Chapter 12
Experimental Study of Lubricating Property at Grinding Wheel/Workpiece Interface Under NMQL Grinding

ABSTRACT

Nanofluid is the suspension formed by lubricating oil and nanoparticles with particles sizes of 1~100 nm, and common nanoparticles include metal nanoparticles (Cu, Ag, etc.), oxide nanoparticles (Al2O3, SiO2, ZrO2, etc.), carbides (CNT, diamond), and MoS2 nanoparticles, etc. Different nanoparticles exhibit various physicochemical properties (e.g., structure and shape), which can influence their tribological characteristics. In this work, six nanofluids, namely, MoS2, SiO2, diamond, carbon nanotubes (CNTs), Al2O3, and ZrO2, were used as minimum quantity lubrication grinding fluids to select the kind of nanoparticles with optimum lubrication performance in grinding nickel alloy GH4169. Experimental results concluded the following: 1) Nanoparticles with spherical or sphere-like molecular structure and nanofluids with high viscosity demonstrate superior lubrication performances. 2) The polishing effect of nanodiamond particles enhances their surface morphology. 3) The lubricating property of the six nanofluids is described in the following order: ZrO2 < CNTs < ND < MoS2 < SiO2 < Al2O3.

12.1 INTRODUCTION

Grinding is widely used in machining and the process is a random integration of sliding, ploughing, and cutting by abundant irregular abrasive grains scattered on a grinding wheel/workpiece interface viewed from microstructure (Malkin & Guo, 1991). The abovementioned process exerts higher units of grinding force and grinding speed than other machining processes, thus utilizing significantly higher grinding energies. In particular, hard materials in the grinding process will generate a lot of additional heat (Ding et al., 2015). Flood technology is the most common cooling–lubrication method used to improve the machining quality of workpieces and cutters. However, the surface processing quality of workpieces

DOI: 10.4018/978-1-7998-1546-4.ch012
is not satisfactory because the grinding wheel at high-speed forms a layer of gas-barrier, which makes entry into the grinding wheel and workpiece interface difficult for numerous grinding fluids (Li, Wang, & Zhang, 2013). Minimum quantity lubrication (MQL) technique is a green processing method (Baheti, & Guo, 1998). The MQL technology uses a minimum quantity of lubricants to achieve satisfying lubrication performance. This technique mixes a minimum quantity of lubricants in high-pressure gases, which can break through the air-barrier layer of the grinding wheel and arrive at the grinding area after mixing atomization. In particular, high-pressure gas plays a role in cooling and debris removal. Li et al. (Li, Hou, Xiu, & Cai, 2008) performed experiments to evaluate the performance of MQL technology compared with that of conventional flood cooling. Mao et al. (Mao et al., 2013) analyzed the heat-transfer coefficient on workpiece surface during MQL grinding and concluded that the theory of surface heat-transfer coefficient during MQL grinding is creditable. Numerous studies and experiments have indicated that the grinding process is improved by MQL technology. More importantly, the dosage of the grinding fluid significantly decreases, thereby reducing hazards to workers and the environment (Zhang, Li, Jia, Zhang, & Zhang, 2015).

To increase the machining performance and disposal of grinding fluids, as well as to address the related environmental and health problems, some scholars attempted to use vegetable oils as MQL base oil. Emami et al. (Emami, Sadeghi, Sarhan, & Hasani, 2014) investigated the performances of four types of lubricants, namely, mineral, hydrocracked, synthetic and vegetable oils; their results showed that MQL not only considerably affects the cutting force, specific energy, and surface roughness, but the vegetable oils can also diminish environmental hazards of cutting fluids. Rahim et al. (Rahim & Sasahara, 2011; Rahim & Sasahara, 2011a, 2011b) conducted a series of experimental studies in which palm oil and synthetic ester were used as MQL base oils. To develop a more advanced processing method using lubricants with less energy consumption and less environmental pollution, nanoparticles are employed as additives of nanofluids to significantly improve the lubrication effect and heat-transfer. Nanofluids are colloidal mixtures of nanometer-sized particles (1 nm to 100 nm) in a base fluid. Such nanoparticles can be metallic (Fe, Cu, Ag), non-metallic (diamond), oxide (Al2O3, SiO2, ZrO2), carbide (carbon nanotubes), sulfide (MoS2), ceramic, and hybrid. Nanofluids demonstrate many advantages, including superior lubrication performance and thermal conductivity (Hu, Bai, Lv, Wang, & Li, 2014). Given that different nanoparticles exhibit various physicochemical properties like molecular structure and shape, the corresponding nanofluids will demonstrate diverse lubrication properties and heat-transfer capabilities. Shen et al. (Shen, Shih, & Tung, 2008) investigated the wheel wear and tribological characteristics in wet, dry, and MQL grinding with water-based Al2O3 and diamond nanofluids. Their results showed that a dense and hard slurry layer was formed on the wheel surface, thereby reducing the grinding force. The authors claimed that MQL grinding can also significantly reduce the grinding temperature. Ge et al. (Ge & Cao, 2015) studied the surface morphology of the workpiece after tribological tests with oleophilic nanometer-TiO2 and nanometer-SiO2 as additives. In their experiment, a layer of protective oil film was generated by the deposited Ti and Si or metallic oxide, which can reduce friction and improve the tribological properties. Kalita et al. (Kalita, Malshe, Kumar, Yoganath, & Gurumurthy, 2012) per formed nanofluid MQL grinding experiments by using soybean oil and paraffin oil as base oils; their results revealed good tribological property of MoS2 nanoparticles. Lee et al. (Lee, Kim, Nam, & Lee, 2012) added ND and nanoAl2O3 particles into paraffin oil with nanofluids for MQL microgrinding; their findings showed that nanofluid MQL can effectively reduce the grinding forces and enhance the surface quality. Mao et al. (Mao, Tang, Zou, Huang, & Zhou, 2012) used four different lubrication conditions (i.e., dry, flood, pure MQL, and Al2O3 nanofluid MQL) for grinding experiments; their results indicated