International Journal of Heat and Mass Transfer 127 (2018) 173–181

Contents lists available at ScienceDirect

International Journal of Heat and Mass Transfer

journal homepage: www.elsevier.com/locate/ijhmt

Thermal analysis of cellulose nanocrystal-ethylene glycol nanofluid coolant

L. Samylingam [a], K. Anamalai [a], K. Kadirgama [a,*], M. Samykano [a], D. Ramasamy [a], M.M. Noor [a], G. Najafi [b], M.M. Rahman [a], Hong Wei Xian [c], Nor Azwadi Che Sidik [c,*]

[a] Faculty of Mechanical Engineering, Universiti Malaysia Pahang, 26600 Pekan, Pahang, Malaysia
[b] Tarbiat Modares University, Tehran, Iran
[c] Department of Mechanical Precision Engineering, Malaysia-Japan International Institute of Technology, University Technology Malaysia, Jalan Sultan Yahya Petra, Kuala Lumpur, Malaysia

ARTICLE INFO

Article history:
Received 2 March 2018
Received in revised form 14 July 2018
Accepted 15 July 2018

Keywords:
Nanofluid
Ethylene glycol
Cellulose
Nano crystals
Thermal analysis

ABSTRACT

In this paper, cellulose nanocrystal (CNC) – ethylene glycol (EG) + Water (W) based nanofluid was developed and assessed for their thermophysical properties and the usefulness towards machining performances. The nanofluid was prepared by adopting two-step preparation method and at volume concentration of 0.1%, 0.3%, 0.5%, 0.7%, 0.9%, 1.1%, 1.3% and 1.5%. The nanofluid with 1.3% and 1.5% concentration showed to have superior the conductivity properties, around 0.559 W/m·K at 70 °C. However, the 0.5% concentration has the highest stability with 0.52 W/m·K at 70 °C. The 0.5% nanofluid concentration was then selected for the machining performance evaluation. The machining performance was evaluated by using a lathe machining operation to determine the heat transfer and tool life properties. The cutting variables such as cutting speed, depth of cut and feed rate are varied to understand the effect of developed nanofluid on the machining bahaviour. Findings revealed that the tool failure on machining using MWF is flank wear, chipping and abrasion and fractured at the maximum cutting distance of 500 mm. However, machining using CNC-EG+W nanofluid revealed the tool failure to be flank wear, adhesion and build- up-edge (BUE) and fractured at the maximum cutting distance of 772 mm.

© 2018 Elsevier Ltd. All rights reserved.

1. Introduction

Energy has been an essential aspect of our daily life. Humans have explored all the possible way to produce the energy which has cost the impact to the environment. Thus, numerous efforts are being taken to preserve the environment for appalling catastrophes [1,2]. In the industrial world, especially in manufacturing trades, machining is the most crucial process as the desired profile, dimensions and surface finish is achieved by removing the unrequired material in the form of chip [3,4]. The removal of unwanted material is achieved through mechanical contact between the workpiece and cutter [5,6]. This contact generates heat and continues to rise as the process continues causing a decrease in tool strength that leads to quicker tool wear and failure [7–9]. Thus, the removal of this heat is essential to improve the machining performance [9–11]. One of the possible ways to remove the produced heat is through the use of cutting fluid known as coolants. The primary function of this coolant is to remove the heat, wash out the produced chip, eradicate the development of BUE (build-up edge) and BUL (build-up layer) [12–17]. The traditional coolant used for machining is known as metalworking fluid (MWF) and this coolant usually used in flood cooling technique. However, the traditional coolants still not capable of reducing the heat efficiently. Also, the heavy usage of this coolants has led to serious environmental and health hazards such as skin illness, human respirational complications and also greens house effect. These have impelled scientist to discover ways to either reducing or developing new alternative coolants and the application methods in machining [18,19]. In terms of application method, the minimum quantity lubrication (MQL) identified to be the promising method as this technique streams out the coolant in mist which will be directed precisely to the contact point [19–21]. However, since the coolant is supplied in mist, the present MWF fails to perform its duties. Higher heat transfer, lubricating properties and environmentally friendly lubricant are required. To accomplish this, nanofluids would be the best-suited candidate [22–25]. Numerous investigation findings reported that nanofluids have superior thermophysical properties and an excellent candidate for heat transfer

* Corresponding authors.
E-mail addresses: kumaran@ump.edu.my (K. Kadirgama), azwadi@mail.fkm.utm.my (N.A. Che Sidik).

https://doi.org/10.1016/j.ijheatmasstransfer.2018.07.080
0017-9310/© 2018 Elsevier Ltd. All rights reserved.

applications [26,27]. Typically, these nanofluid contains metal oxide particles such as TiO_2 and SiO_2 which the primary cause for improvement. However, these metal oxides which may introduce significant environmental problems [28,29]. As such, this study focuses on introducing the potential of using a plant-based material such as CNC extracted from Canadian Hemlock tree to develop an enhanced and environmentally friendly coolant for machining process [30]. This CNC-EG+W based coolant aptitudes superior thermal conductivity that capable to improve the thermal transport and machining performance.

2. Materials and methods

2.1. CNC-EG+W nanofluid preparation

The cellulose nanocrystal used in this work was purchased from Blue Goose Biorefineries. This CNC was extracted from Western Hemlock Plant and supplied at eight percent suspended weight to weight ratio. Since the purchased CNC is in wt%, the CNC-EG+W were prepared by dilution method adopting a two-step method [31]. The nanofluid is prepared by dissolving CNC in EG+W mixture. Initially, the weight concentration, ω is converted to volume concentration, ϕ by using Eq. (1). Then, the CNC is dispersed in base fluid (40% EG and 60% W), ΔV at preferred concentration, ϕ_2 which determined using Eq. (2), followed by stirring by using a magnetic stirrer for 30 min. Finally, the prepared solution is ultrasonicated for 2 h by using Fisher brand model number-FB1505 to produce a stable and homogenous nanofluid. Table 1 lists the CNC specification as provided by the provider.

$$\phi = \frac{\omega \rho_{bf}}{\left(1 - \frac{\omega}{100}\right)\rho_p + \frac{\omega}{100}\rho_{bf}} \tag{1}$$

$$\Delta V = (V_2 - V_1) = V_1\left(\frac{\phi_1}{\phi_2} - 1\right) \tag{2}$$

2.2. Measurement procedure for thermal conductivity

KD2 Pro Thermal Property Analyser (Decagon Devices, Inc., USA) is used in this work to investigate the thermal behavior of the prepared nanofluid as shown in Fig. 1. This analyzer comprises a controller and KS-1 (60 mm) sensors that are used to measure the thermal properties. The measurement was performed at a temperature between 30 °C and 70 °C (controlled condition). Memmert water bath (with an accuracy of 0.1 °C) is used to regulate the temperature. Prior to the actual experiments, the KD2 pro is validated by determining the thermal conductivity of the benchmark solution supplied by the equipment manufacturer (glycerine, k = 0.285 W/m K at 20 °C) solution. Also, the measurement is further authenticated by measuring the base fluid thermal conductivity (40% EG and 60% W) and compared with the predetermined values from ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) as shown in Fig. 2. The comparison shows a very small maximum deviation of about 1.4% between the base fluid and ASHRAE data. These affirm the ability and reliability of the equipment in performing the measurement. The actual measurement was carried out for 20 readings at 15 min interval time for each sample concentration and averaged to minimize the experimental error.

Table 1
Cellulose nano crystal specification.

Parameter	Value
Hydrodynamic Index	150 nm (diameter)
Crystal	9–14 nm (diameter) 100–150 nm (length)
Crystallinity	80%

Fig. 1. KD2 Pro thermal conductivity measurement setup.

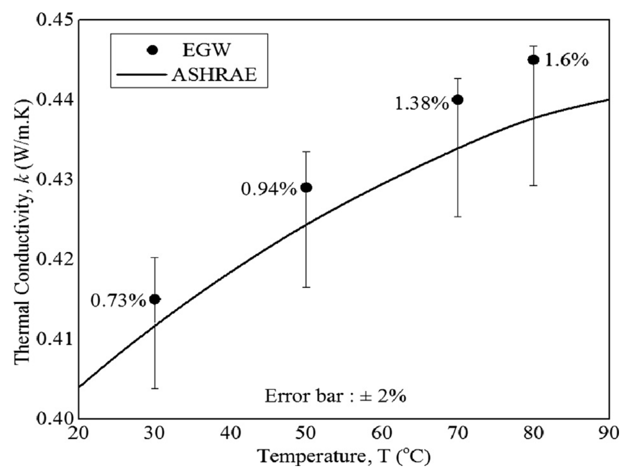

Fig. 2. Thermal Conductivity error measurement between EG+W (base fluid) and ASHRAE data.

2.3. Measurement procedure for dynamic viscosity

Dynamic viscosity is measured by measuring the viscous drag created by the spindle rotation on Brookfield LVDV-III Rheometer as shown in Fig. 3. The data is collected using a personal computer which connected to the rheometer. A minimum of five (5) readings are obtained from each concentration and averaged to minimize the error and to obtain an accurate data. The collected data shows the maximum deviation of 12.19% upon compared with ASHRAE data as shown in Fig. 4. Prior to the actual nanofluid viscosity measurement, the rheometer ability is validated. The validation was carried out by measuring the base fluid (containing 40% EG and 60% W) and compared with the value obtained from predetermined ASHRAE values. The measurement is proceeded once a good covenant is obtained between the actual and the modeled value.

2.4. Turning machining operation

In the present study, the MQL technique using Unist Coolubricator (UC) is adopted as the cooling method. The used UC capable of holding 1893 ml of nanofluid as shown in Fig. 5. The flow rate used for this investigation is 10 ml/hr. The UC setup used in this study are as shown in Fig. 5.

Whereas, the cutting tool used for the machining operation was made by Ceratizit. The turning insert used in this work is the tungsten-cobalt (cemented WC-Co) CVD coated with Ti (C,N) + Al_2O_3. The total thickness of the coating is 15 μm. The insert with

Download English Version:

https://daneshyari.com/en/article/7053662

Download Persian Version:

https://daneshyari.com/article/7053662

Daneshyari.com