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Influence of different types of sharpening in straight flute drills on burr formation

Rodrigo Barros de Borba, Sergio Luiz Moni Ribeiro Filho and Lincoln Cardoso Brandão*

*Centro de Inovação em Manufatura Sustentável, Universidade Federal de São João del-Rei, Praça Frei Orlando, 170, 36307-352, São João del-Rei, Minas Gerais, Brazil. *Author for correspondence. E-mail: lincoln@ufsj.edu.br*

ABSTRACT. Drilling is among the most important manufacturing processes in modern industry. Information on the dynamics of the drilling process is very important to define optimum input parameters. The minimization of burrs is a great challenge in drilling process. Current analysis was carried out with stepped solid carbide drills with straight flutes in drilling of the aluminum alloy A306. Burr height was measured at hole exits and evaluated with ANOVA technique. Results showed that the feed rate and cutting speed variation exhibited significant influence while sharpening was the most important parameter on burr formation.

Keywords: drilling, burr, SAE A306 aluminum alloy, sharpening angles, straight flute.

Influência de diferentes tipos de afiação em brocas de canais retos na formação de rebarbas

RESUMO. O processo de furação está entre os mais importantes processos de manufatura na indústria moderna. O conhecimento na dinâmica do processo de furação é muito importante para definir os parâmetros ótimos de entrada. O grande desafio encontrado no processo de furação é a minimização de rebarbas. Este estudo foi realizado com brocas escalonadas de metal duro com aresta de corte reta na furação da liga de alumínio A306. A altura da rebarba foi medida na saída dos furos e foi avaliada usando a técnica de ANOVA. Os resultados mostram que o avanço e a velocidade de corte apresentam significante influência e a afiação das brocas foi o parâmetro mais importante na formação de rebarbas.

Palavras-chave: furação, rebarba, liga de alumínio A306, ângulo de afiação, aresta reta.

Introduction

Drilling is one of the most important processes in modern industry even though it is the last item performed within the manufacturing process. Traditionally, twist drills have been used in most manufacturing processes due to their high flexibility. According to Sambhav, Tandon, and Dhande (2012) geometric modeling of the tool is a very crucial part of tool design because its geometry affects surface roughness and burrs. Paul, Kapoor, and DeVor (2005) studied the optimization of chisel edge and cutting lip shape in drills and found a 40% reduction in thrust force and torque when drill point geometry is optimized. Thrust force and process dynamics are highly relevant to define input parameters and predict tool life. Gong, Li, and Ehmann (2005) studied the dynamics of initial penetration in drilling with twist drills and verified that cutting speed at the chisel edge is small when compared to the main cutting edges. Moreover, the effect on feed rate may no longer be neglected in this region.

The analysis of drill geometry is strongly linked to burr due to its influence on chip and burr formation. Kilickap (2010) studied the modeling and optimization of burr height in the drilling of 7075 aluminum alloy and stated that lower feed rates and cutting speeds are preferred.

Aurich et al. (2009), state that burrs are sharp and may cause small injuries on finger to assembly workers. Furthermore, they may become loose during operation on a product and provoke damages. Some helpful devices have been employed to minimize burr height and improve the surface quality. However, many researches on burr formation, surface roughness, thrust force and torque have been carried out with twist drills, because straight flute drills are not frequently used in industries nowadays.

According to Jung and Ke (2007), the straight flute design, such as that in gun drills, adds strength to the drill and reduces the distance the chip must travel to escape the bore, when compared to twist drills. Current assay analyses drilling on SAE 306 aluminum alloy with straight flutes and different sharpening angles.

Material and methods

Experiments were carried out on workpieces of SAE A306 aluminum. Stepped solid carbide drills with straight flutes and two diameters 3.9 and 9.75 mm were used. Three different types of sharpness, 'A', 'N' and 'R', were used in drilling tests. Figure 1 displays the geometry of the drills used in the experiments.

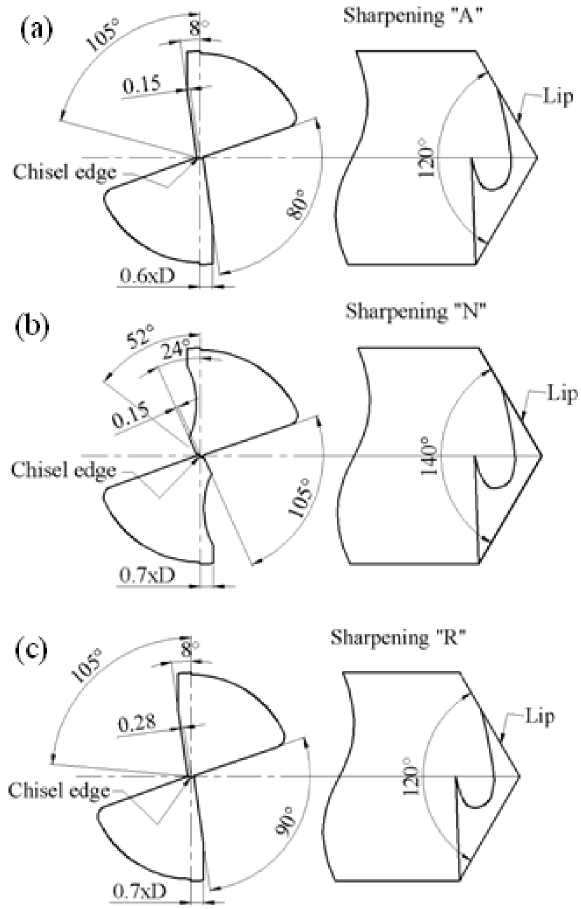

Figure 1. Different sharpening used in experimental tests; a) sharpening 'A'; b) sharpening 'N'; and c) sharpening 'R'.

A factorial design, type 3^3 2^1 (162 drilling experiments) with three replicates, was performed to examine the effect of input parameters; feed rate (0.1, 0.15, and 0.2 mm rev^{-1}), cutting speed (50, 80 and 100 m min^{-1}), type of sharpening ('A', 'N' and 'R'), and drills coated with TiN, and uncoated drills. The response was burr dimension measured at the end of the holes. Burr height was measured in micrometers with an optical microscope model TM 500, manufactured by Mitutoyo.

Results and discussion

Figure 2 exhibits the main effect plots for the burr formation response. Figure 2a shows the effect of the feed rate on the burr formation, with a perceptual variation of 83% between the feed rate of 0.1 and 0.2 mm rev^{-1}. This behavior may be explained by an increase in chip thickness, which according to Hashimura, Hassamontr, and Dornfeld (1999), causes increase in the deformation zone prior to crack growth along the cutting line. On the other hand, a 141% increase between cutting speeds 80 and 100 m min^{-1} was observed, as Figure 2b reveals.

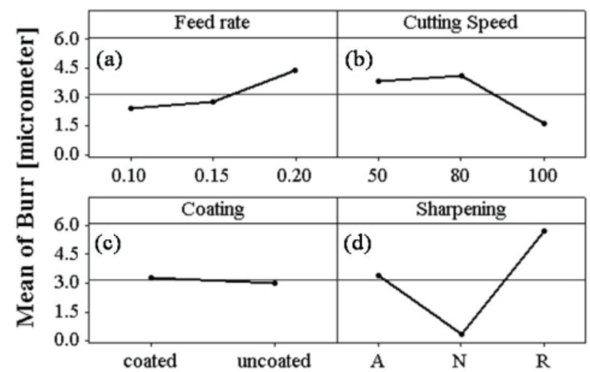

Figure 2. Main effect plot for burr formation taking into consideration feed rate, cutting speed, coating and sharpening.

Ko and Dornfeld (1991) reported a similar situation in which the burr size was reduced when the cutting speed increased during the orthogonal cutting of the ductile material. Crack propagation is different for ductile and brittle materials. According to Aurich et al. (2009), the crack in a machining process initiates at the tool tip, exactly on the primary shear zone, since ductile materials have a large critical fracture strain. Furthermore, the same authors report that the use of high-speed cutting in the machining of aluminum and its alloys causes good surface quality and small burrs.

Figure 2c demonstrates that coating of drills had no significant influence on burr formation since rates are near the midline with no significant difference. According to Rivero, Aramendi, Herranz, and Lacalle (2006), the Balinit Hardlube coating (TiAlN + WC C^{-1}) decreases the torque at the end of the hole and reduces the burr size. However, coating TiN used in these experiments failed to provide the same effect and demonstrated that the burr formation is related not only to the type of material but also to type of coating.

Finally, it may be presumed that sharpening was the most input parameter affecting burr formation. Sharpening 'N' showed an 862% reduction when compared to sharpening 'A' and a 1,534% reduction when compared to sharpening 'R'. The larger burr measured for sharpening 'N' was 0.35 μm, while the burr sizes were 3.37 and 5.72 μm respectively for sharpening 'A' and 'R'. The burr formed when a sharp drill exits at the workpiece was a Poisson burr which, according to Aurich et al. (2009), tended to decrease the burr formation by increasing the point angle due to the reduction of rubbing at the drill margins.

Figure 3 shows the interaction effect plot for feed rate, cutting speed, coating and sharpening. Figure 3a shows an interaction effect plot of 'feed rate vs. cutting speed'. A decrease of burr height when drilled with high-speed cutting may be observed, except for feed rate of 0.15 and 0.20 mm rev^{-1} with a cutting speed of 80 m min^{-1} that provided an increase of the burr. Therefore, the best choice to minimize burr formation is low feed rate with high cutting speed. Figures 3b and d present the interaction effect plot for 'feed rate vs. coating' and 'cutting speed vs. coating'. The use of coated or uncoated tools did not show any significant influence on burr formation.

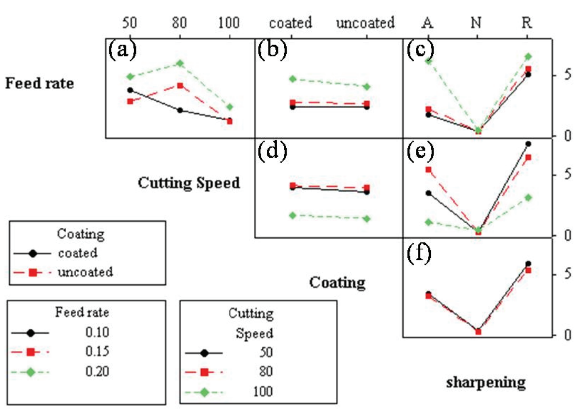

Figure 3. Interaction effect plot for burr size for feed rate, cutting speed, coating and sharpening.

In the wake of statistical analysis, it may be presumed that coating did not influence burr formation when input parameters, such as feed rate, cutting speed, and sharpening, were changed. However, the use of low feed rate (0.10 mm rev^{-1}) in the first interaction effect plot and high cutting speeds (100 m min^{-1}) in the second interaction effect plot demonstrated the lowest burr height. Figures 3c, e, and f exhibit the interaction effect plot for 'feed rate vs. sharpening', 'cutting speed vs. sharpening' and 'coating vs. sharpening'.

In fact, sharpening 'N' provided the lowest burr height. When the interaction effect plot was taken into account, sharpening 'N' generated a range of burr height ranging between 0.185 and 0.455 μm. Results confirm study by Dornfeld, Kim, Dechow, Hewson, and Chen (1999), or rather, increase in point angle causes a significant reduction in burr height and burr thickness in the drilling of non-ferrous metals.

Figure 4 shows some examples of burr height at the end of the hole. Figure 4a represents the burr height for sharpening 'N' with cutting speed 80 m min^{-1}, feed rate 0.2 mm rev^{-1} and TiN coating. Figure 4 b shows sharpening 'N' for cutting speed 80 m min^{-1}, feed rate 0.1 mm rev^{-1} and uncoated drill. Results represent the range of burr height for sharpening 'N' in which highest value was 0.455 μm due to feed rate 0.2 mm rev^{-1}. The use of lower feed rate and high cutting speed provided a maximum burr height 0.185 μm. On the other hand, Figure 4c and d show the burr height for sharpening 'A' and 'R'.

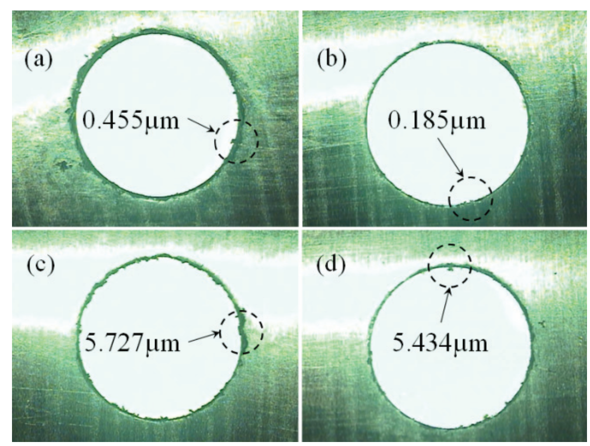

Figure 4. Details of burrs; a) Sharpening 'N', Vc = 80 m min^{-1}, f = 0.2 mm rev^{-1} TiN coating; b) Sharpening 'N', Vc = 80 m min^{-1}, f = 0.1 mm rev^{-1} uncoated drill; c) Sharpening 'A', Vc = 50 m min^{-1}, f = 0.1 mm rev^{-1} uncoated; and d) Sharpening 'R', Vc = 50 m min^{-1}, f = 0.2 mm rev^{-1} TiN coating.

Variation in type of coating or in the input parameters does not produce burr height with sizes smaller than sharpening 'N'. In summary, sharpening 'N' provides the lowest burr height due to two strategic parameters: point angle and geometry of lips. The chisel edge angle in sharpening 'N' is 52° and provides the lowest chisel edge of the three types of sharpening. Moreover, lips in sharpening 'N' have an edging curve in the opposite situation of sharpening 'A' and 'R' which are straight.

The edging curve generates a spin in chip during its removal and facilitates the burr clearance from the center to the outer diameter. This effect contributes to the pivoting of the burr due to the large deformation in the plastic zone at the edge of workpiece. Furthermore, point angle controls burr height at the end of holes. Increase of point angle provides uniform burrs without drill caps. However, a significant increase of the point angle may generate crown burrs that are more complex to remove than uniform burrs.

Conclusion

Current study showed the influence of input parameters and drill geometry in the minimization of burr formation in the drilling of SAE 306 aluminum alloy. The main conclusions are:

A) Feed rate and cutting speed variation affected significantly burr formation. Low feed rates and high cutting speeds provided the lowest burr height.

B) Two types of drills were used, uncoated and coated with TiN. However, results demonstrated that coating did not influence burr formation.

C) Sharpening was the most important and influential parameter on burr formation. Sharpening 'A' and 'R' showed the greatest rates for burr height.

D) Sharpening 'N' demonstrated lowest burr rates. Drills with sharpening 'N' have a curved cutting edge and high point angles, which minimize burr formation.

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