Available online at www.sciencedirect.com
ScienceDirect
Procedia Manufacturing 2 (2015) 130 – 134
Procedia MANUFACTURING

2nd International Materials, Industrial, and Manufacturing Engineering Conference, MIMEC2015, 4-6 February 2015, Bali Indonesia

Effect of Al_2O_3 nanolubricant with SDBS on tool wear during turning process of AISI 1050 with minimal quantity lubricant

A.N.M Khalil[a], M.A.M Ali[b], A.I. Azmi[c]

[a,b] *School of Manufacturing Engineering, University Malaysia Perlis, Arau, 02600, Malaysia*
[c] *Faculty of Engineering Technology, Universiti Malaysia Perlis (UniMAP), UniCITI Alam, 02100 Padang Besar, Perlis, Malaysia*
[c]*nabilkhalil@unimap.edu.my,* [b] *acap.rave@gmail.com* [c]*azwaniskandar@unimap.edu.my*

Abstract

A nanolubricant is a new kind of engineering lubricant made of suspended particles in a base lubricant. It offers quality-machined part with minimum power consumption during machining. However, the application of nanolubricant without surfactant leads to agglomeration after a certain period of time. Hence, this paper investigates the effect of Al_2O_3 nanolubricant with surfactant Sodium Dodecylbenzene Sulfonate (SDBS) on tool wear during turning process of AISI 10150, mild steel bar with minimum quantity lubricant. Different cutting fluid conditions namely; dry; nanolubricant and nanolubricant with SDBS surfactant were tested. Tool wear rate were evaluated at constant cutting speed of 1273 rpm, feed rate of 0.2 mm/rev, and depth of cut of 0.1 mm. The results exhibit positive influence of Al_20_3 nanolubricant with surfactant in alleviating tool wear during turning operations.

Selection and Peer-review under responsibility of the Scientific Committee of MIMEC2015

Keywords: Nanolubricant; MQL; Surfactant; Tool wear

1. Introduction

In recent years, environmental issues such as reduction of environmental pollution, promoting quality of life and elimination of impurities are of high importance in developed countries. It is a well-known fact that extensive and overuse of lubricants in metal working industries to prolong the life of mechanical tools, improve surface finish, and slow down tool wear and to reduce friction [1]. Nevertheless, this greatly contributes towards environmental pollution. Hence, minimal quantity of lubrication have been attempted and suggested by researchers worldwide for the metal cutting industries.

Nomenclature

SDBS	Sodium Dodecylbenzene Sulfonate
MQL	Minimum Quantity Lubricant

*Corresponding author
Email address: nabilkhalil@unimap.edu.my

Selection and Peer-review under responsibility of the Scientific Committee of MIMEC2015
doi:10.1016/j.promfg.2015.07.023

Meanwhile, recent studies on lubricants with additives such as nano-particles, that have attracted the interest of many researchers, may hold the promising answers to address this issue. Polytetrafluoroethene, graphite, and molybdenum disulphide are the most common commercial particles employed as additives in this type of lubricant [2]. These base fluids suspended with nano-meter sized particles referred to as nanolubricant, improves lubrication performance by averting contact between metal surfaces. Moreover, the thermal conductivity of a nanolubricant increases linearly with the concentration, thus facilitates hydrodynamic interaction to enhance thermal transport capability and improve heat carrying capacity, anti-wear and friction reduction properties [3–5].

It has been reported that the suspended nanoparticle in base oil leads to agglomeration after some period of time. Thus, it is necessary to study and analyze the influencing factors to the dispersion stability of nanofluids [6-7]. Surfactants are amphiphilic compounds that can reduce surface and interfacial tensions by accumulating at the interface of immiscible fluids. It increases the solubility, mobility, bioavailability and subsequent biodegradation of hydrophobic or insoluble organic compounds [8]. Nanolubricant with surfactant has been shown to yield better results in terms of stability, thermal conductivity and fluid viscosity [9–10]. In a recent study, surfactants have been also proved to make a significant contribution to the dispersion stability of Al_2O_3 nanofluids [11]. Several recent studies however, mainly focus on the advantages of the use of nanolubricants on the performance of machining operations, i.e. surface roughness. Fundamental understanding of the effects of nanolubricant with surfactant on the the tool wear is still inadequate. Hence, in this study, the optimal operating condition employing minimum quantity nanolubricant with surfactant to improve tool life is proposed. It is important to note here that minimum quantity lubrication (MQL), also known as near dry machining (NDM), refers to the use of cutting fluids in tiny quantities, which is only about ten-thousandth of the amount of cutting fluid used in flood-cooled machining.

2. Methodology

2.1. Preparation of nanolubricant

Al_2O_3 nanoparticles (0.1% wt - pure nanolubricant) suspended in soluble cutting oil (SolCut) was prepared by using ultrasonics liquid processor within 4 hours at 25 % amplitude and output power of 100 W at 18–23°C. 3% wt Sodium Dodecylbenzene Sulfonate (SDBS) was added to minimize the agglomeration in the mixture.

2.2. Experimental conditions

Experiments were carried out by plain turning a 50 mm diameter by 100 mm long rod of AISI 1050 steel in a CHEVALIER FCL-608 CNC turning machine. The experimental conditions employed in this current study are given in Table 1. These conditions were based on previously reported studies of turning AISI 1050 steel.

2.3. Lubrication-cooling conditions

Three different lubrication-cooling conditions were investigated: (a) without any cooling lubricant (dry cutting), (b) minimal quantity pure nanolubricant (MQL cutting), and (c) minimal quantity nanolubricant (MQL cutting) with added SDBS. For the purpose of MQL implementation, a two-channel external supply system was used: oil and air are fed separately, and the air–oil mixture was produced directly ahead of the tool just before it is sprayed via a nozzle. The turning tests under MQL conditions were carried out with an oil flow of 20 ml/h.

2.4. Tool wear measurement setup

The present work deals with experimental investigation on the role of Al_2O_3 nanolubricant on tool wear in plain turning of mild steel at industrial speed-feed by a single type of carbide inserts at constant cutting parameter configurations. The cutting insert was withdrawn from the tool holder at regular intervals in order to study the pattern and extent of wear on main flanks for all the trials. The average width of the principal flank wear, V_B was measured using Leica EZ4 stereo microscope with Dino capture software and camera.

3. Results and Discussion

3.1. The influence of SDBS in nanolubricant

The nanolubricant with no added surfactant often agglomerates after 4 hours. The additional SDBS surfactant into the pure nanolubricant helps to minimize the agglomeration and create strong bonding between the base oil and the nanoparticles. The surfactant makes a significant contribution to the dispersion stability of Al_2O_3 nanolubricant. Fig. 1 shows the characteristic of nanolubricant pure and nanolubricant with additional SDBS. The characteristics can be distinguished through the different colour. The colour of pure nanolubricant tends to change into light brown compared to original pure SolCut cutting fluid.

Table 1.Experimental condition

Item	Description
Machine Tool	CHEVALIER FCL-608 CNC Turning Machine
Work specimen	
Materials	AISI 1050 , Mild Steel
Size (mm)	50 mm diameter
Cutting tool (insert)	
Cutting insert	Finishing coated carbide insert (nose radius: 2 mm)
Process parameters	
Cutting speed	1273 rpm
Feed rate	0.2 mm/rev
Depth of cut	0.1 mm
MQL supply	Air: 6.0 bar, lubricant: 20 ml/h (through external nozzle)
Environment	Dry, minimum quantity lubrication (MQL) - pure nanolubricant and MQL nanolubricant with SDBS

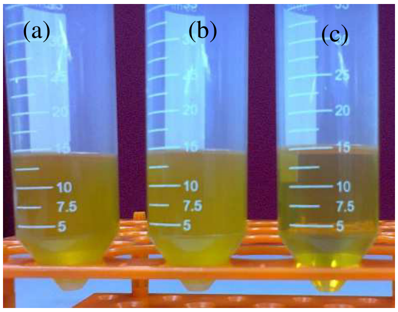

Fig. 1. Characteristics of three different solution. (a) Nanolubricant with SDBS, (b) pure nanolubricant and (c) pure SolCut cutting fluid

3.2. The effect of nanolubricant with SDBS on tool wear

Tool-wear is one of the most significant and necessary parameters required for process planning and total machining economics. The tool wear growth of dry machining, pure nanolubricant and nanolubricant with SDBS have been compared in this present work, Fig. 2 Highest tool wear growth can be observed during dry machining of specimens. While wet machining with pure nanolubricant shows lowest growth of average tool wear throughout the experiment. It is apparent that wet machining by using nanolubricant with SDBS exhibits a very close and almost the same pattern of average tool wear as the pure nanolubrication. The difference in average tool wear between the two wet machining conditions becomes less significant towards the end of the experiment. This indicates that substantial benefit of nanolubricant with SDBS on the extension of tool life. This may be mainly attributed to reduction in cutting zone temperature and favorable change in the chip–tool interaction. Fig. 3 exhibits the progressive of flank wear for three different cutting environments. Meanwhile, from Fig. 2, the tool life of this experiment was estimated by setting up the tool wear criterion of 0.25 mm flank wear. It was found that the tool life for dry cutting is approximately 40 minutes. The life of cutting tool nanolubricant with SDBS and under pure nanolubricant are approximately 60 and 72 minutes with this tool wear criterion. The flank wear measurements were recorded at every 30 min, 50 min and 72 min under magnification of 116 times. From this result, it is apparent that the nanoparticles helps to alleviate the heat generated during turning through the base oil. Hence, the new formulation of nanolubricant with surfactant presents a huge potential in increasing the life of cutting tools and reducing the agglomeration of suspended nano particles in the base fluid.

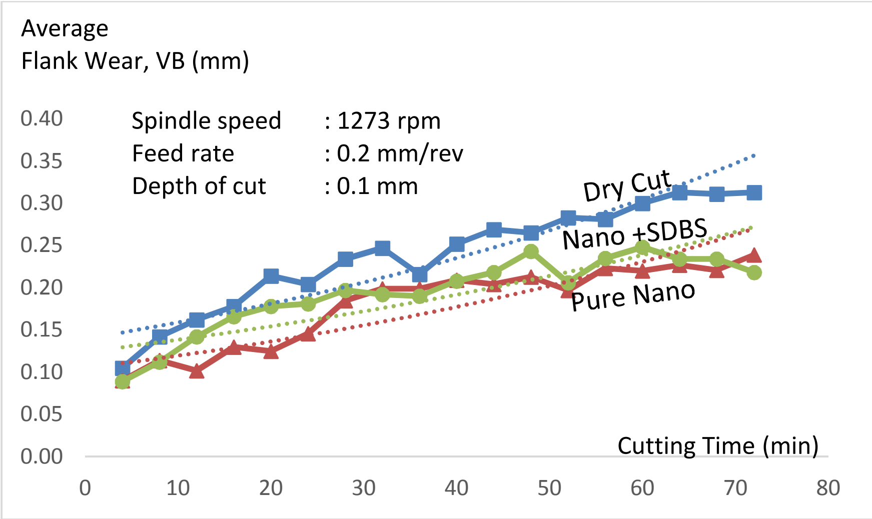

Fig. 2. Growth of Average tool wear for dry machining, wet machining - nanolubricant with SDBS and pure nanolubricant.

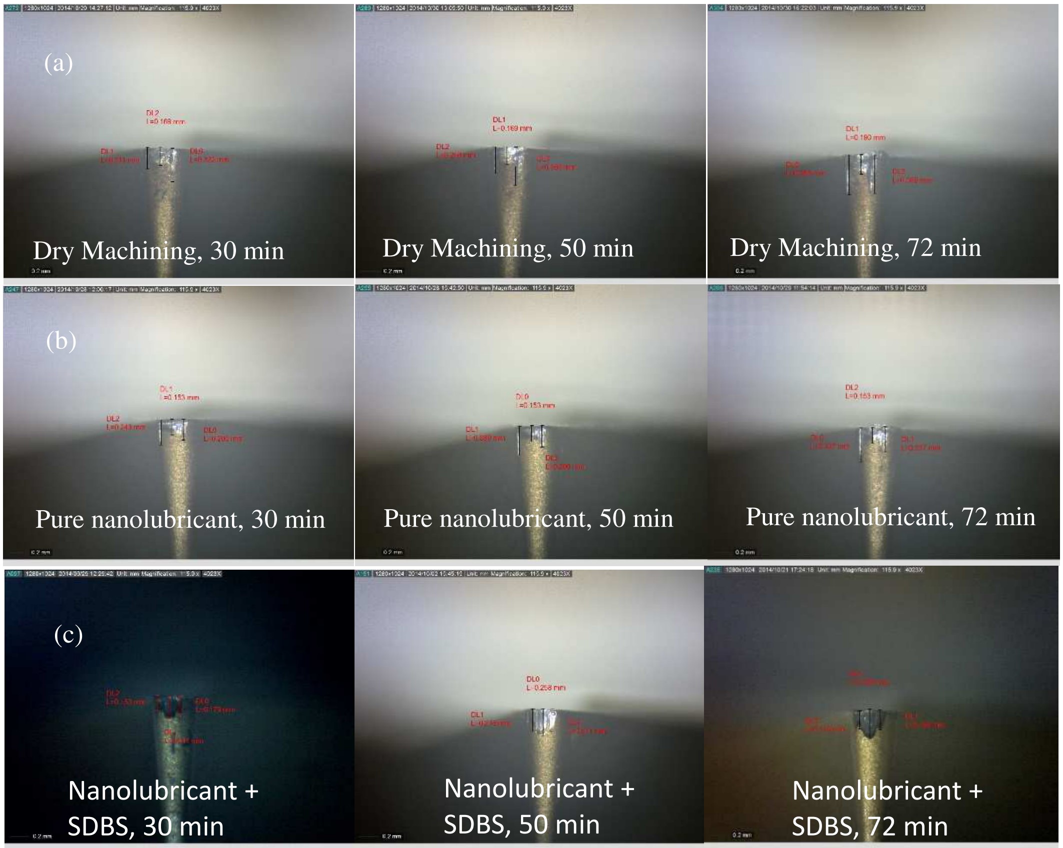

Fig. 3. Optical views of flank wear of insert after machining AISI 1050 steel at 30 min, 50 min and 72 min under (a) dry, (b) wet - pure nanolubricant, and (c) nanolubricant with SDBS environment.

4. Conclusion

The experimentally observed role of nanolubricant in machining AISI 1050 mild steel on coated carbide inserts can be summarized as follows:

i. Dry machining of steel caused highest tool wear growth while wet machining (pure nanolubricant and nanolubricant with SDBS) reduces tool wear and improves tool life.
ii. Al_2O_3 nano particles suspended in base oil helps to alleviate and flush away the heat generated during turning.
iii. The beneficial effects of nanolubricant with SDBS may be attributed to effective cooling, retention of tool hardness and favorable chip–tool and work–tool interactions.

Acknowledgements

The authors gratefully acknowledge the financial support of the Ministry of Higher Education Malaysia (FRGS/1/2014/TK01/UNIMAP/02/9).

References

[1] B. Rahmati, A. A. D. Sarhan, and M. Sayuti, "Investigating the optimum molybdenum disulfide (MoS 2) nanolubrication parameters in CNC milling of AL6061-T6 alloy," pp. 1143–1155, 2014.
[2] S. Y. Sia, E. Z. Bassyony, and A. A. D. Sarhan, "Development of SiO 2 nanolubrication system to be used in sliding bearings," 2014.
[3] C. Mao, H. Zou, and X. Huang, "The influence of spraying parameters on grinding performance for nanofluid minimum quantity lubrication," pp. 1791–1799, 2013.
[4] M. Sayuti, A. a. D. Sarhan, and M. Hamdi, "An investigation of optimum SiO2 nanolubrication parameters in end milling of aerospace Al6061-T6 alloy," Int. J. Adv. Manuf. Technol., Oct. 2012.
[5] M. Sayuti, A. A. D. Sarhan, and T. Tanaka, "Cutting force reduction and surface quality improvement in machining of aerospace duralumin AL-2017-T4 using carbon onion nanolubrication system," pp. 1493–1500, 2013.
[6] W. Yu and H. Xie, "A Review on Nanofluids: Preparation, Stability Mechanisms, and Applications," J. Nanomater., vol. 2012, pp. 1–17, 2012.
[7] T. Otanicar, J. Hoyt, M. Fahar, X. Jiang, and R. a. Taylor, "Experimental and numerical study on the optical properties and agglomeration of nanoparticle suspensions," J. Nanoparticle Res., vol. 15, no. 11, p. 2039, Oct. 2013.
[8] M. K. Moraveji, M. Golkaram, and R. Davarnejad, "Effect of CuO nanoparticle on dissolution of methane in water," J. Mol. Liq., vol. 180, pp. 45–50, Apr. 2013.
[9] A. Ghadimi and I. H. Metselaar, "The influence of surfactant and ultrasonic processing on improvement of stability, thermal conductivity and viscosity of titania nanofluid," Exp. Therm. Fluid Sci., vol. 51, pp. 1–9, Nov. 2013.
[10] C. Mao, H. Zou, X. Zhou, Y. Huang, H. Gan, and Z. Zhou, "Analysis of suspension stability for nanofluid applied in minimum quantity lubricant grinding," Int. J. Adv. Manuf. Technol., Feb. 2014.
[11] L. Yang, K. Du, X. S. Zhang, and B. Cheng, "Preparation and stability of Al2O3 nano-particle suspension of ammonia–water solution," *Appl. Therm. Eng.*, vol. 31, no. 17–18, pp. 3643–3647, Dec. 2011.