

Comparison of deionized water and quarry dust suspension as coolant in drilling of titanium alloy

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ABSTRACT –In this research, thrust force, surface roughness and burr formation of titanium alloy using drilling process were compared between pure deionized (DI) water and 0.02wt% of quarry dust suspension as a coolant. The results indicate that by using 0.02wt% of quarry dust suspension, thrust force and surface roughness were improved 12.3% and 49%, respectively compared to pure deionized water. Burr formation, particularly at the exit hole also significantly reduced by using quarry dust suspension.

1. INTRODUCTION

In the field of aerospace, commercially titanium alloy such as Ti-6Al-4V are extensively used for the airframe and the engine parts (fan and compressor) to improve aircraft fuel consumption. The growing demand of titanium alloy can be attributed to its good properties for example light weight, high specific strength, excellent corrosion resistance and good resistance to creep and fatigue [1]. However, during the machining operation, high chemical reactivity and the poor thermal conductivity of the titanium alloy often leads to quick temperature ascend in the cutting region, causing untimely apparatus disappointment and poor hole quality [2].

In order to reduce the temperature produced in the cutting zone, different types of cooling techniques were employed by researchers, such as cryogenic [3] and nanofluid [4]. There are several particles that have been used in nanofluid machining such as silicon dioxide (SiO₂), molybdenum disulfide (MoS₂), titanium dioxide (TiO₂), aluminum oxide (Al₂O₃) and nanodiamond. Recycled quarry dust which is high in SiO₂ and Al₂O₃ content can be a great economical alternative to replace the expensive conventional ceramic particles in liquid suspension for cooling and lubrication purpose in drilling process. Therefore, in this study, the potential of quarry dust suspension as coolant was compared with deionized water for improving the quality of drilled hole on titanium alloy.

2. METHODOLOGY

Drilling process was conducted with a HAAS VOP-C 3-axis CNC machine. The drill bit used was 6mm of cobalt twist drill, and titanium alloy was selected as the workpiece in this research. For the preparation of 0.02wt% of quarry dust suspension, DI water was used as a base fluid, while sodium lauryl sulphate was used as a surfactant to prevent agglomeration of quarry dust particles. Ultrasonic homogenizer was used to mix the

solutions. The frequency was set at 50 amplitudes and 0.5 cycles.

After the drilling process, the surface roughness of the titanium alloy was measured using surface roughness tester (Mitutoyo SJ-301). Kistler 5697 dynamometer was used to measure the thrust force during machining process, and burr formation was measured using SEM machine.

3. RESULTS AND DISCUSSION

3.1 Thrust Force

Figure 1 shows the effect of DI water and 0.02% of quarry dust on the thrust force. The graph shows that the thrust force is high by using deionized water. However, when 0.02wt% of quarry dust was used, the thrust force was reduced. During the drilling process, high temperature was generated due to the friction between the cutting tool and workpiece [5]. Due to the poor thermal conductivity of titanium alloy, the heat generated will not dissipate easily and tend to concentrate at the cutting edge which will cause the edge temperature reach 1000°C easily. When the present of quarry dust suspension in the drilling process, the quarry dust may act as a lubricant that help to lower the frictional force between tool and workpiece and thus lower the thrust force.

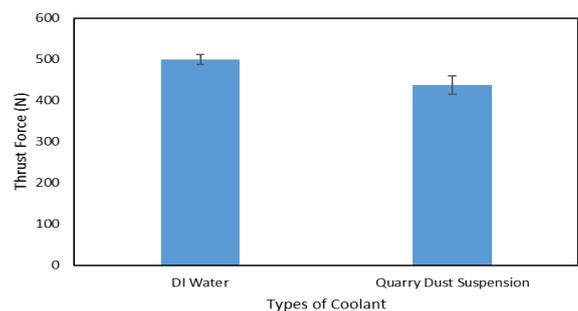


Figure 1 Effect of different types of coolants on the thrust force

3.2 Surface Roughness

Figure 2 shows the effect of DI water and 0.02wt% of quarry dust suspension on the surface roughness. As can be seen from Figure 2, the surface roughness decreases significantly when using 0.02wt% of quarry dust suspension. This phenomena can be explained as quarry dust particle play a role as polishing effect [6]. As the recycled quarry dust is very high in SiO₂ and

Al₂O₃, during machining SiO₂ particles would act as a combination of rolling and sliding bearings at the tool chip interface. These, in turn, could reduce the coefficient of friction and improve machining performance significantly [7]. Thus, smoother surface was obtained as this polishing effect occurred during machining.

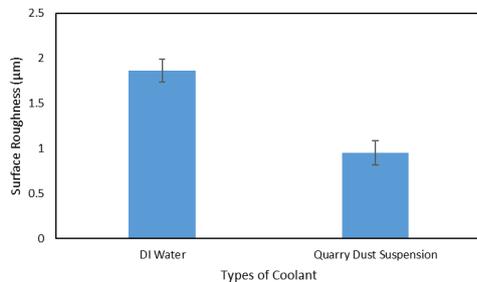


Figure 2 Effect of different of types coolants on the surface roughness

3.3 Burr Formation

Figure 3 and 4 show the burr formation of the entrance and exit holes for DI water and 0.02wt% of quarry dust suspension, respectively. As can be seen from the figures, uniform burr was formed on the entrance hole, either by using DI water or quarry dust suspension. However, when DI water was used, burr with torn cap can be observed vividly at the exit of drilled hole, whereas the exit hole that produced by using 0.02wt% of quarry dust showed a uniform burr with lower height. According to Prisco et al. [8], with the increased of temperature of cutting tool, the height of burr formation will also increase. By using quarry dust suspension as a coolant, more heat was dissipated which retained the hardness of drilling bit. Hence, it leads to a lower tool wear rate and resulting a better quality of hole with minimal burr.

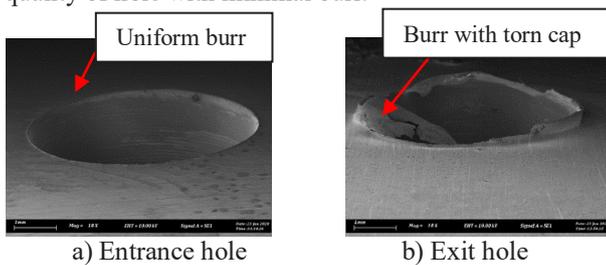


Figure 3 SEM images of drilled hole by using DI water

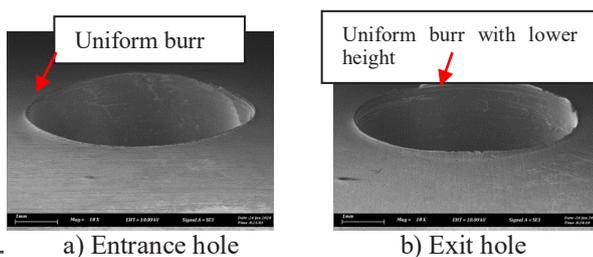


Figure 4 SEM images of drilled hole by using 0.02wt% of quarry dust

4. CONCLUSIONS

This study focused on the effect of DI water and 0.02wt% of quarry dust suspension as coolant on thrust force, surface roughness and burr formation of the titanium alloy using drilling process. The results show that by using 0.02wt% of quarry dust suspension, lower thrust force and better surface finish and quality of the hole can be obtained compared to that of deionized water.

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