Journal of Manufacturing Processes 26 (2017) 94–104

Contents lists available at ScienceDirect

Journal of Manufacturing Processes

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

Research paper

Comparative evaluation of the lubricating properties of vegetable-oil-based nanofluids between frictional test and grinding experiment

Yaogang Wang[a], Changhe Li[a,*], Yanbin Zhang[a], Benkai Li[a], Min Yang[a], Xianpeng Zhang[a], Shuming Guo[a], Guotao Liu[a], Mingge Zhai[b]

[a] School of Mechanical Engineering, Qingdao University of Technology, 266520 Qingdao, China
[b] College of Mechanical and Electrical Engineering, Qingdao Binhai University, 266520 Qingdao, China

ARTICLE INFO

Article history:
Received 26 June 2016
Received in revised form 6 January 2017
Accepted 4 February 2017

Keywords:
Nanoparticles
Vegetable oils
Lubricating properties
Frictional test
Grinding experiment
Friction and wear

ABSTRACT

This paper presents the lubricating properties of different vegetable-oil-based nanofluids through a comparative evaluation between frictional test and grinding experiment. Two series of experiments were performed. The first experiment aimed to prejudge the lubricating properties of different nanofluids via a frictional test, which simulated the interface state of grinding between the abrasive grains and the workpiece. The second aimed to test and verify the lubricating properties of the same nanofluids through a grinding experiment. The mechanism of oil-film formation of nanofluids in the grinding zone was analyzed by morphology and element analysis of the worn surface. Overall, results indicate that all the nanoparticles can remarkably improve the lubricating properties of the base oil, and nanofluids effectively reduce sliding friction by forming a stable and low-friction film on the surface of friction pairs. In the frictional test, the average friction coefficient of Al_2O_3 nanofluids decreased by 19.3%, and the mass wearing ratio increased by 65% compared with that of pure palm oil. The lubricating properties of different nanofluids in the frictional test were in good agreement with those in the grinding experiment. Thereby, the results can provide theoretical support and experimental guidance to explore the lubricating properties and film-formation mechanism of nanofluids in grinding zones. The results also prove that the Al_2O_3 and MoS_2 nanoparticles are suitable as anti-friction additives for machining lubricants.

1. Introduction

Lubrication plays an irreplaceable role in reducing friction and wear and ensuring workpiece machining precision. In machining processing, friction not only consumes abundant energies but causes serious damage to workpiece and machining equipment [1–3]. Therefore, lubricants have an important role in lubricating and removing chips to reduce friction and wear. Traditional lubricants have many problems, such as leakage and volatilization, which cause poor lubrication effect and serious damage to human health and the environment. Hence, vegetable oil is recommended as the base oil of lubricants because it is a renewable resource, environmentally friendly and biodegradable, as well as having high viscosity and low volatilization, among other characteristics [4,5]. All these advantages make vegetable oil an excellent candidate as base oil for lubricants.

Nanofluids can significantly improve the tribological properties of lubricants. The anti-friction performance of nanoparticles depends on their physical features, such as shape, size, and molecular structure [6–8]. Owing to the small size effect and high surface energy of nanoparticles, they are accepted as a new promising environmentally friendly lubricant additive.

In the past decade, numerous scholars have reported abundant research on the anti-friction performance of nanoparticles in machining and frictional tests, such as metals [9], metal oxides [6], metal sulfide [7], and carbide [10]. Adding nanoparticles in vegetable oil can not only reduce friction effectively but also result in environmentally friendly and sustainable lubricants. In machining process, Shen et al. [3] investigate the tribological characteristics in wet, dry, and MQL grinding with nanofluids. They found that nanofluids help reduce grinding forces. Kalita et al. [11] investigated the performance of MQL grinding using nanolubricants and found that the nanolubricants increase the process efficiency.

* Corresponding author.
E-mail address: sy_lichanghe@163.com (C. Li).

http://dx.doi.org/10.1016/j.jmapro.2017.02.001

Nomenclature

MQL	Minimum quantity lubrication
MWCNT	Multi-walled carbon nanotube
SDS	Lauryl sodium sulfate
G-ratio	Grinding ratio
ms	Mass wearing of the grinding wheel block (mg)
mb	Wearing mass of the steel ball (mg)
PPO	Pure palm oil
ND	Diamond nanoparticle
CNT	Carbon nanotube
WSD	Wear scar diameter
SEM	Scanning electron microscope
EDS	Energy dispersive spectroscopy

By contrast, Alves et al. [12] conducted a frictional test to study vegetable-oil-based nanofluids with a reciprocating tester. The results showed that the tribological properties of nanofluids can be significantly improved. ManojKumar and Ghosh [13] researched the tribological characteristics of MWCNT nanofluid using a ball-on-disc tribotester. They found that the nanofluid can substantially outperform soluble oil. Mao et al. [14] investigated the tribological properties of Al_2O_3 and MoS_2 nanofluids and of pure canola oil in a tribotester and a surface grinder respectively. The results show that Al_2O_3 nanofluid exhibits noticeable friction reduction and anti-wear properties. In addition, Xie et al. [15] studied the tribological properties of SiO_2 and MoS_2 nanoparticles by using a reciprocating sliding tribometer. They found that nanoparticles significantly improve the tribological properties of base lubricants. In short, several lubrication mechanisms of nanoparticles have been proposed, including bearing effect [3,6,16], protecting film [17–19], and repair effect [20,21].

Although research has been conducted on the lubricating properties of nanofluids in machining and frictional test, few studies have compared the lubricating properties of different nanoparticles. Therefore, which type of nanoparticle has the best lubricating property is still unknown. Moreover, employing the frictional test to evaluate the lubricating property of lubricants is a conventional method. By contrast, using a grinding experiment to capture experimental phenomena and evaluate the lubricating properties of lubricants is difficult. Nonetheless, grinding experimental conditions can be simulated by using the principle of frictional test to characterize the lubricating characteristics of lubricants, thus providing guidance for actual industrial production. This aspect still remains blank at present. Therefore, the aims of this study are as follows:

- Prejudge the lubricating properties of different nanoparticles by performing a frictional test, which simulates grinding conditions, to study different vegetable oil-based nanofluids.
- Test and verify the lubricating properties of the same nanofluids used in the grinding experiment.

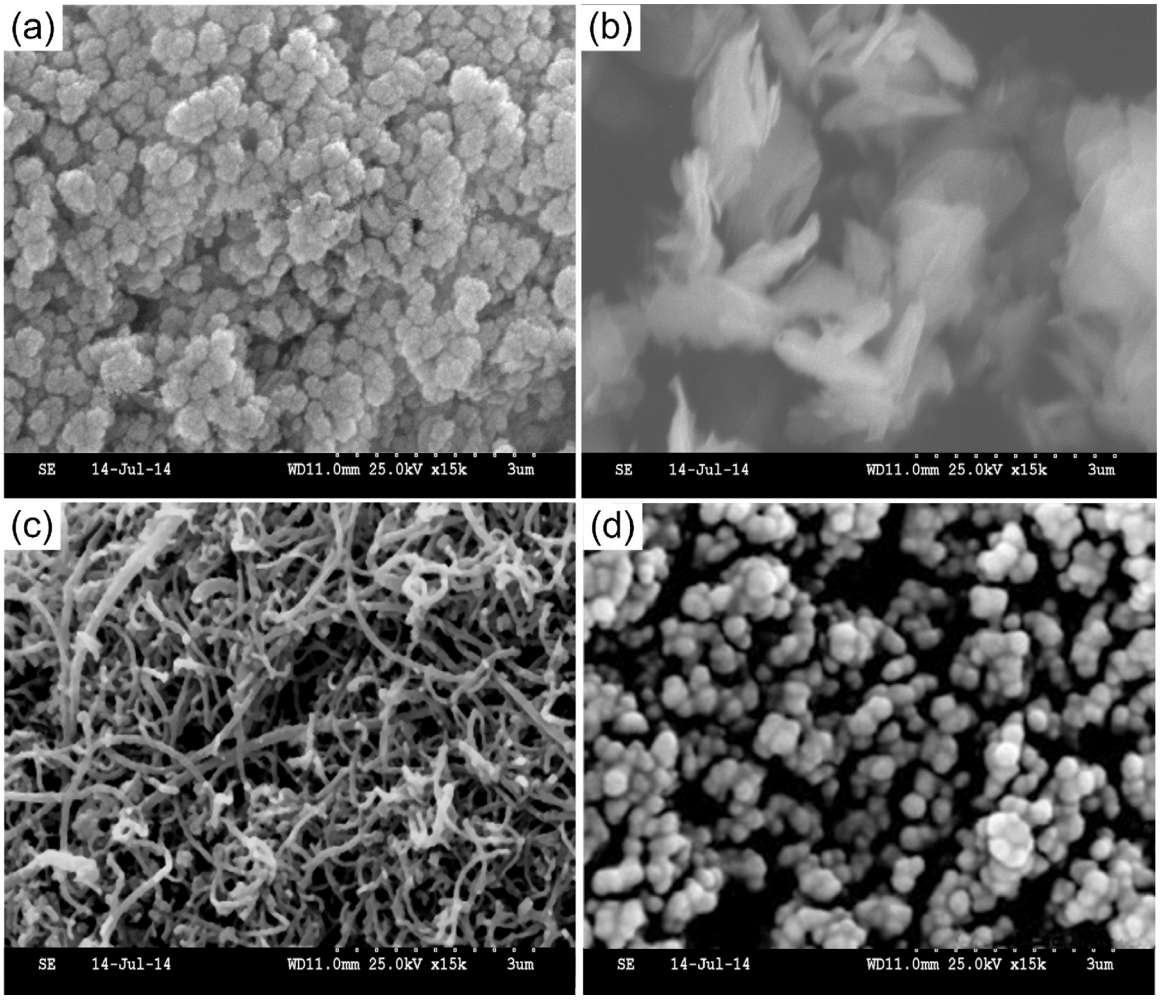

Fig. 1. SEM images of (a) Al_2O_3, (b) MoS_2, (c) CNTs, and (d) ND nanoparticles.