Non-Traditional Machining Process of Composite Materials using Renewable Lubricants

Abdulaziz S. Alaboodi, S. Sivasankaran, Hany R. Ammar

Abstract*: The global increasing alertness of the environmental and health problems linked to the use of mineral based metal cutting fluids in machining is lead industry to develop alternative fluid. The fluid should be environmentally friendly and sustainable like vegetable oil with suspended nanoparticle. The low thermal conductivity of cutting fluids of natural based oil requires the addition of nanoparticles. The most common nanoparticle that suitable to be added to cutting fluid are non-metals, carbide, oxide, Carbon Nano Tubes (CNTs) and metal nitrides. In this paper, a comparison had made of dry machining and machining with cutting coolant oil, sunflower oil+MoS2, Sunflower, oil Graphene. The study concludes that, the addition of such minerals to the cutting fluids increased the thermal conductivity of cutting fluids.

Keywords:* Composite Materials, *Machining, Renewable Lubricants.

I. INTRODUCTION

Composite material made of carbon fiber reinforced plastic [CFRP] is having good strength to weight ratio so the demand of CRPF in automobiles and aerospace industry is higher than steel. Since CRPF is a combination of two or more constituents with inversely chemical and physical properties. The conventional and non-conventional machining technique like high speed milling, water jet cutting and laser cutting are influenced with surface quality of end product. Furthermore, the tool wear, that reduce the life of tool, delamination of CFRP and fiber pull-out must be minimized.

The degradable vegetable oil has high viscosity, good biodegradability, non-toxicity, plentiful resources, high yield and smaller change in viscosity with temperature. In addition, it would reduce environment contamination and cost of handling. Moreover, the large molecular weight and boiling point of oil decreases its mass losses during atomizing and gasifying that make it capable to hydrolyze [1].

There are two more main fibers used to reinforced plastic materials which are aramid fiber reinforced plastic and glass fiber reinforced plastic (GFRP). GFRP have famously used in the building industry because of their variety of shapes, styles and textures. Besides, this material has low weights of 2 to 4 lbs. per square foot which can make the installation faster, less structural and lower shipping cost. To have chemically free, this GFRP also can resists salt water, acid rains and friendly to the environment. The composite materials have high strength, high resistance and light weight which make the composite materials as a good choice in the industrial sector.

The composite materials have different texture and fiber reinforced plastic (FRP). The composite material is very difficult for machining using conventional method [2]. Due to this, the tool will damage quickly so fiber material tool must be chosen for machining of composites. Thus, laser machining and waterjet offers an alternative for machining of composites [3]. In the conventional metal machining, liquid provide flood fluid between tool and workpiece then the liquid filtered then recirculated again. The micro-lubrication delivery system has provided low volumes of fluids to the process. The volume of 50 to 500 ml/hour is commonly used in flood cooling condition. The airborne cutting fluid particles must be added with base fluid for the purpose of coolant in composite material machining. Since the cutting fluid usage is minimized and lubricant costs, tool, work piece and machine cleaning cycle time can be saved [4]. The capacity of heat removing to cutting fluids was improved by through the enlarged the nanoparticles surface area, the higher thermal conductivity, lower Reynolds number and the streamline motion [5]. The addition of small nanoparticles increased the thermal conductivity of the suspension by almost 20–30% [6]. The thermal properties and stability of suspensions can be increased with larger surface area [7] in the composite materials. The Carbon fiber reinforced plastic (CFRP) composite material is used widely in aerospace and automobile industries instead of stainless steel due to the modulus, enhanced specific strength, corrosion, damping, low thermal expansion, wear resistance and good dimensional stability [8]. During machining of CFRP, the complaints such as low quality of surface roughness, abrasive wear of the tool and fiber pull-out have been noticed due to plastics dissimilar composition and different mechanical and thermal properties of carbon fibers [9]. Due to high heat generation during hard materials machining, the use of Minimum quantity cutting fluids (MQCF) is limited to mild conditions on machining [10].

Revised Manuscript Received on April 21, 2020.

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The alternatives promising of conventional dry or near dray grinding process are the use of minimum quantity lubrication (MQL) [11]. The near-dry machining technique called electrostatic minimum quantity lubrication (EMQL). It used to lower oil mist concentration in machining workshops and to improve machining performance. The nano-lubricants in EMQL used graphene nano-platelets (GPLs) as additives can be used. The GPL lubricant in EMQL reduced the worn scar diameter and coefficient of friction besides improving the performance of machining with lower concentration of oil mist [12].

Nano-lubricant (nano-fluid) is consist of base oil suspended by nanoparticles in it. One study was done to investigate the effects of minimum quantity nano-lubrication MQNL in grinding of Tungsten carbide grade. The study shows that the MQNL technique improves the grinding efficiency by decreasing the specific energy, grinding force, and increasing surface quality. [13]. The effect of air pressure and nozzle surface roughness have also influenced on the effectiveness of lubricant droplet in micro-milling. When using rough internal surface nozzle, the droplet distribution and diameter were most sensitive. [14]. The coolant-lubricant medium and grinding variables improve the finishing quality and reduce the energy dissipation [15]. In the MQL technique, the graphite particles lubricant gives superlative in machinability. Lubricating and cooling capacities of the experiment techniques were set to study machining performances [16]. Flood lubrication and MQL has been used as the source for lubrication. To find optimal values on minimizing the tool wear and the surface roughness, the Technique for Order of Preference by Similarity to ideal solution TOPSIS method has been used [17]. Kevlar is widely used in optoelectronics applications where enclosed seals needed between glass and metal. In machining of Kevlar, the abrasive wear is the major tool wear mechanism that could be minimize by using MQL [18]. The application of different cooling systems has investigated and analyzed through surface integrity microstructure, microhardness and roughness in addition to the grinding wheel diametric wear [19,20]. The methods of preparing Nano fluids and its thermal conductivity have been reviewed. Furthermore, numerous engineering applications of nano-fluids are discussed to give a better understanding of the of machining by the application of nanoparticles in lubricant [21].

Thus, it is necessary to develop new environmentally friendly Nano fluid to solve the complications during machining of composite materials. Hence, the present study is focused to develop new environmentally friendly based Nano fluids in composite materials machining operations.

The present study will focus on a novel technique of machining of expensive, the eco and environmental friendly, renewable and economical machining processes which will give a great impact to the global society.

II. RESEARCH METHODOLOGY

This study will explore three method of composite machining techniques; milling and turning (traditional), laser cutting (non-traditional) and water jet cutting. The environmental friendly lubricants will be used in machining of composite materials. A two-step method (Dong et al. 2010) of Nano fluid will be prepared with nanoparticle of mass fraction ranging from 1.25% to 5% and vegetable oil. The components of nanoparticle are Al_2O_3, MoS_2 or TiO_2, MoS_2 (50 nm). Palm kernel oil, Liquid paraffin (control), soybean oil and jatropha oil are base oils; alkane sulfonate has used as cationic surface-active agent. Dimethyl sulfate (C2H6O4S) is a numerical control ultrasonic oscillator and dispersing agent is used for mixing. The procedure for preparation of oil-based Nano fluid of 150 mL with mass fraction 5% is as follows:

Nanoparticle (6.12 g) and $C_2H_6O_4S$ (5 g) mix with base oil (150 mL), keep in oscillator for 60 minutes. Taguchi's robust design will be used for machining processes (turning or milling process). A mathematical tool called Orthogonal Array (OA) method will be used to study the decision variables by experiments. The input variables are cutting speed, depth of cut and feed rate.

Experimental work was done using lathe machine with a 1100 rpm of spindle speed. The cutting environment used in are with dry machining and with different cutting coolant.

The coolant has passed from the tank to the mixing chamber using pump. The coolant quantity is adjusted by controller value of the delivered liquid to the machining area. The end turning experiment was performed on an AISI 304 steel workpiece that represent higher corrosion resistance.

The factors are chosen as cutting speed and environment of cutting. To minimize the consequence of unsuitable factors, the experiments were done at random manner. For each reading, two replications were accomplished, then the average values were taken for investigation. Further, based on the degrees of freedom (DOF). the orthogonal array is chosen. The array DOF must be equal or greater than the selected parameters of the process. The experiments are done with two factors. Each of them is varied with five levels.

The fluid used in the experiment are:

1. Dry machining
2. cutting coolant oil
3. Sunflower oil+MoS2
4. Sunflower
5. oil+Graphene

Using five cutting velocity of (44, 110, 350, 750, 1100 rpm)

III. RESULTS AND DISCUSSION

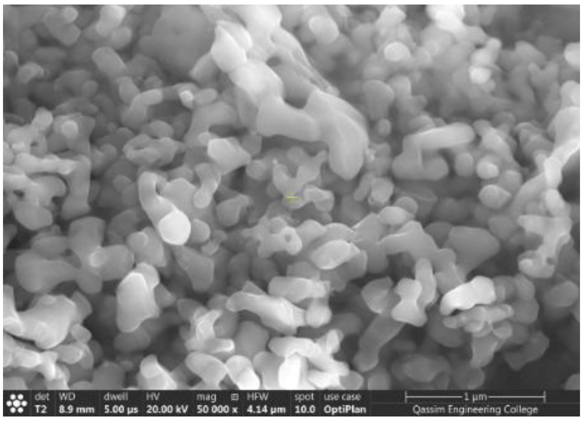
In this section, the results of the study will illustrate and discussed. The Surface roughness of the workpiece was measured using instrumentation machine TR1900 as shown in Figure 1. To minimize the experimental errors, the measured values of roughness were attained at two points parallel to the tool direction on the machined surface. Then, the average values were used. Moreover, the worn-out of tool inserts and the generated chips during machining was observe using Scanning Electron Microscope SEM as in Figure 2. The tool inserts are substituted by a new tool each time after machining process. In addition, the atomic force microscope AFM is used to observe the machined surface obtained profile.

Fig. 1.Surface Roughness Measurement

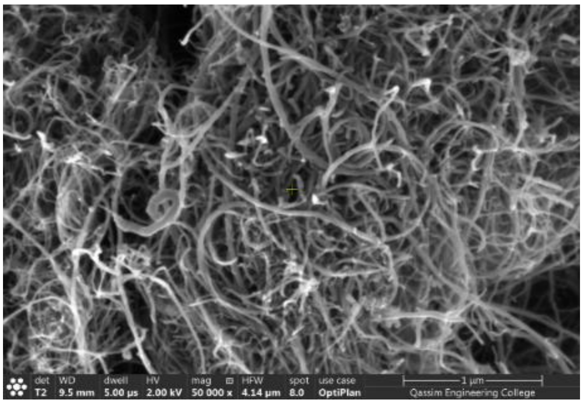
Fig. 2.Scanning Electron Microscope (SEM) of FEI Teneo LV

The quality of the surface achieved is one of the important parameters of any machined part. The better machined faces are affected by the amount of indiscretions and the contour obtained. In addition, the mechanical strength properties of the material products are decreased due to poor surface finish during fatigue loads. Consequently, it is important to assess the surface roughness to attain a satisfactory product after machining. The combination of the initial parameter condition of flood lubrication and cutting speed as it has the highest TOPSIS grade. Under the flood lubrication, the surface roughness increases with the increase of cutting speed. The water-based flood lubricant offers a less contact between chip–tool surface area. Thus, the temperature increases through machining process then, the surface roughness increases at the surface of machined part.

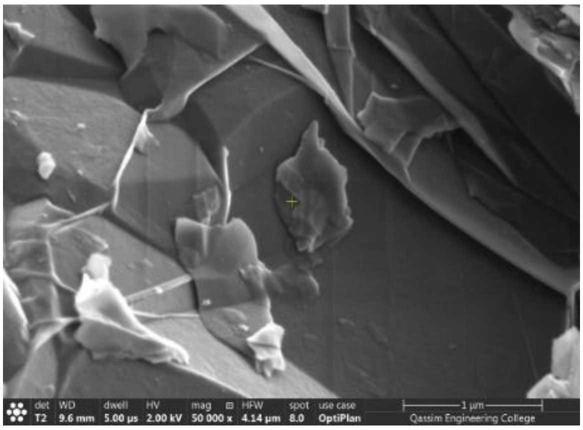
Figure 3. show the SEM images of three kind of lubricant liquid using magnification 50,000 time of AL2O3-T1, CNT-T2 and GNP-T2-50KX.



AL2O3-T1-50KX



CNT-T2-50KX



GNP-T2-50KX

Fig. 3.Lubricants Morphology using SEM Images and the corresponding XRD charts

Figure 4 shoes the chip segments using feed of 300 mm/min and the speed of cut of 150 m/min, while using of flood lubrication.

Figure 5 show the SEM images of the tool inserts indicate the wear starting at the edge of tool. The initial setting is using feed of 300 mm/min and the speed of cut of 150 m/min, while using of flood lubrication. The lubricant is allowed in flood lubrication to flow between the workpiece and the tool.

The friction between tool and workpiece increases at insufficient lubrication that increase the developed thermal stress of cutting-edge due to cooling and heating. In sequences, the edge chipping affected by the increase or decreasing of friction between workpiece and tool.

The cutting edge will crack due to thermal stress, as machining is continued and overlay toward chipping of the edge forming nose wear. The wear is propagated if the cutting speed is increased.

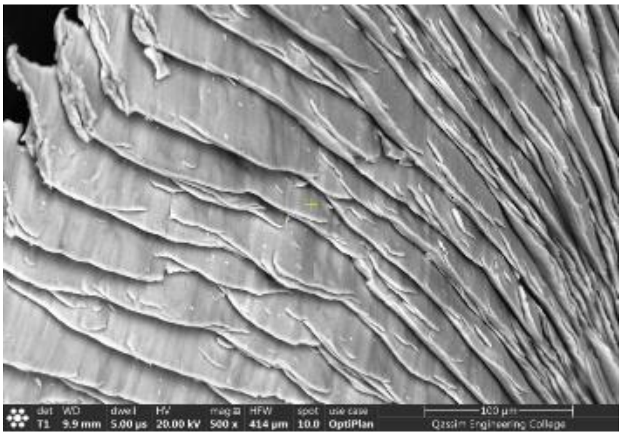


Fig. 4. SEM Images of chips

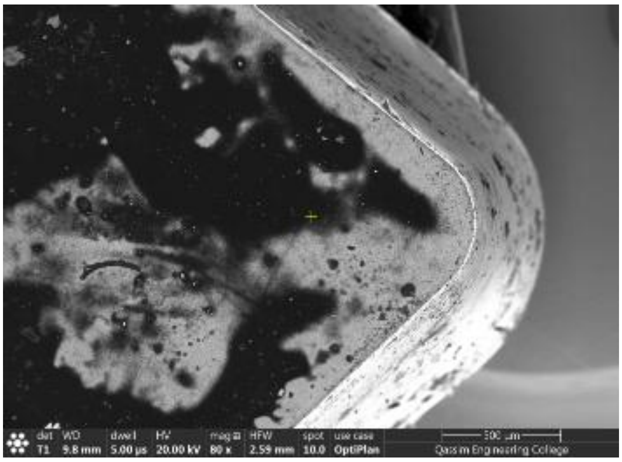


Fig. 5. Tool Morphology using SEM Images

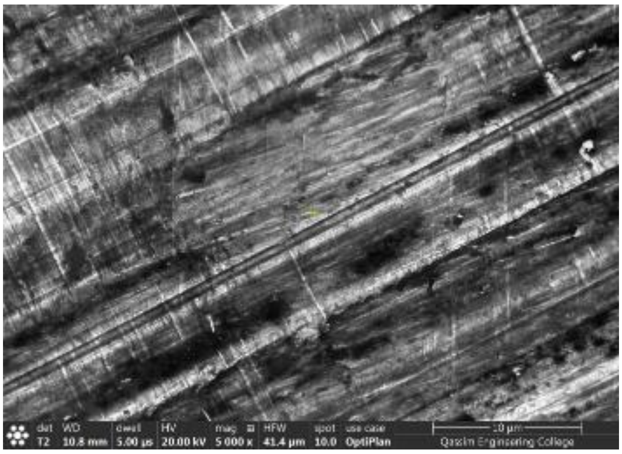


Fig. 6.SEM Images of workpiece

Figure 6. Show the workpiece after machining with feed of 300 mm/min and using speed of cut at 150 m/min using dry machining. The line print shows that the cutting is not fine due to the environment of cut as a dry cutting. Thus, indicate the necessity of using lubrication on cutting to give smooth and fine cutting on the workpiece, in addition to the reduction of tool wear. Furthermore, a bulky notched from cutting tool is noticed at the workpiece top surface represent a rough cutting process achieved at the machining area. Thus, the flood lubrication is not affording sufficient cooling and penetration at the tool, workpiece and chip contact zone.

IV. CONCLUSION

Thermal conductivity of lubricant fluid for machining is one of the most important and required properties which is not sufficient in renewable lubricant liquid. The proposed solution on this research is adding nano additive material to the renewable fluid to increase its thermal conductivity.

This study consists of comparing composite machining using dry machining and machining with cutting coolant oil, sunflower oil+MoS2, Sunflower, oil Graphene. The experimental analysis shows that the renewable lubricants may give a good alternative of the chemical lubricant. Furthermore, it is sustainable, environmentally friendly and economically. The additive material increases the required properties of lubricant liquid to be suitable for composite machining.

ACKNOWLEDGMENT

The authors gratefully acknowledge Qassim University, represented by the Deanship of Scientific Research, on the material support for this research under the number (3807-qec-2018-1-14-S) during the academic year 2018.

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