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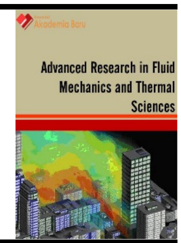

Comparison between Carbon Nanofiber (CNF) Nanofluid with Deionized Water on Tool Life and Surface Roughness in Turning of D2 Steel

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ABSTRACT

This paper presents the experimental study of the comparison between carbon nanofibers (CNF) nanofluid with deionized water in turning of D2 steel. The CNF nanofluid was prepared by mixing the nanofiller with surfactant using an ultrasonic homogenizer. CNC lathe machine and PVD coated carbide insert was used to perform the machining performance study with regards to a difference of cutting fluids. The cutting parameter was at the constant values for each cutting speed, feed rate and depth of cut. For machining performances evaluation, tool life and surface roughness are measured. From the results, it was found that by using CNF nanofluid, the tool life and surface finish were improved 25% and 22%, respectively compared to the one obtained with deionized water.

1. Introduction

D2 steel is widely used in many industrial applications as tool and dies, punches, rollers etc., due to high hardness characteristic, D2 steel is lying under difficult to cut material. To ease and improve the cutting performances, many researchers have come out with various cooling method and alternative techniques. The performances that always lay under investigation are tool flank wear and surface roughness.

According to Zhang *et al.*, [1], flank wear had increases with cutting time. Meanwhile, according to Kumar *et al.*, [2] flank wear affects the tool life at a lower speed. However, crater wear or notch wear would affect the tool life at a higher speed [3-4]. Cutting speed is the most significant that would affect the tool life followed by the feed rate and depth of cut [5-6].

Das *et al.*, [7] also stated that when increasing the cutting speed, it would also increase the tool wear and had cause deterioration to the machined surface quality. Cutting fluid is enable in reducing the cutting force as it has improved and intimate the chip-tool interaction, which lead to reduce tool

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wear [8]. Elmunafi *et al*., [9] studied the tool life when turning hardened steel by using MQL technique and found that it will improve the tool ability to perform at high range of cutting speed and feed rate. Meanwhile Navas *et al*., [10] used the cryogenic machining and found that it could reduce heating problems, leading to tool life improvement with better surface integrity.

With recent advancements in material technology, the usage of nanofluids has becoming significant in the regime of cooling due to its superior lubrication and heat dissipations characteristic [11]. Rahmati *et al*., [12] found that the inclusion of MoS_2 nanoparticles in lubricant had improved the machined surface quality due to the rolling, filling, and polishing actions at the machining zone. Prabhu and Vinayagam [13] has concluded that the surface quality was enhanced from a microlevel to nanolevel by using CNT nanofluid. Meanwhile, Sayuti *et al*., [14] investigated the novel usage of SiO_2nano-lubrication system in hard turning process of hardened steel AISI 4140 and has found that it could enhance the tool life and surface roughness. Investigation by Behera *et al*., [15] had discovered the lowest magnitude of cutting force has been found with Al_2O_3 nanofluid because of a tribo-film formation which could effectively reduce the sliding friction forces. The tribo layer formation also has reduced the flank wear and tool nose wear when it is compared to based fluid.Therefore, the aim of this present paper is to compare the performance of carbon nanofibers (CNFs) nanofluid and deionized water in turning of D2 steel in terms of tool life and surface roughness.

2. Experimental Work

2.1 Formulation of Nanofluid

In this research, the nanofluid has been produced by using the two-step method [16]. 0.02 wt% of nanofluid was prepared by dispersing the CNFs particle into the deionized water by adding surfactant. CNF which having 20nm~30nm diameter were purchased from the local supplier. Gum Arabic was chosen as the surfactant to stabilize the nanofluid. First, 0.1g gum arabic was dissolved in 1000ml of deionized water using ultrasonic homogenizer at 50 amplitudes for 15 minutes. Then, another 0.1g CNFs were dispersed into the solution for another 40 minutes. Before performing the turning process, the nanofluid mixture is being placed in an ultrasonic bath for 30 minutes to avoid agglomeration and sedimentation of the materials were used without further purification.

2.2 Machining

The workpiece used in this investigation was D2 steel of 50mm in diameter which having the Rockwell hardness of 62HRc. D2 steel falls under difficult to cut material. The experiment was conducted on HAAS SL-20 CNC lathe machine. PVD coated carbide insert types DNMG 150408N from Sumitomo has been used for the present work. It has coating of nanometre thick TiAlN and AlCrN layer. The DDJNR2525M15 type tool holder was used to hold the insert.

There are two different types of cutting fluids which were based on deionized water and CNF based nanofluid that has been used in this experiment. The coolant was channelled to the cutting zone by using a Masterflex pump at a constant flow rate of 200 ml/min. The experiment was set up similarly as shown in Figure 1.

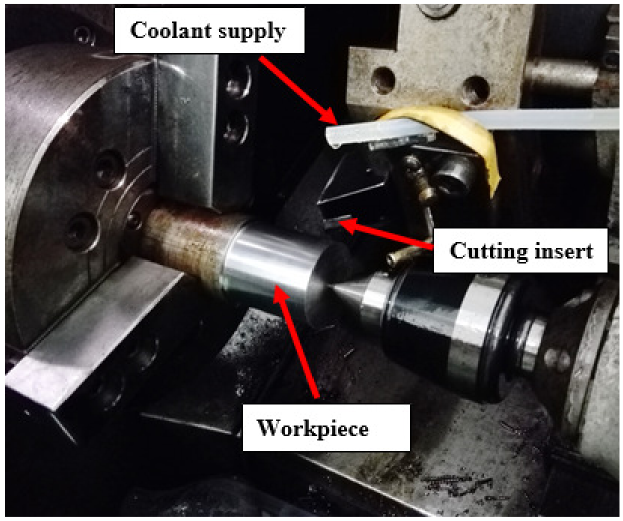

Fig. 1. Experimental setup

Cutting speed, feed rate and depth of cut were kept constant during the machining process. The cutting conditions that are used in all machining test are cutting speed vc =150m/min, feed rate f=0.15mm/rev and depth of cut of ap = 25mm.

2.3 Machining Performances

The measured responses were tool life and surface roughness. Each experiment has been performed by using a fresh cutting edge. The criterion to stop the experiment was following the condition when flank wear (Vb) reached into 0.2mm in accordance to JIS B4011–1971 standard. The tool wear was measured by using Mitutoyo tool maker-microscope. Meanwhile the surface roughness value was measured by using a Mitutoyo portable surface roughness tester. Vb and Ra values were measured every preset of cutting length at 400mm until the tool wear has been met the tool life criteria. When flank wear reached 0.2mm, the tool edge was replaced and a new experiment was started.

3. Results and Discussion

3.1 Tool Life

Figure 2 depicts the tool flank wear variation with cutting length, for the experimented conditions. As expected, the Vb is gradually increases with the increase of the machined length under both cutting fluid. It can be noted that flank wear behaviour is similar for both conditions. However, it can be clearly seen that the flank wear for the CNF nanofluid is lower than deionized water. It is clear that by using CNF it could prolong the tool life into cutting extension up to 2000mm before it reached the tool life criterion. This phenomenon may be occurring due to the present of CNF. The higher temperature at a cutting zone can increase the tool wear and this problem could be solved with the presence of cutting fluid [17]. The higher thermal conductivity of CNF particles [18], was successfully assisted to reduce the cutting temperature as it would allow the efficient heat transfer and dissipation. When the accumulated temperature at the cutting zone is reduced, the flank wear also can be reduced and this will lead to longer tool life. This finding was also supported by Murshed *et al.*, [19] as they mentioned that the nanofluids, which engineered by dispersing nanometer-sized solid particles in conventional heat transfer fluids, have been found provides higher thermal conductivity as compared than their base fluids.

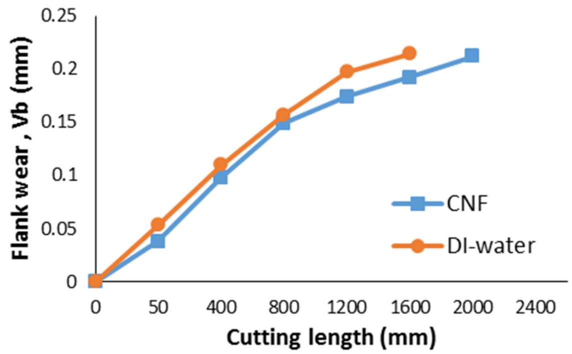

Fig. 2. Tool life of coated carbide insert under CNF nanofluid and deionized water

3.2 Surface Roughness

Surface roughness (Ra) is usually important in measuring the performance as it could represent the quality of finished product. Figure 3 shows the evolution of surface roughness for both of CNF nanofluid and deionized water alongside with the machined length. CNF nanofluid had resulted in lowering the surface roughness as compared to deionized water. Even, when the tool has reached the tool life conditions, the Ra value for CNF is still lower than the utilization of deionized water. From this result, it can prove that by adding the nano materials, better surface finish could be obtained as the nano particles can be acted as the polishing agent [20-21]. Sharma [22] also claimed that by adding nano particles, the surface roughness of machined products could be significantly improved. This is because the CNFs particles are acknowledged to transfer heat produced during machining better than using DI-water alone which lead to the reduction of cutting force that affect surface roughness [23].

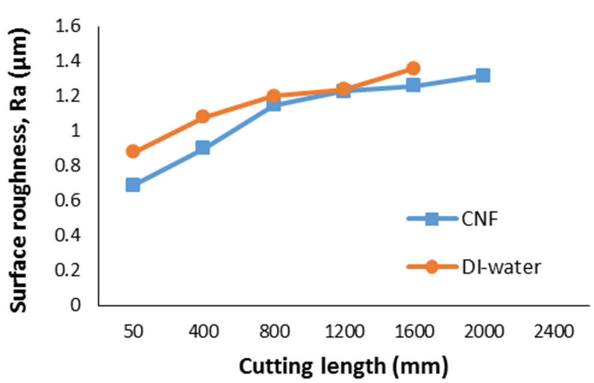

Fig. 3. Evolution of surface roughness for CNF nanofluid and deionized water

4. Conclusion

The present study was to compare the performance of CNF nanofluid and deionized water on turning of D2 steel. From the results, the following conclusions could be established:

1. CNF nanofluid could reduce the flank wear and thus prolong the tool life as compared than the deionized water.
2. When using CNF nanofluid, better surface roughness could be obtained compared to deionized water.

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