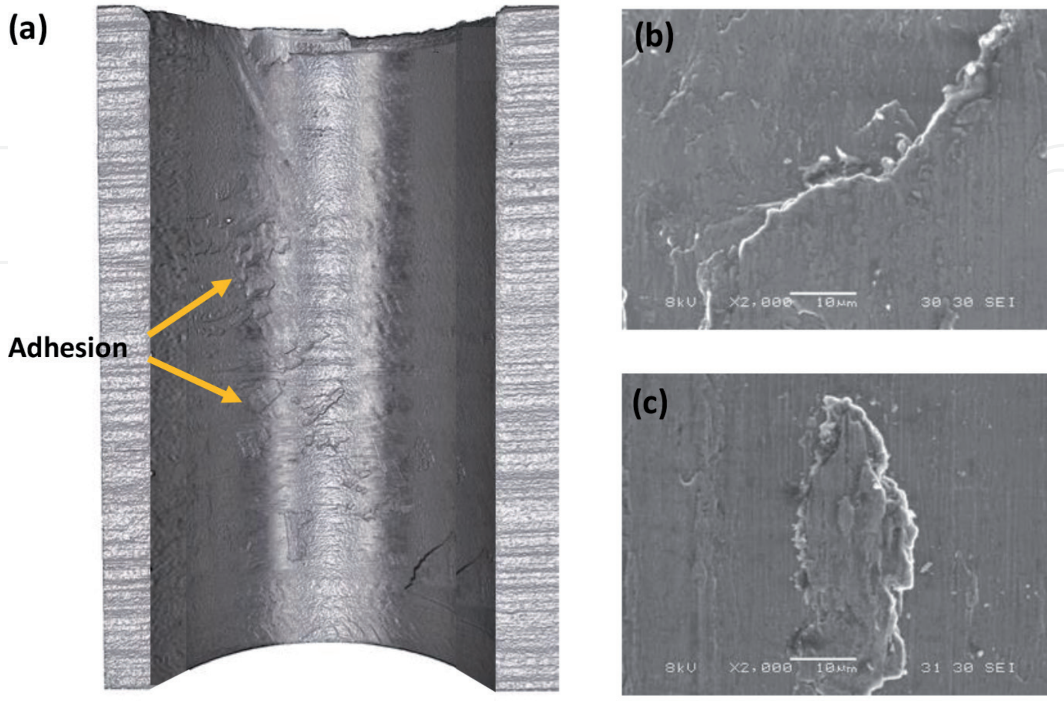

Figure 10.
Thermal softening and material adhesion on the machined surface of Al 7075-T6 caused by drilling operations at high cutting speed (a) 5x magnification (b, c) 2000x magnification.

softening of the workpiece, consequently, more material adhesion on the machined surface, as shown in **Figure 10**, hence higher surface roughness (Ra).

Furthermore, the increasing feed rate when drilling Al 7075-T6 was also found to result in increased surface roughness, as shown in **Figure 11**. The material removal rate increases when the feed rate increases, which leads to higher cutting forces hence poor surface finish of drilled holes and higher Ra value. Whereas, using chilled air (10°C) during drilling resulted in 25–60% higher Ra than dry drilling, as can be seen in **Figures 6** and **8**. Therefore, using chilled air in drilling Al 7075 is not favorable in terms of surface finish. This is likely due to chilled air causing which works hardening of the chip, which causes poor machined surface finish as the chip evacuates from the holes. The higher Ra when using a higher feed rate is typically due to the feed mark on the machined surface as shown in **Figure 12**. The application of high-pressure internal water-based cutting fluid has been recommended in drilling aluminum alloy to result in lower surface roughness [27]. The assistance of high-pressure cutting fluid (i.e., with a pressure of 50 bar) can improve chip evacuation hence less tendency of the chip scratching the machined surface. However,

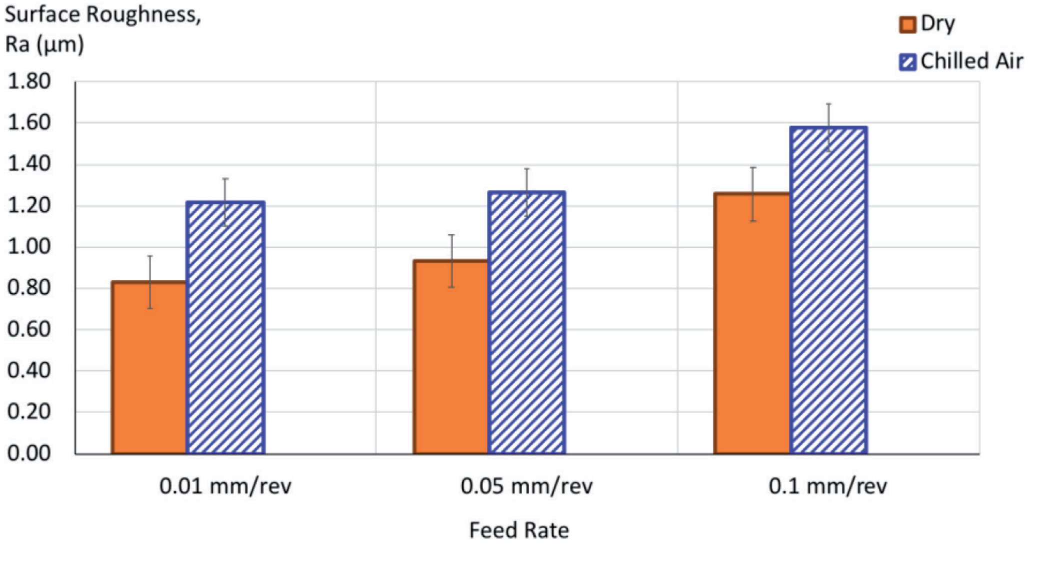

Figure 11.
The effect of feed rate and condition on surface roughness (Ra) in drilling Al 7075-T6 (heat-treated) using feed rates of 0.01, 0.05 and 0.1 mm/rev at a constant cutting speed of 120 m/min and 6 mm diameter carbide drills.

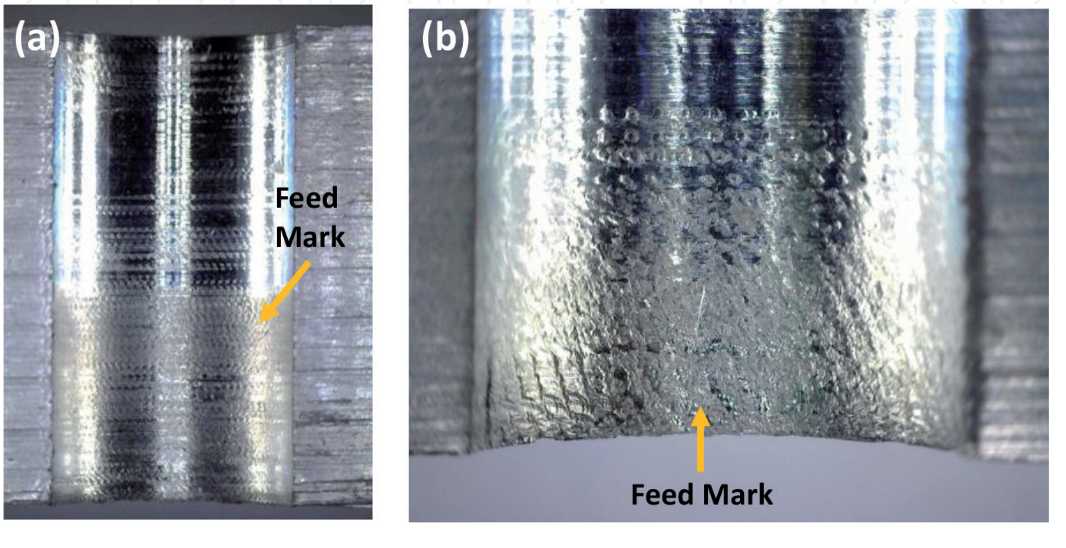

Figure 12.
Feed mark on the machined surface of Al 7075-T6 (heat-treated) caused by drilling at a high feed rate of 0.1 mm/rev; (a) the surface of the drilled hole that was sectioned into a half (b) the hole exit.

careful handling and appropriate fluid disposal must be practiced to avoid environmental pollution and health issues to operators.

7.3 Burr formation

Burrs are the common defect that occurred due to the machining process. A burr is the protrusion of workpiece material typically at the hole edges (entry and exit of the hole), as shown in **Figure 13a** and **b**. The burr height is measured as indicated in **Figure 13b**. The burr is hard and sharp, which can cause difficulty in assembly and may cause injury to the operators. Therefore, the burr is unwanted and needs to be deburred to ensure the good assembly of the parts.

The machining process could result in primary and secondary burrs. The primary burr occurs during the drilling operations after the material has been removed by the cutting edges. The secondary burr is the remaining material at the edge of the drilled hole after breakage of the primary burr due to deburring process. The formation of burr depends on the cutting parameters (cutting speed and feed rate), ductility of workpiece material, and tool geometry especially point angle. The authors experimented on dry drilling of Al 7075-T6 using carbide drills and it was found that using a higher cutting speed of 120 m/min generally resulted in a higher burr compared to 80 m/min, as shown in **Figure 14**. This is likely due to an increase

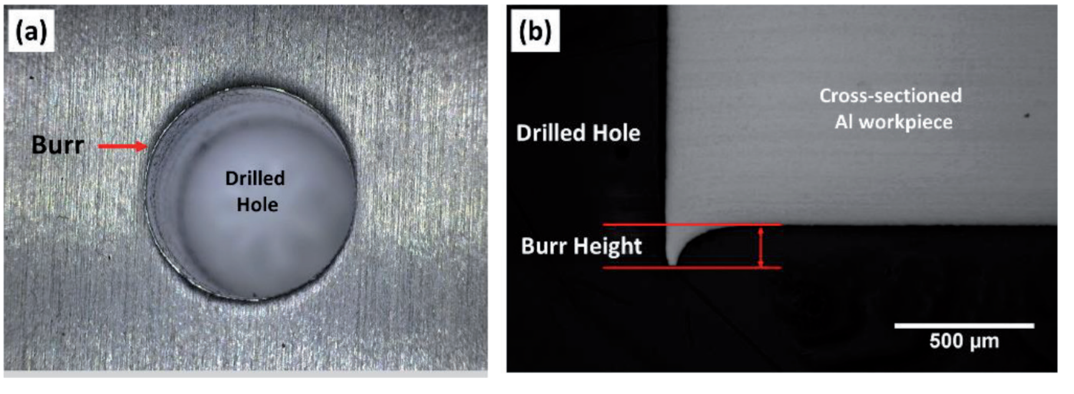

Figure 13.
(a) Burr at the edge of the drilled hole (b) Burr height which is measured after the hole was sectioned into a half.

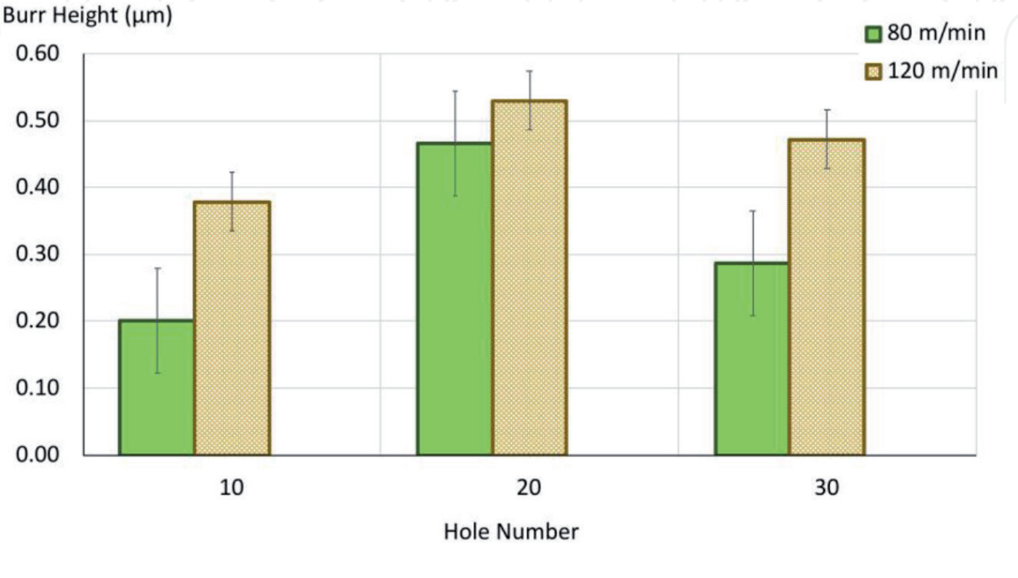

Figure 14.
The burr height when drilling Al 7075-T6 (heat-treated) using cutting speeds of 80 and 120 m/min at a constant feed rate of 0.05 mm/rev.

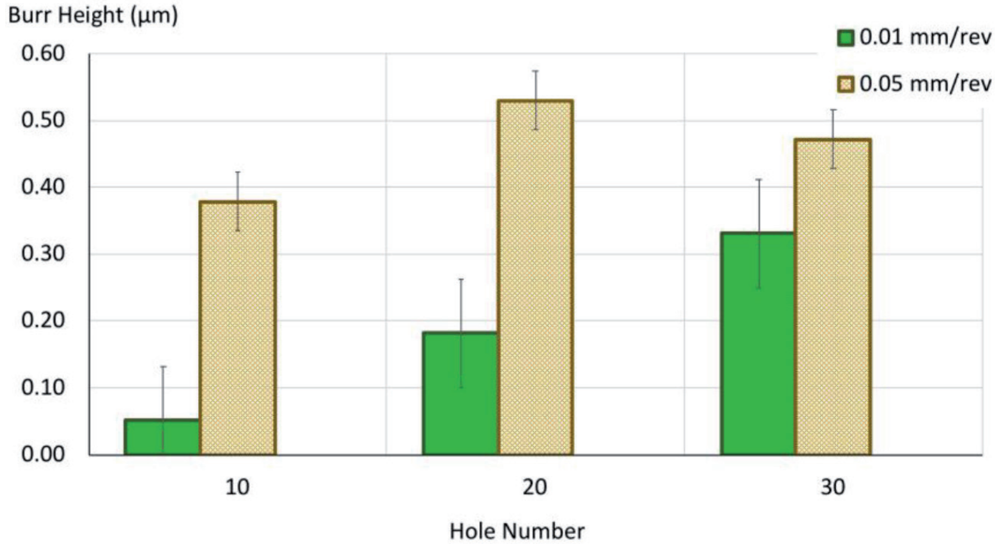

Figure 15.
The burr height when drilling Al 7075-T6 (heat-treated) using feed rates of 0.01 and 0.05 mm/rev at a constant cutting speed of 120 m/min.

in ductility of the alloy as more heat is generated with a higher cutting speed, causing the material to project at the edge [28]. In addition, the burr formation can also be influenced by feed rate. As shown in **Figure 15**, the usage of a higher feed rate of 0.05 mm/rev resulted in higher burr compared to the lower feed rate of 0.01 mm/rev. This is likely due to the higher volume of material removed.

A previous study [7] on the burr formation of Al 5083 caused by cutting parameters has also been conducted, in which the finding could be related to the case of Al 7075. Feed rates within the range of 0.04 to 0.14 mm/rev and cutting speed range within 19 to 57 mm/min were used [7]. It was found that the feed rate highly influences the growth of burrs during drilling compared to cutting speed. Drilling at feed rate 0.14 mm/rev with 57 m/min cutting speed produced high burr formation, which is 7 µm, while drilling at 0.04 mm/rev feed rate produced the lowest burr formation which is 3.8 µm. The burrs resulting from drilling Al 5083 were observed to be more visible at the exit holes compared to entry holes. Therefore, using a low cutting speed and feed rate in drilling Al 7075 could be beneficial to minimize the burr formation, however, this may cause low productivity in the industry.

8. Future development in drilling technology

Drilling operations have always been necessary for the manufacturing and assembly of mechanical components, which are made of aluminum alloys. This motivates the industry and researchers to further investigate the drilling technology that can produce good hole quality with longer tool life, hence optimizing productivity. Ultrasonic Assisted Drilling (UAD), which employs a cutting tool that is vibrated during the material removal process, has been receiving attention in the industry. The application of UAD on high-performance materials, including aluminum alloys, Carbon Fiber Reinforced Polymer (CFRP), and titanium alloys, has shown potential to reduce tool wear, reduce thrust forces and increase material removal rate, which is reported to be due to intermittent cutting and reduced chip resistance [21, 29]. In addition, the use of cryogenic coolant (i.e., carbon dioxide and liquid nitrogen) could be useful to facilitate heat removal during the drilling process, especially for deep hole production, which could result in less material adhesion and improved hole surface finish. Therefore, further research involving these drilling technologies, particularly on aluminum alloys, is necessary for industrial applications.

9. Conclusions

In conclusion, tool wear and hole quality of drilled holes of Al 7075 are highly influenced by cutting parameters, cutting tool and conditions during the drilling operations. Results showed that lower cutting speed and lower feed rate are favorable to produce low tool wear and better hole quality in terms of diameter, roundness, surface roughness and burr. Low cutting speed causes less heat generation, hence there is less tendency of chip adhesion on the cutting edges and machined surfaces. This can result in low surface roughness as well as less bur formation, therefore leading to good hole quality. Whereas, low feed rate means there is less material removed per one rotation of the tool, which results in a smaller chip, better chip evacuation, low cutting forces and hence good machined surface finish. However, it is important to note that when using lower cutting speed and lower feed rate, the workpiece cutting length per minute is slower, and this leads to longer time consumption in producing the hole. To improve productivity, higher cutting speed and feed rate may be used in drilling Al 7075, however, cutting fluid should be used to dissipate the heat and facilitate chip evacuation hence producing good hole quality. Nevertheless, careful consideration needs to be taken in handling and disposing of the fluid to avoid environmental pollution and also health issues to the operators.

Acknowledgements

This publication is supported and funded by the Ministry of Higher Education Malaysia and International Islamic University Malaysia (IIUM) under Fundamental Research Grant Scheme, FRGS/1/2018/TK03/UIAM/03/5.

Conflict of interest

The authors declare no conflict of interest.

DOI: http://dx.doi.org/10.5772/intechopen.102864

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