Experimental Investigation on the Effect of Pre-holes on Drilling Process Performance of Aluminum Alloys: Forces, Surface Finish and Dust Emission

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***Abstract*-In most drilling applications, pre-holes are often performed prior to the final hole drilling in order to obtain holes with good quality (dimensional accuracy, surface finish, and reduced burr). While this operation can improve the process stability, it might however also have an impact on process performance indicators such as dust emission, energy required for the drilling process, cycle time and chip breakability.**

This work investigates the effects of pre-holes on cutting forces, chip formation, surface finish and dust emission. Aluminum alloys (6061-T6 and 7075-T6) were drilled at different cutting speeds using uncoated HSS drills and the thrust forces, dust emissions and surface finish were analysed. It was found that drilling with pre-holes reduced the cutting forces, improved hole surface finish and chip breakability, and increased the total amount of metallic particle emission.

Keywords- Aluminium; Dry Drilling; Pre-hole; Thrust Forces; Surface Finish; Dust Emissions

NOMENCLATURE

ϕ (10): Drilling hole of 10 mm diameter
ϕ (4): Drilling hole of 4 mm diameter
ϕ (2): Drilling hole of 2 mm diameter
ϕ (10-4): Drilling hole of 10 mm diameter after a 4 mm diameter pre-hole
ϕ (10-2): Drilling hole of 10 mm diameter after a 2 mm diameter pre-hole
ϕ (2) + ϕ (10-2): Process performance indicators (thrust forces, surface finish and particle emission) for ϕ (2) and ϕ (10-2)
ϕ (4) + ϕ (10-4): Process performance indicators (thrust forces, surface finish and particle emission) for ϕ(4) and ϕ(10-4)
Fz: Thrust force (N)
Ks: Specific cutting force (MPa)
f: Feed rate (mm/rev)
ϕ: Radial depth of cut (mm)
Kr: Tool point angle (degree)
R_a: Average Roughness (μm)

I. INTRODUCTION

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Today, manufacturing processes need to be constantly evaluated and optimized in terms of new tooling, new machining strategies or new process performance indicators, such as those related to environmental and occupational safety [1-6]. This task will impact the machining process window, the parameter level, the quality and the machining cost.

The machinability of an alloy defines its ability to be machined or shaped using a cutting tool [7]; it can be evaluated based on tool wear, tool life, productivity, part quality, cutting forces and chip formation. Mahdy [8] established a logic algorithm for determining the optimum values of cut for both pre-drilling and enlarging, which gives maximum productivity and satisfies the imposed constraints and leads to the minimum possible manufacturing cost of both drilling and electrochemical deburring. Consequently, the result analysis of his work showed that burr can be reduced to a minimum value or will approach zero following proper selection of pre-drilling and enlarging or chamfering/countersinking. Sometimes, because of the hole quality or because there is no energy left for machining, a smaller diameter pre-hole is drilled to achieve the desired hole size with a large tool diameter. The drilled hole quality has a much greater effect on fatigue life than does residual stress, and the pre-hole greatly reduces machining marks, which are the most significant factor in fatigue life [9]. These differences are due to the

DOI: 10.5963/AMSA0301003

reduction in the material to be removed by the primary bit and the path that the pre-hole provides for the primary bit. The length of the bit also produces a significant difference in drilled hole quality, while a short bit generally improves hole quality due to a smaller possible deflection of the tip of the bit [10]. The surface finish is an indicator of the quality of the material following the machining process. In their work, Okasha et al. [11] found that the cutting speed has the highest effect on hole cylindricity. DeChiffre [12] showed that a higher feed rate leads to lower and more repeatable roughness, but at the same time, to higher and less repeatable reaming thrust and torque.

Dilley et al. [13] showed an increase of the drill natural frequency as a function of hole depth to predict the tool stability. The frequency increase was attributed to the margin of the interaction with the hole, as the frequency shift did not occur when drilling tubes. Novakov and Jackson [14] showed that it is necessary to incorporate axial-torsional, lateral, and bending vibrations into one system, as well as other influential parameters, such as the chisel edge, the margin effect, the pre-hole size, tool grinding errors, misalignment, etc. Tsao and Hocheng [15] indicated that the critical thrust force was reduced with pre-drilled holes and largely reduced by removing the chip effect. Tsao [16] identified the role of the pre-hole in reducing the thrust force induced during saw drilling. It was shown that the critical thrust force reduced with the increase in the pre-hole ratio when it is above 50% [17]. Won and Dharan [18] investigated the effect of the chisel edge of the drill with and without pre-holes drilled on the overall thrust force. They showed that the presence of a pre-hole reduced the applied thrust force drastically, allowing for the use of much higher feed rates. Hamade et al. [19] used the inherent variation of speed and rake angle over the lip in extracting the cutting force coefficients by performing a few drilling experiments on drilled pre-holes.

In the case of chip formation and chip breakability, several research works have been done in order to identify the optimal conditions for improving machining and machinability. Hua [20], Sandstrom et al. [21] and Trent [22] found that at low speeds, the crack propagated towards the tip of the tool because of the high hydrostatic stresses, and tended to produce a discontinuity in the chip. They showed that the high temperature on the surface of the tool caused a thermal softening effect, and no crack therefore occurred on the side of the tip tool. Xie et al. [23] developed a coefficient identifying chip segmentation that could be used for evaluating and predicting the onset of instability of the chip.

In today’s metal cutting industry, a major concern is the occupational safety and health hazard associated with cutting fluids usage and metallic particle emission. Dry machining has become an increasingly viable machining operation in commercial manufacturing sectors, and is used to further decrease costs and reduce the environmental pollution caused by oil-based cutting fluids [24]. The process produces fine and ultrafine metallic particles, also called dust, which can harm the health of operators as well as the environment [1, 3, 25 and 26]. In this subject area of activity, Ren and Liu [5] showed in their research study that particle emission (PM2.5, less than 2.5 μm in size) from dry machining could penetrate deep into human lungs and cause various diseases.

Machining processes must be improved to achieve safe, economical and environment-friendly machining. Sutherland et al. [1] showed that particle emission is high in wet machining, as compared to dry machining. Songmene et al. [25] and Balout et al. [27] found that a ductile material generates more fine and ultrafine particles than a brittle material because of the chip formation process; discontinuous chip formation leads to lower particle emission than does the longer chip. Songmene et al. [28] also showed that the machining strategies commonly used in industry (such as peak drilling, drilling with pre-holes and machining with variable parameters) that affect chip formation and influence dust emission. A simple process like drilling may be improved substantially by an investigation of dust.

The main objective of this work is to examine the influence of pre-hole size and different cutting speeds on cutting forces, part quality, chip formation and metallic particle emission during dry drilling of wrought aluminum alloys (6061-T6 and 7075-T6). A literature review shows that no comparable work has been done on this subject matter.

II. EXPERIMENTAL PROCEDURE

Drilling tests were carried out on two aluminum materials (i.e., 6061-T6 and 7075-T6). The cutting forces were measured using a dynamometric table connected to a computer. The machining unit used consisted of a CNC drilling machine (12000 rpm maximum speed cutting), with a Plexiglas box of 30x30x20 cubic centimeters added to the table in order to allow the drilling process to be carried out in a closed environment (Fig. 1). This increased the measurement efficiency as less dust was able to escape into the environment. Polluted air within the closed box was dragged into the dust measurement unit through a 10 mm diameter polyester tube. The tube was short and kept straight to minimize dust loss in the tube. Particle emission (total mass concentration) was measured using Dusttrak Aerosol Monitor equipment Model 8530, in which a 2.5 μm diameter impactor was used, and at 1.5 l/min flow rate. The roughness values were obtained using Mitutoyo S-J400 equipment. For each hole, the measurement was performed four times, and the average value of the four measurements was taken into account.

The following cutting conditions and parameters were used during machining:

- Cutting speed: 1000 –10000 rpm
- Feed rate: 0.058 mm/rev
- Cutting depth: 12.75 mm

DOI: 10.5963/AMSA0301003

- Drill: HSS, 2, 4 and 10 mm diameter, 118 °point angle, no coating
- Lubrication: none

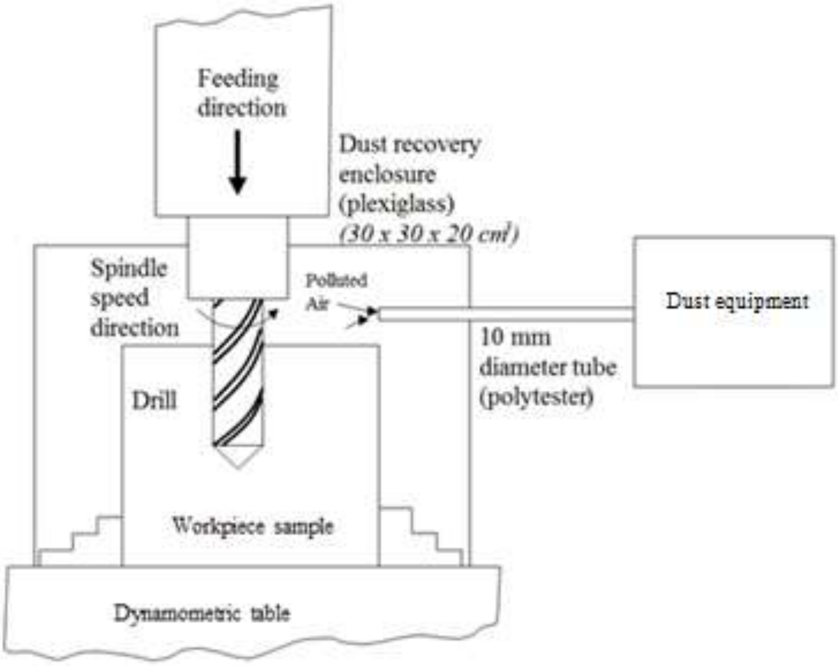


Fig. 1 Experimental setup

III. RESULTS AND DISCUSSION

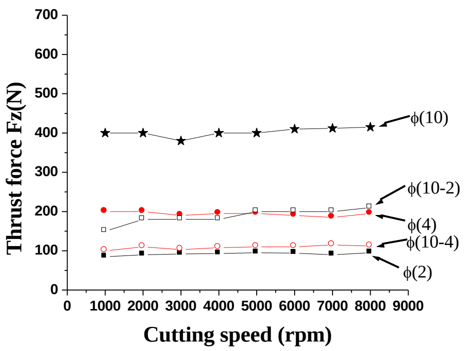
A. Cutting Forces

Fig. 2 presents the resulting thrust forces of 6061-T6 and 7075-T6 aluminium recorded during the drilling tests. For both materials, as illustrated in Fig. 2, it is observed that the thrust force is independent of the cutting speeds for the tested conditions, but it is impacted by tool geometry, working materials and radial depth of cut. The thrust force Fz could be expressed by Eq. (1) as follows [7]:

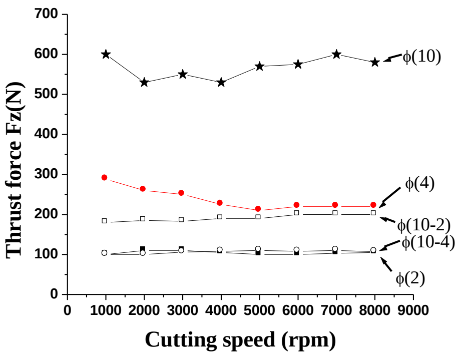
$$Fz = K_s. f. \phi. \sin(K_r/2), \quad (1)$$

where K_s is the specific cutting force, which is a workpiece material property; f is the feed rate; ϕ is the radial depth of cut, depending on the pre-hole size and final hole; and K_r is the tool point angle.

Eq. (1) shows that for both materials, at the same feed rate and tool point angle, the thrust force Fz increases as the radial depth of cut ϕ increases. This observation could be due to the fact that the plastic deformation is great in ϕ(10), as compared to ϕ(4) and ϕ(2). It was also observed that after a pre-hole performed with ϕ(10-2) and ϕ(10-4), the thrust force was high for ϕ(10-2), as compared to ϕ(10-4), for both materials. This observation could be due to the fact that after a pre-hole, there is more removable material in ϕ(10-2), as compared to ϕ(10-4).



(A) Al. alloy 6061-T6



(B) Al. alloy 7075-T6

Fig. 2 Thrust force Fz at different cutting speeds for 6061-T6 and 7075-T6 materials

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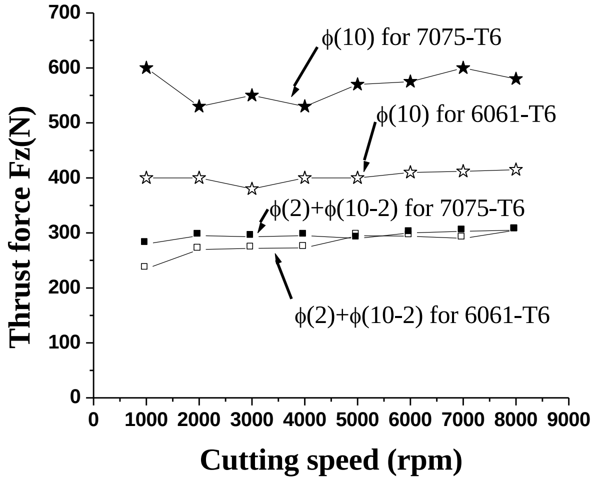
Fig. 3 presents the thrust force Fz comparison for 6061-T6 and 7075-T6 after 2 and 4 mm pre-holes, respectively. In Fig. 3, the thrust force Fz for $\phi(2) + \phi(10\text{-}2)$ represents the sum of the thrust force recorded when drilling with a 2 mm tool diameter followed by a 10 mm tool diameter final drill and Fz for $\phi(4) + \phi(10\text{-}4)$ represents the sum of the thrust force recorded when drilling with 4 mm tool diameter followed by a 10 mm tool diameter final drill, respectively.

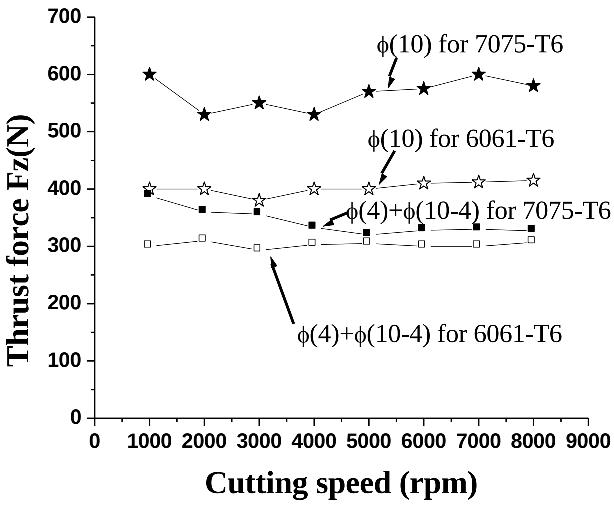
It is observed in Fig. 3 that for $\phi(10)$, the thrust force was high in 7075-T6, as compared to that in the 6061-T6 material. This observation can be attributed to their mechanical property difference. In Fig. 3a (after a 2 mm pre-hole), the thrust force in the case of $\phi(2) + \phi(10–2)$ was high at low cutting speeds (less than 5000 rpm) for 7075-T6, as compared to the 6061-T6 material, and the thrust forces are similar for both materials at a cutting speed up to 6000 rpm. In this case there is no real influence of the material mechanical property.

In Fig. 3b (after a 4 mm pre-hole), the thrust force in the case of $\phi(4) + \phi(10–4)$ was a little higher for 7075-T6 than it was for the 6061-T6 material. This could be due to the lower effect of the plastic deformation because of the presence of the pre-hole when drilling.

In general, the presence of a pre-hole reduces the cutting forces by about 50 to 70%, depending on the pre-hole size (see Figs. 2 and 3). It is therefore expected that the cutting energy will be reduced by a similar percentage. While the cutting forces could play an important role during the machining of materials, in the case of aluminum alloys, they are relatively low, and could nevertheless constitute a good indicator for the comparison of different alloys under the same machining conditions.



(a) Without pre-hole and after 2 mm pre-hole



(b) Without pre-hole and after 4 mm pre-hole

Fig. 3 Thrust force Fz comparison for 6061-T6 and 7075-T6 materials

Machining a material with high strength requires a high force to generate chips. The thrust force of the 6061-T6 material was low as compared to the 7075-T6 material. This observation is due to the difference in their mechanical properties.

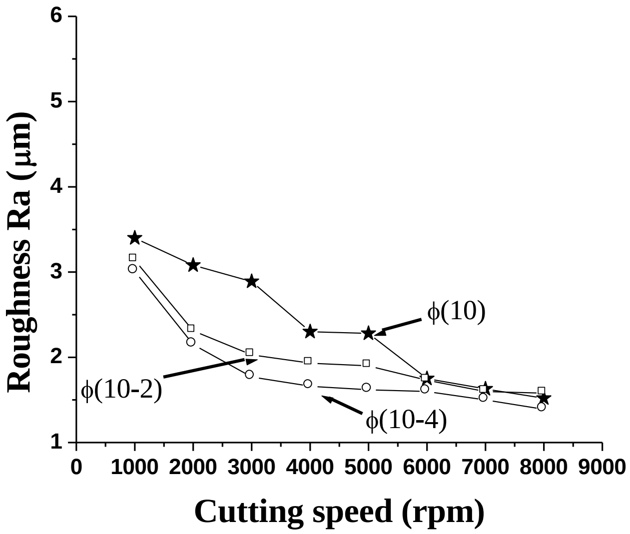
DOI: 10.5963/AMSA0301003

B. Surface Finish

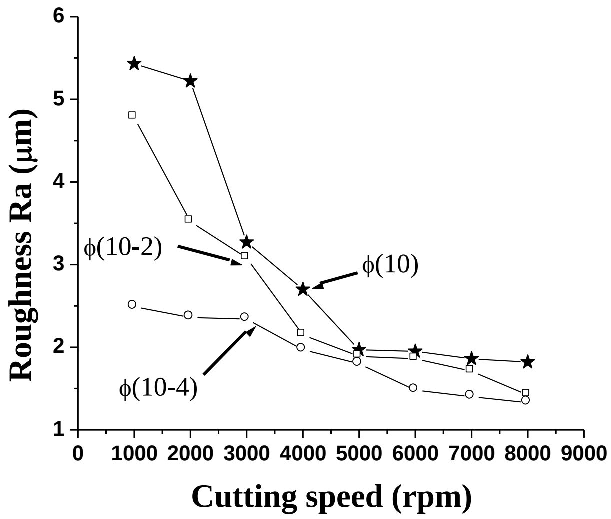
Fig. 4 presents the roughness at different cutting speeds for the 6061-T6 and 7075-T6 materials. It is observed that in both Fig. 4a (for 6061-T6) and in Fig. 4b (for 7075-T6), the roughness decreased as the cutting speed increased. This observation confirms the fact that the surface finish improves as the cutting speed increases, and has been confirmed by the work undertaken by Fu et al. [2], who showed that the surface roughness decreases when the cutting speed of aluminum increases. Their study involved the high-speed (about 1500 m/min) milling of aluminum, and they used the following equation for the roughness R_a [2]:

$$R_a = CV^{-b1} f^{b2} a_p^{b3} a_e^{b4} \tag{2}$$

where, V is the cutting speed, f is the feed rate, a_p is the cutting depth, and a_e is the cutting width, whereas C, $b1$, $b2$, $b3$ and $b4$ (all positive) are materials and cutting condition constants. The cutting speed (V) is the only parameter with a negative exponent, and the roughness R_a decreases when the cutting speed increases. This observation has also been confirmed by the work done by Kouam et al. [29]. Their study involved the friction of aluminum with the tool in rotation (similar to the drilling process).



(A) Al. alloy 6061-T6



(B) Al. alloy 7075-T6

Fig. 4 Roughness *Ra* at different cutting speeds for 6061-T6 and 7075-T6 materials

It was also observed that the roughness was higher for 7075-T6 (Fig. 4b), as compared to 6061-T6 (Fig. 4a) under different testing conditions. This observation could also be due to their different mechanical properties. On the other hand, it was observed that for both materials, at the same cutting speed, the roughness was higher for ϕ(10), as compared to ϕ(10-2) and ϕ(10-4), respectively. The roughness was also higher for ϕ(10-2), as compared to ϕ(10-4). This observation may be due to the fact the removable material during the drilling process is less for ϕ(10-4), as compared to ϕ(10-2).

DOI: 10.5963/AMSA0301003

C. Chip Formation

Fig. 5 presents the chip formation during drilling obtained using scanning electronic microscopy (SEM). At low speeds, the chips produced without pre-hole and with pre-hole were not really different. However, during high-speed cutting, it was observed that the chip formed with a pre-hole was more segmented than the one formed without a pre-hole. This can be due to the fact that the pre-hole diminishes the mechanical properties of the chip, and that the mere presence of a pre-hole in fact modifies the formation of chip. Without the web drill effect, the chip is segmented. The presence of the web drill decreases the formation of macro-segmentation. Fig. 5 also presents different chip forms and lengths (small chips, medium chips and long chips) for 6061-T6 and 7075-T6 materials. In Fig. 5, it is observed that for 6061-T6, discontinuous chips appeared after the cuttings at a cutting speed of 6000 rpm with a 2 mm pre-hole and at a 4000 rpm cutting speed with a 4 mm pre-hole. For 7075-T6, the discontinuous chips appeared after the cuttings at a 8000 rpm cutting speed with a 2 mm pre-hole and at a 5000 rpm cutting speed with a 4 mm pre-hole. For 6061-T6 material, the segmentation was observable at a cutting speed of 6000 rpm with 2 and 4 mm pre-hole, whereas for 7075-T6, the segmentation was observable at a cutting speed of 9000 rpm with a 2 mm pre-hole and a cutting speed of 7000 rpm d with a 4 mm pre-hole.

Fig. 5 suggests that the chip length depends not only on the material properties but also on the cutting conditions. Chip breakability is one of the major issues faced in machining aluminum alloys; in fact, long chips can cause damage to the machined surface, the cutter and the machine evacuation system. Chip segmentation is one of the practical tools used to compare the chip breakability of different alloys. Fig. 5 also suggests that drilling after pre-hole could help to obtain a chip breakability that will be easier to remove. This observation has been confirmed by Kouam et al. [6] in their study on A319 and A356 aluminum alloys.

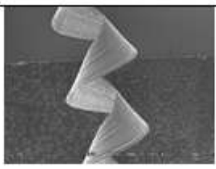
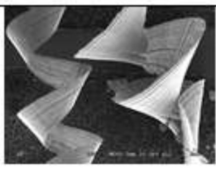
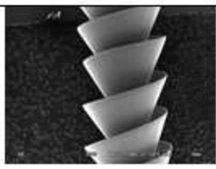
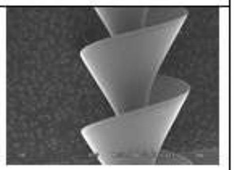
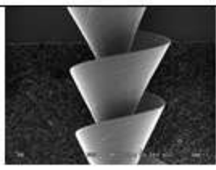
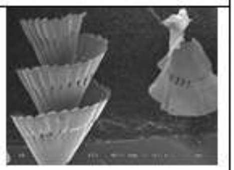
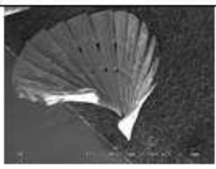
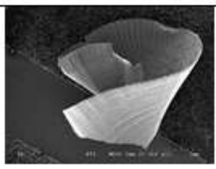
	6061-T6		7075-T6	
Cutting speed (rpm)	After 2 mm pre-hole	After 4 mm pre-hole	After 2 mm pre-hole	After 4 mm pre-hole
1000				
3000				
6000				
8000				

Fig. 5 Scanning electronic microscopy (SEM) images of chip morphologies of 6061-T6 and 7075-T6 materials

Fig. 6 presents the SEM images of the free surfaces of the chips. It is observed that at the same cutting speed, the distance between the segmentation was high after a 4 mm pre-hole, as compared to after a 2 mm pre-hole for each material. This observation could be due to the fact that during the drilling process, the material removal was less after the 4 mm pre-hole, as compared to the 2 mm pre-hole using a 10 mm tool diameter.

DOI: 10.5963/AMSA0301003

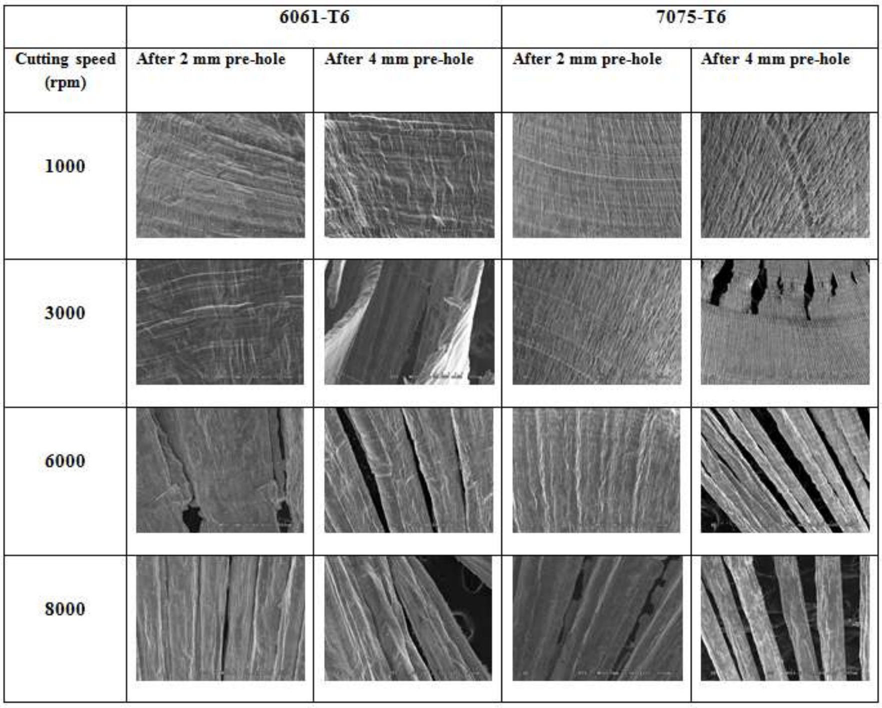


Fig. 6 Scanning electronic microscopy (SEM) images of the free surfaces of the chips of 6061-T6 and 7075-T6 materials

It was also observed that after a 2 mm pre-hole and a 4 mm pre-hole, the chip segmentations increased with the increase in the cutting speed for both materials. A difference was observed in the distances between the segmentation lines of the 6061-T6 material and the 7075-T6 material. This could be explained by the fact that 7075-T6 has a high hardness, which causes the material to become ductile.

Fig. 7 presents the optical microscopy images of the chip morphologies of 6061-T6 and 7075-T6 aluminum alloys without pre-hole and after pre-hole. It was observed that at low cutting speeds (less than 3000 rpm) there was no pre-hole effect on the chip morphology. It was also observed that at a cutting speed of up to 6000 rpm, the chips became more segmented when machining after pre-hole, as compared to without pre-hole. This segmentation is more pronounced when machining after a 4 mm pre-hole, as compared to after a 2 mm pre-hole.

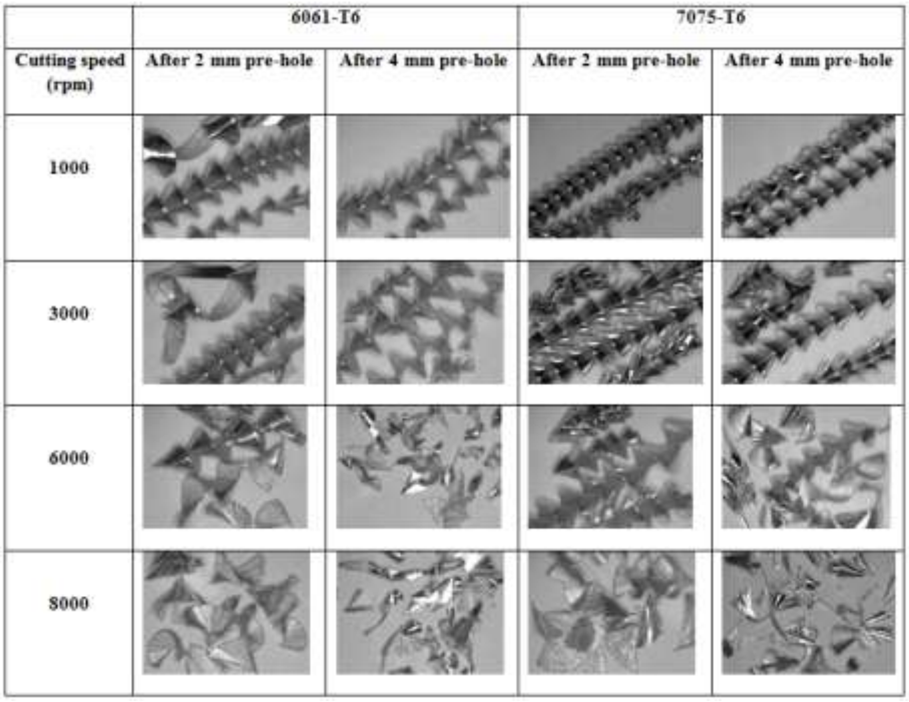


Fig. 7 Optical microscopy images of chip morphologies of 6061-T6 and 7075-T6 materials

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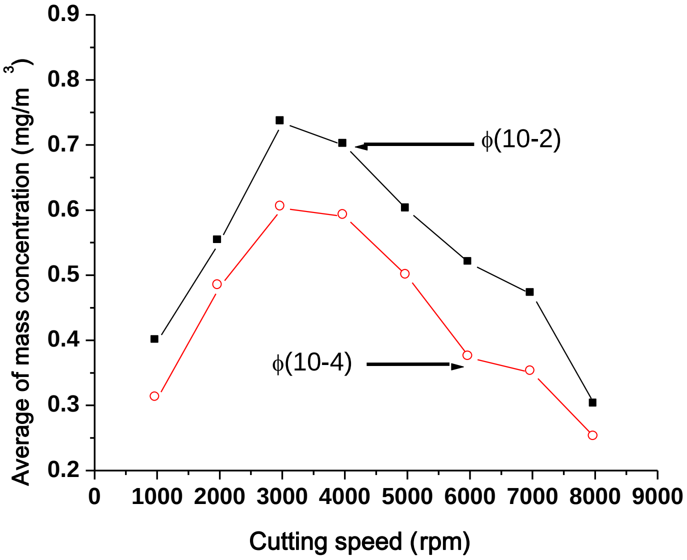
D. Dust Emissions

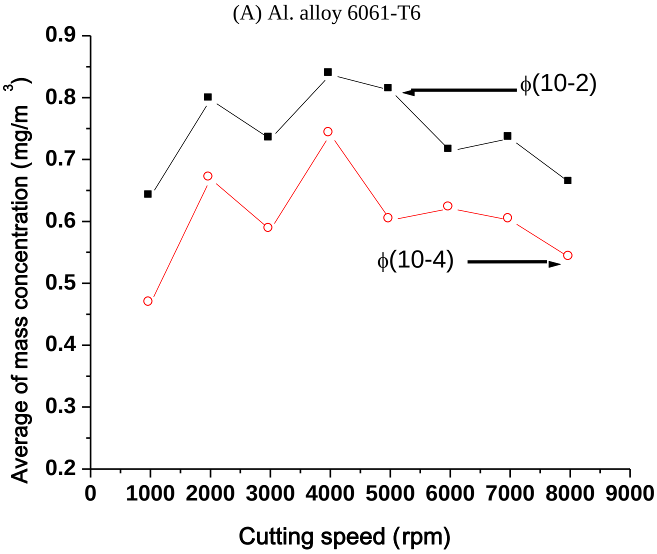
Figs. 8 and 9 present the average of mass concentration and the sum of the average of mass concentration of particle emission, respectively, at different cutting speeds for the 6061-T6 and 7075-T6 materials.

In Fig. 8, curves ϕ(10-2) are for the average of mass concentration when drilling with a 10 mm tool diameter after a 2 mm diameter pre-hole and curves ϕ(10-4) are for the average of mass concentration when drilling with a 10 mm tool diameter after a 4 mm diameter pre-hole (as defined in the nomenclature). It is observed in Fig. 8a for the 6061-T6 material, and in Fig. 8b for the 7075-T6 material, that the maximum particle emission were obtained at the same cutting speed for ϕ(10-2) and ϕ(10-4). For each of the tested materials, the speed at which maximum emission occurs seemed to be independent of the tool diameter, but the magnitude of the emission followed the drill size. It is also observed in Figs. 8a and 8b that the average of mass concentration of particle emission were high for ϕ(10-2), as compared to ϕ(10-4). This can be due to the fact that the chip quantity removal is higher for ϕ(10-2) as compared to ϕ(10-4).

In Fig. 9, curves ϕ(10) are for the average of mass concentration when drilling with a 10 mm tool diameter, curves ϕ(2) + ϕ(10-2) are for the sums of the average of mass concentration when drilling with a 2 mm tool diameter and with a 10 mm tool diameter after a 2 mm diameter pre-hole and curves ϕ(4) + ϕ(10-4) are for the sums of the average of mass concentration when drilling with a 4 mm tool diameter and with a 10 mm tool diameter after a 4 mm diameter pre-hole.



(A) Al. alloy 6061-T6



(B) Al. alloy 7075-T6

Fig. 8 Average of mass concentration at different cutting speeds using 10 mm HSS diameter after pre-holes of 2 and 4 mm

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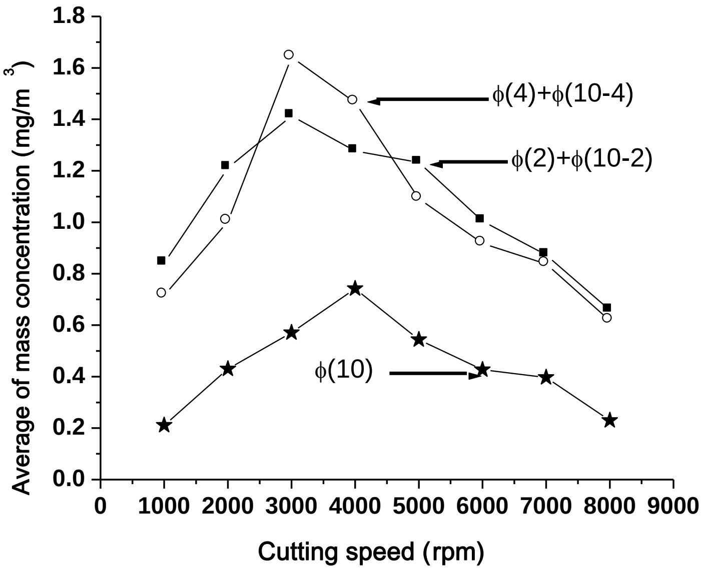
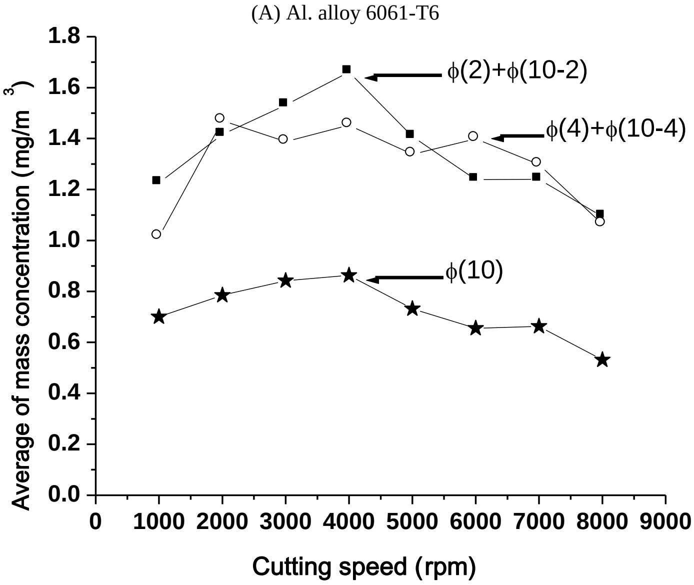


(A) Al. alloy 6061-T6



(B) Al. alloy 7075-T6

Fig. 9 Average of mass concentration at different cutting speeds (★ using 10 mm tool diameter without pre-hole; ■total using 2 mm tool diameter without pre-hole and 10 mm HSS diameter after 2 mm pre-hole; ○total using 4 mm HSS diameter without pre-hole and 10 mm HSS diameter after 4 mm pre-hole)

It is observed in Fig. 9a for the 6061-T6 material and in Fig. 9b for the 7075-T6 material that the maximum particle emission were obtained at the same cutting speed for ϕ(2) + ϕ(10-2) and ϕ(4) + ϕ(10-4). It is also observed that the particle emission were twice as high for ϕ(2) + ϕ(10-2) and ϕ(4) + ϕ(10-4), as compared to ϕ(10), for both materials. This observation shows that drilling twice (without and after pre-hole) generates more particles.

At very low speeds, the amount of particles is small, and then it increases and reaches the maximum value, and eventually decreases. These two speed regimes were observed by Khettabi et al. [3] in their work on turning, and by Kouam et al. [30] in their work on drilling. The critical speeds for maximum particle emission were the same after 2 and 4 mm pre-hole drilling for both materials. On the other hand, the maximum particle emission for the 6061-T6 and 7075-T6 materials occurred at the speeds of 3000 rpm and 4000 rpm, respectively. This observation may be attributable to the fact that the two materials have different toughness, and that the hardness of the 7075-T6 is higher than that of the 6061-T6.

The presence of a pre-hole in the workpiece reduces the thrust force, but increases the amount of dust generated, especially when the cutting speed critical value, at which emission is maximal, is reached. This type of operation is used when the quality of the hole generated is important, or when there is not sufficient power available on the machine to achieve the desired hole sizes in a single operation with a large tool diameter.

DOI: 10.5963/AMSA0301003

IV. CONCLUSIONS

In this work, the effect of pre-holes on the dry drilling of 6061-T6 and 7075-T6 aluminum alloys was studied in terms of cutting force, surface roughness, chip formation and metallic particle emission. It was found that the cutting force and energy used to drill with pre-holes were lower than what were required for drilling without pre-holes. Drilling with pre-hole reduced the cutting forces by 50 to 70%, depending on the pre-hole size, in addition to improving the chip breakability. The presence of pre-hole improved the final hole surface finish as compared to drilling without a pre-hole, especially at low and moderate speeds. With high speeds, no significant difference was found on the hole surface finish drilled with or without a pre-hole. It was also found that the total amount of particles recorded during pre-hole drilling and the final drilling operation was higher by a factor of 2 to 3 compared to the case of the hole drilled without a pre-hole.

This study indicates that it is possible to machine the desired hole size with a pre-hole at high speeds. Such drilling ensures high productivity, good hole quality, and without producing harmful dust. The outlook of this study will be the effect of pre-hole during and/or through hole drilling on the burr formation.

REFERENCES

[1] J. W. Sutherland, V. N. Kulur and N. C. King, “Experimental investigation of air quality in wet and dry turning,” *CIRP Annals - Manufacturing Technology*, vol. 49(1), pp. 61-64, 2000.

[2] X. Fu, Y. Pan, Y. Wan and X. Ai, “Research on predictive model surface roughness in high speed milling for aluminum alloy 7050-T7451,” *Proceeding of Int. Conference on Computing, Control and Industrial Engineering*, pp. 186-189, 2010.

[3] R. Khettabi, V. Songmene, I Zaghbani and J. Masounave, “Modeling of particle emission during dry orthogonal cutting,” *J. of Materials Engineering and Performance*, vol. 19, pp. 776-789, 2010.

[4] U. Çaydaş, H. Ahmet, B. Ömer, and M. Ahmet, “Performance evaluation of different twist drills in dry drilling of AISI 304 austenitic stainless steel,” *J. of Materials and Manufacturing Processes*, vol. 26, pp. 951-960, 2011.

[5] F. Ren and F. Liu, “Estimation of fine dust particles distribution in machining workshop based on Cowz model,” *Chinese Journal of Mechanical Engineering*, vol. 24, pp. 1-7, 2011.

[6] J. Kouam, V. Songmene, Y. Zedan, A. Djebara and R. Khettabi, “On chip formation during drilling of cast aluminum alloys,” *J. of Machining Science and Technology*, vol. 17, pp. 228-245, 2013.

[7] C. Sandvik, “Modern Metal Cutting, A practical Handbook,” Sandvick, Sweden, 1994.

[8] M. A. M. Mahdy, “Economic drilling conditions for a given deburring radius,” *Journal of Materials Processing Technology*, vol. 110, pp. 197-205, 2001.

[9] C. W. Ralph, W. Steven Johnson, A. Makeev and J. C. Newman, “Fatigue performance of production quality aircraft fastener holes,” *International Journal of Fatigue*, vol. 29, pp. 1319-1327, 2007.

[10] C. W. Ralph, W. Steven Johnson, P. Toivonen, A. Makeev and J. C. Newman, “Effect of various aircraft production drilling procedures on hole quality,” *International Journal of Fatigue*, vol. 28, pp. 943-950, 2006.

[11] M. M. Okasha, N. Driver, P. T. Mativenga and L. Li, “Mechanical micro-drilling of negative-tapered laser-predrilled holes: a new approach for burr minimization,” *Int. J. of Adv. Manuf. Technol*., vol. 61, pp. 213-225, 2012.

[12] L. DeChiffre, G. Tosello, M. Píška and P. Műller, “Investigation on capability of the reaming process using minimal quantity lubrication,” *CIRP Journal of Manufacturing Science and Technology*, vol. 2, pp. 47-54, 2009.

[13] D. N. Dilley, D. A. Stephenson, P. V. Bayly and A. J. Schaut, “Frequency shift in drilling due to margin engagement,” *Journal of Manufacturing Science and Engineering*, vol. 127, pp. 271-276, 2005.

[14] T. Novakov and M. J. Jackson, “Chatter problems in micro- and macrocutting operations, existing models, and influential parameters - a review,” *Int. J. of Adv. Manuf. Technol*., vol. 47, pp. 597-620, 2010.

[15] C. C. Tsao and H. Hocheng, “Effect of chisel length and associated pilot hole on delamination when drilling composite materials,” *International Journal of Machine Tools & Manufacture*, vol. 43, pp. 1087-1092, 2003.

[16] C. C. Tsao, “Effect of pilot hole on thrust force by saw drill,” *International Journal of Machine Tools & Manufacture*, vol. 47, pp. 2172-2176, 2007.

[17] C. C. Tsao, “Effect of pilot hole on delamination when core drill drilling composite materials,” *Int. J. of Machine Tools & Manufacture*, vol. 46: 1653-1661, 2006.

[18] M. S Won and C. K. H. Dharan, “Chisel edge and pilot hole effects in drilling composite laminates,” *J. of Manufacturing Science and Engineering*, vol. 124, pp. 242-247, 2002.

[19] R. F. Hamade, C. Y. Seif and F. Ismail, “Extracting cutting force coefficients from drilling experiments,” *Int. J. of Machine Tools & Manufacture*, vol. 46, pp. 387-396, 2006.

[20] J. Hua and R. Shivpuri, “Influence of crack mechanics on the chip segmentation in the machining of titanium alloys,” *Proceedings of the Ninth ISPE International Conference on Concurrent Engineering*, Cranfield, UK, 27-31 July 2002.

[21] D. R. Sandstrom and J. N. Hodowany, “Modeling the physics of metal cutting in high-speed machining,” *J. of Machining Science and Technology*, vol. 2, pp. 343-353, 1998.

[22] E. M. Trent, Metal Cutting, Butterworth Heinemann Ltd., Oxford, UK, 1991.

[23] J. Q. Xie, A. E. Bayoumi and H.M. Zbib, “Study on shear banding in chip formation of orthogonal machining,” *International Journal of Machine Tools and Manufacture*, vol. 36(7), pp. 835-847, 1996.

DOI: 10.5963/AMSA0301003

[24] P. U. Arumugam, A. P. Malshe and S. A. Batzer, “Dry machining of aluminum-silicon alloy using polished CVD diamond-coated cutting tools inserts,” *J. of Surface & Coatings Technology*, vol. 200, pp. 3399-3403, 2006.

[25] N. R. Dhar, M. W. Islam, S. Islam and M. A. H. Mithu, “The influence of minimum quantity of lubrication (MQL) on cutting temperature, chip and dimensional accuracy in turning AISI-1040 steel,” *J. of Materials Processing and Technology*, vol. 171(1), pp. 93-99, 2006.

[26] V. Songmene, B. Balout and J. Masounave, “Clean machining: Experimental investigation on dust formation: Part I,” *Int. j. of environment conscious machining (ECDM)*, vol. 14(1), pp. 1-16, 2008.

[27] B. Balout, V. Songmene and J. Masounave, “An experimental study of dust generation during dry drilling of pre-cooled and pre-heated workpiece material,” *Journal of Manufacturing Processes*, vol. 9(1), pp. 23-34, 2007.

[28] V. Songmene, B. Balout and J. Masounave, “Clean machining: Experimental investigation on dust formation: Part I,” *Int. j. of environment conscious machining (ECDM)*, vol. 14(1), pp. 17-33, 2008.

[29] J. Kouam, V. Songmene, A. Djebara and R. Khettabi, “Effect of friction testing of metals on particle emission,” *J. of Materials Engineering and Performance*, vol. 21(6), pp. 965-972, 2012.

[30] J. Kouam, Y. Zedan, A. Djebara, J. Masounave and V. Songmene, “Machinability of A356 and A319 Aluminum alloys,” *CIM Proceeding, Montreal 2011, Conference of metallurgist, COM 2011, symposium on Light Metals*, Montreal, QC, Canada, 3-5 October 2011, pp. 281-292, 2011.

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DOI: 10.5963/AMSA0301003