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An Experimental Evaluation of SiO_2 Nano Cutting Fluids in CNC Milling of Aluminium Alloy AL6061-T6.

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KEYWORDS

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Minimum Quantity Lubricant (MQL)
AL 6061 Aluminum Alloy

ABSTRACT

The present study explores the efficiency of SiO_2 nano cutting fluid in machining AL6061-T6 Aluminium Alloy using CNC Milling. The cutting performance, namely surface roughness and cutting temperature, were investigated against feed rate and spindle speed. The cutting performances of SiO_2 nano cutting fluid were then compared to the conventional CNC cutting fluid. Beforehand, the suspended form of SiO_2 is dispersed in CNC cutting fluid base. The nanofluid is prepared in three-volume concentrations (0.5, 1.0 and 1.5%) by using one-step and dilution methods. The stability of SiO_2 Nano cutting fluid is observed via visual sedimentation. The result shows that SiO_2 nano cutting fluid with 1.5% volume concentration produces the lowest surface roughness of 0.679μm and lowest cutting temperature of 29.3^{0}C. It can be concluded that the higher the SiO_2 nanofluid volume concentration, the better the surface roughness quality and lowering the cutting temperature. Finally, viscosity test onto the SiO_2 nano cutting fluid is recommended in future work in order to determine maximum volume concentrations allowed to be used in CNC milling machine.

1.0 INTRODUCTION

Nowadays, machining performs a significant role in the manufacturing industry. It is arguably the most useful manufacturing process in which the desired shape, size and surface finish are achieved through the removal of excess materials in the form of small chips. Heat generation and friction in the machining zone affect tool life and surface quality negatively during metal cutting processes. Cutting fluids have been the available choice to reduce the surface friction of machining processes, and dissipate the heat generated, improving the tool life and surface finish.

There are various types of cooling technique, namely flood cooling, solid coolant and minimum quantity lubricant (MQL) are applied during machining to remove the heat generated in the cutting zone. For example, in the flood cooling method, conventional soluble oil is made to

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flood over the cutting area to dissipate the heat caused by the machining. The cutting fluid helps to improve the surface finish as well as to facilitate chip flushing. The major disadvantage of this method is that the coolant will never be allowed to penetrate properly into the actual chip-tool contact area, due to the high speed of the chip flowing at high cutting speeds. Moreover, the wastage of the coolant oil will be considered as it is made to flood. On the other hand, MQL or near dry machining is a method where a minimal amount of lubricant flow is used. In MQL, the coolant medium is generally straight oil, but some applications have also utilized an emulsion or water (Weinert et al., 2004).

While nanofluids are a new class of fluids engineered by dispersing nanometer-sized materials (nanoparticles, nanofibers, nanotubes, nanowires, nanorods, nanosheet, or droplets) in base fluids, nanofluid has been shown to have higher heat transfer rates and better thermal conductivity (Redhwan et al., 2017; Zawawi et al., 2018), plus reducing the coefficient of friction and wear rate (Aminullah et al., 2018; Zawawi et al., 2017). The application of conventional cutting fluids creates some techno-environmental problems, such as environmental pollution, biological problems to operators and water pollution (Paul et al., 2001). The unsuitability of the conventional liquid coolants leads to the selection of biodegradable cutting fluids or elimination of the cutting fluids. Further, the cutting fluids also incur a significant portion of the total manufacturing cost (Sreejith et al., 2000). Machining with solid lubricants is one attempt to avoid the use of cutting fluids (Shaji et al., 2003).

An experimental investigation was conducted to compare the performance of conventional coolant by SiO_2 nano cutting fluid and investigation was conducted to determine the best SiO_2 nano cutting fluid concentration in CNC Milling of AL6061-T6 Aluminium Alloy. The material used for this experimental work is AL6061-T6 Aluminium Alloy with 2 Flutes HSS End Mill Ø6 mm by CNC Milling at volume concentration 0.5, 1.0 and 1.5 % SiO_2 nano cutting fluid. The machining performance will be evaluated on surface roughness and cutting temperature.

2.0 EXPERIMENTAL PROCEDURE

2.1 Materials and equipment

This section describes the methodology of the evaluation of CNC cutting performance onto AL6061-T6 aluminium alloy using silicon dioxide (SiO_2) nano-cutting fluid. The SiO_2 nano-cutting fluid is prepared by using one-step and dilution methods. Meanwhile, the stability of the SiO_2 nano cutting fluid is done by visual sedimentation observation. The suspended form of SiO_2 was procured US Research Nanomaterials, Inc. in weight concentrations of 25%. SiO_2 is a chemical compound that is an oxide of silicon with the chemical formula. Silica is most commonly found in nature as quartz, as well as in various living organisms. Silica is one of the most complex and most abundant families of materials, existing both as several minerals and being produced synthetically. Notable examples include fused quartz, crystal, fumed silica, silica gel, and aerogels. SiO_2 typically applications range from structural materials to microelectronics to components used in the food industry.

CNC milling is a cutting process in which material is removed from a block by a rotating tool. In CNC milling the cutting tool is moved in all three dimensions to achieve that desired part shape. In CNC milling the cutting tool usually rotates about an axis that is perpendicular to the table that holds the material to be cut. This milling machine is used because they have high precision and suitable RPM compare with conventional Milling Machine. There are many advantages to using CNC Machining. The process is more precise than conventional machining and can be repeated in precisely the same manner over and over again. Since of the precision possible with CNC machining, this process can produce complex shapes that would be almost impossible to achieve with conventional machining. The CNC machine is used in the development of three-dimensional shapes that may be complex. It is because of these qualities that the CNC machine is used in jobs that need a high level of precision or very repetitive tasks. The machining experimental was carried out on a Deckel Maho DMU 50 milling machine as shown in Figure 1.

Figure1: Deckel Maho DMU 50 milling machine and the experimental Setup

The material was selected in this experiment is AL6061-T6 Aluminium Alloy rectangular workpiece geometry 170×35×10mm. AL6061-T6 Aluminium Alloy has good mechanical properties, exhibits good weldability, and is very commonly extruded. It also is precipitation-hardened aluminium alloy, containing magnesium and silicon as its major alloying elements. It is one of the most common alloys of aluminium for general-purpose use.

2.2 Cutting fluids preparation

The most frequently used one-step process for the preparation of nano cutting fluids. Silicon dioxide SiO_2 used in this method are first produced as a wet liquid. After that, it will be measured the volume of SiO_2 in 1.5%, which is the higher volume concentration by using a measuring cylinder. The volume of distilled water and the volume of coolant measured would then be used according to the measurement. Through stirring process, combine distilled water and coolant. Silicon dioxide SiO_2 nanofluid dispersed into conventional coolant preparation. SiO_2 nanofluid are applied and stirred within one hour with a mixture of distilled water and coolant. Finally, the solution will be placed of water bath ultra sonicator for two hours to make sure its dissolve completely. Then cutting fluids were used is conventional coolant and nanofluid enhancement conventional coolant. Infrared thermometer was used during the machining process estimated length is about 50 meter to measure the cutting temperature. The experiment was running at 2700, 3250 and 3800 rev/min spindle speed and 324, 390 & 456 mm/min.

The low and high levels were shown in Table 1. Thirty-three full factorial designs with three centre point were used to determine significant factors and as screening process before pursuing to response surface methodology (RSM) as used by (Redhwan et al., 2020). The objective of RSM is to best the response based on the factor investigated. The response variables under investigate were surface roughness and cutting temperature.

Table 1: Factor and experiment condition level

Symbol Variable Factors	Level		
	Level 1	Level 2	Level 3
A=Nanoparticle Concentration	0.5 %	1.0 %	1.5%
B=Spindle Speed (rev/min)	2700	3250	3800
C=Feed Rate (mm/min)	324	390	456

2.3 Stability of nanofluid

Sonication is applied by using an ultra-sonicator an instruction to make stable nanofluid and reduce the size of agglomerates as suggested by (Redhwan et al., 2018). Nanofluid were produced in a volume of 1000 ml for each volume concentration and put into a sonicator for 2 hours. Then, the nano cutting fluids became very stable throughout the measuring process. The nanofluid was prepared as above without milling or using any surfactant/pH adjustment displayed good stability without any visible sedimentation for several days**,** as shown in Figure 2.

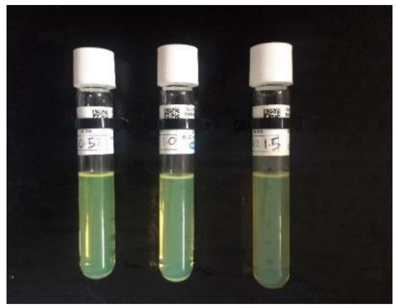

Figure 2: Nanofluid sample after three weeks

3.0 RESULTS AND DISCUSSION

Surface roughness was measured by using the Mitutoyo SJ-210 Surface Roughness Tester profilometer. The surface roughness relation between four different concentrations of 0.0, 0.5, 1.0, and 1.5 was shown in Figure 3. The lower value is the better surface roughness given by, the higher concentration of nano cutting fluids with 1.5 is 0.706 µm, while for the 1.0 concentration, the value was measured is 1.412 µm. The value of 2.201 µm was recorded for 0.5 concentration, and the highest value of Ra is 3.362 µm for the zero concentration or 100% use conventional coolant without nanofluids enhancement. Therefore the higher concentration of nanofluids would give the lowest and better Ra value for this experiment, and the result was the same pattern compared to the other results (Sayuti et al., 2014)

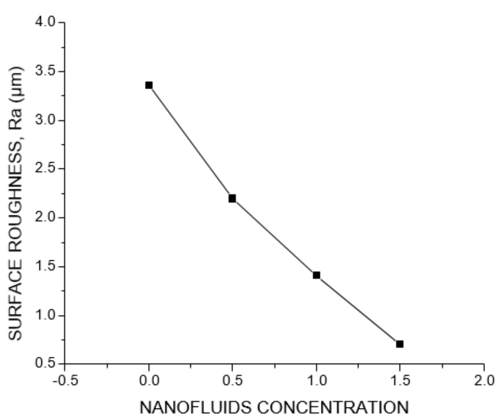

Figure 3: Surface roughness as opposed to nanofluid concentration

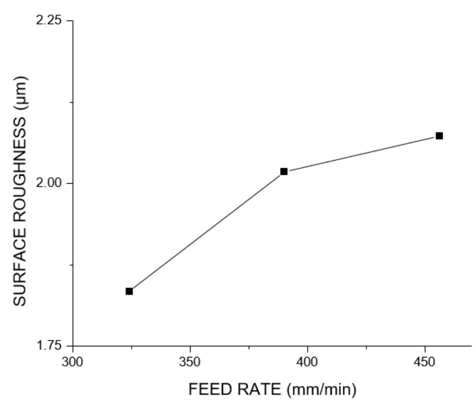

Figure 4: Surface roughness as opposed to feed rate

The relation of surface roughness between the feed rate was shown in Figure 4. The lowest value of feed rate creates the best surface roughness, which is Ra's lower surface roughness. Surface roughness, Ra was average at 1.834 μm for the lowest feed rate of 324 mm/min. Then the surface roughness, Ra was average at 2.018 μm for the medium feed rate of 390 mm/min. Finally, the average for higher for the highest feed rate of 456 mm/min and the higher surface roughness, Ra obtained was average at 2.073 μm.

The surface roughness relation between spindle speeds shown in Figure 5. The higher spindle velocity value will provide the best surface roughness. For 1.5 concentration, which generates the lower of surface roughness value was 0.737μm, 0.701μm and 0.679μm, whereas the surface roughness was estimated at 1.675μm, 1.434μm and 1.127μm for the 1.0 concentration. The surface roughness was measured at 2.236μm, 2.221μm and 2.143μm for 0.5% concentration of nano cutting fluids and the highest surface roughness were 3.434μm, 3.372μm and 3.279μm for non-enhancement cutting fluids. The higher spindle speed is thus substantiated by generating the lower surface roughness for different concentration, even with conventional coolant.

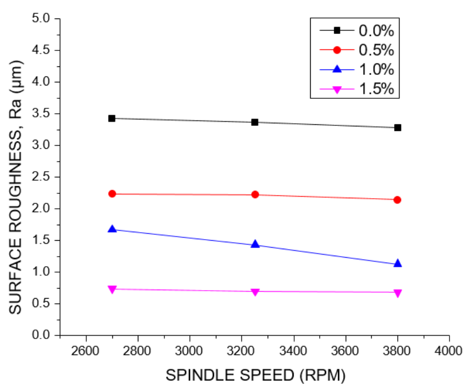

Figure 5: Surface roughness as opposed to spindle speed

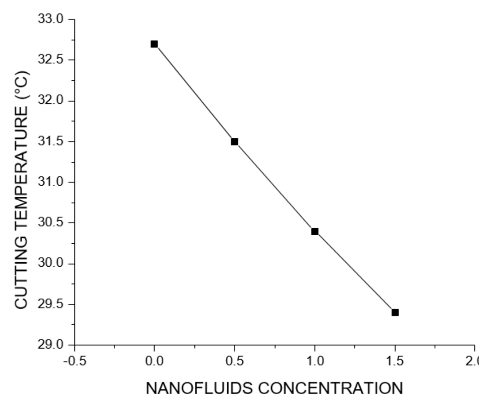

Figure 6: Cutting temperature as opposed to nanofluids concentration

The cutting temperature was measured at a distance of 50 centimeters using non-contact laser infrared thermometer gun (DT8280). A temperature with a range of -50^{0}C to 280^{0}C able to be measured with this infrared thermometer. The cutting temperature relation between four different concentrations was shown in Figure 6. The lower cutting temperature is provided by, the higher nanofluids concentration was observed—the highest 1.5% concentration provided for cutting temperature of 29.4 °C. The temperature was recorded to be 30.4°C for 1.0 concentration of nanofluids. The cutting temperature was recorded at 31.5°C for 0.5 concentration while the highest temperature obtained was 32.7°C for zero nanofluid concentration. The higher concentration of nanofluids would explain the lower cutting temperature for this experiment which similarly obtain by another researcher (Sayuti et al., 2014).

The cutting temperature relation between three different feed rates shown in Figure 7. The more excellent value of feed rate generates a higher temperature of the cutting zone. The nanofluids concentration of 1.5 with a feed rate 345, 390, and 456 mm/min provided for cutting temperature were 29.1, 29.5 and 29.7°C respectively. The cutting temperature has been recorded at 30.2, 30.4 and 30.7°C for 1.0 nanofluid concentration. The cutting temperature was obtained at 31.2, 31.5 and 31.8 °C for 0.5 nanofluid concentration and the higher cutting temperature was given at 32.3, 32.8, 33.1°C for conventional with zero nanofluid concentration. It is therefore justified that the lowest feed rate would give the lowest cutting temperature for all concentration.

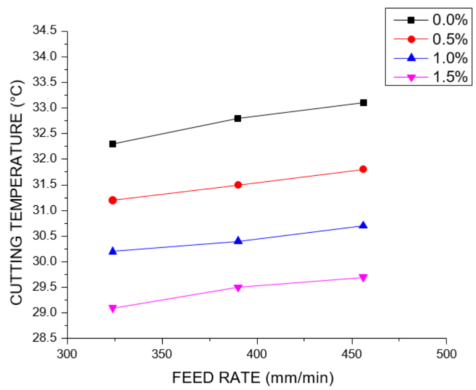

Figure 7: Cutting temperature as opposed to feed rate.

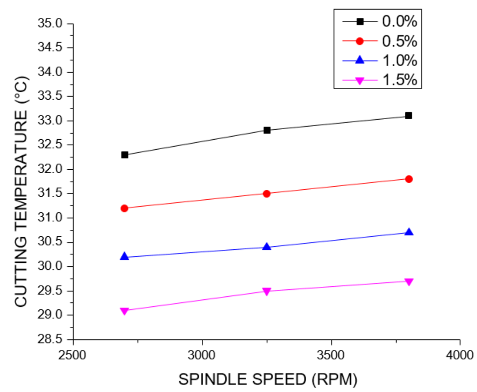

Figure 8: Cutting temperature as opposed to feed rate.

The cutting temperature relation between three spindle speeds shown in Figure 8. The higher spindle speed value causes the highest cutting temperature. For the higher 1.5 nanofluid concentration with a spindle speed of 2700, 3250, 3800 rev/min, which produces the lowest cutting temperature, relative to other concentration at 29.1, 29.5, 29.7°C respectively. The cutting temperature has been recorded at 30.2, 30.4, 30.7°C for the 1.0 nanofluid concentration. The cutting temperature was obtained at 31.2, 31.5, 31.8°C for 0.5 nanofluid concentration, and the higher cutting temperature was given at 32.3 32.8, 33.1°C for conventional with zero nanofluid concentration. It is therefore justified that the lowest feed rate would give the lowest cutting temperature.

4.0 CONCLUSION

In this study, the aim was to assess the objective experiment in achieving, and the result showed the massive containing amount of volume concentration SiO_2 nanofluid improve the surface quality and cutting temperature. The following conclusion can be drawn to describe the performance of different concentration of SiO_2 at Al-6061-T6 in CNC Milling. SiO_2 nanofluid improved surface roughness quality and cutting temperature. The minimum surface roughness and cutting temperature were obtained by using a higher volume concentration of SiO_2 nanofluid. The best volume concentration of SiO_2 nanofluid is 1.5 will result in the best value of surface roughness of 0.679μm and cutting temperature 29.3^{0}C.

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