Int J Adv Manuf Technol (2012) 63:505–512
DOI 10.1007/s00170-012-3940-7

ORIGINAL ARTICLE

Reduction of power and lubricant oil consumption in milling process using a new SiO_2 nanolubrication system

Ahmed A. D. Sarhan · M. Sayuti · M. Hamdi

Received: 23 August 2011 / Accepted: 16 January 2012 / Published online: 3 February 2012

Abstract Manufacturing industries have been pressured to use less power and reduce pollution by the development of power-efficient and pollution-preventing policies from the government. However, quality and cost are of main concern in this agenda. In machining, the key solution for this issue is by increasing the effectiveness of existing lubrication systems as this reduces the power required to overcome the friction component in machining processes for less fuel consumption and pollution. In machining processes, in particular, improved lubrication systems will increase batch production rates with better product quality. Introducing nanolubrication reduces power consumption as the rolling action of a billion units of nanoparticles in the tool chip interface decreases the cutting forces significantly. Additionally, using nanolubrication in machining minimizes the consumption of the lubrication oil, which decreases pollution. Detailed analysis and implementation of nanolubrication in machining process with the proper parameter setup are mandatory to ensure the efficiency of implementing nanolubrication. In this research, SiO_2 nanoparticles are mixed with ordinary mineral oil having 0.2% weight concentration. A proper sonification method is used to mix and suspend the particles thoroughly and efficiently. The results show a reduction in the coefficient of friction in the tool/chip interface. Hence, the cutting force and working power are reduced considerably compared with conventional lubrication systems. Consequently, considerable power savings, less oil consumption, and less pollution are achieved.

Keywords Power reduction · Pollution · Milling · SiO_2 nanolubrication

A. A. D. Sarhan · M. Sayuti (✉) · M. Hamdi
Centre of Advanced Manufacturing and Material Processing,
Department of Design and Manufacturing, Engineering Faculty,
University of Malaya,
50603, Kuala Lumpur, Malaysia
e-mail: mdsayuti@siswa.um.edu.my

A. A. D. Sarhan
Department of Mechanical Engineering, Faculty of Engineering,
Assiut University,
Assiut 71516, Egypt

1 Introduction

In a mere 100 years, the world has, with much skill but little foresight, managed to create a society built almost entirely on a finite source of cheap, dirty energy. We are consuming the equivalent of millions of years' worth of solar energy captured by ancient microorganisms and plants, and locked up in vast oil, gas, and coal reserves, at rates so high that we will probably have no economically recoverable deposits of oil and gas left by 2050. This situation is compounded by an increasing number of environmental concerns. Inevitably, the energy consumption problem must be solved in ways that are both profitable and environmentally aware. Industry is the major user of energy in modern society, accounting for roughly 40% of final energy use. In manufacturing, particularly in the field of machining and metal cutting, there are some areas of energy use where considerable savings could be made. Friction between the rake face of a tool and the freshly formed chip surface plays a vital role in influencing the ease of metal-cutting process and consequentially in power savings [1, 2]. The existence of clean surfaces and high hydrostatic stresses favors the formation of strong adhesive friction junctions; the extent of these can be limited by the provision of a suitable lubricant [3]. Correct application of lubricants has been proven to greatly reduce friction. This results in reduced power consumption.

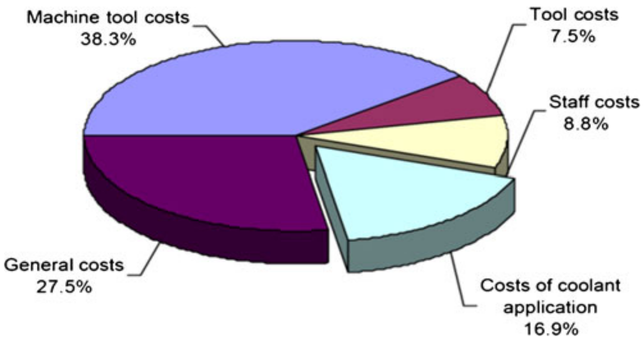

Fig. 1 Pie-chart representations of manufacturing cost at the German automotive industry

Although the significance of lubrication in machining is widely recognized, the usage of conventional flooding application in machining processes has become a huge liability. The Environmental Protection Agency regulates the disposal of such mixtures, and many countries and localities have also classified them as hazardous wastes. In economic terms, it has been reported that the cost related to the lubrication and cutting fluid is 17% of the total production cost which is normally higher than that of cutting tool equipments, which incurs only 7.5% of the total cost [4]. Figure 1 illustrates an example cost of production of camshafts in the European automotive industry [5–7].

At present, many efforts are being undertaken to develop advanced machining processes using less lubrication [8, 9]. Promising alternatives to the conventional flood coolant applications are the minimum quantity lubrication (known as MQL). Klocke and Eisenblätter [4] stated that MQL refers to the use of a minute amount of lubrication with a typical flow rate of 50 to 500 ml/h, which is about three to four orders of magnitude lower than the amount commonly used in flood cooling condition. This has been reported to reduce friction and cutting temperature and improve tool life due to its ability to penetrate into the chip–tool interface and, hence, results in reduced power consumption [10, 11].

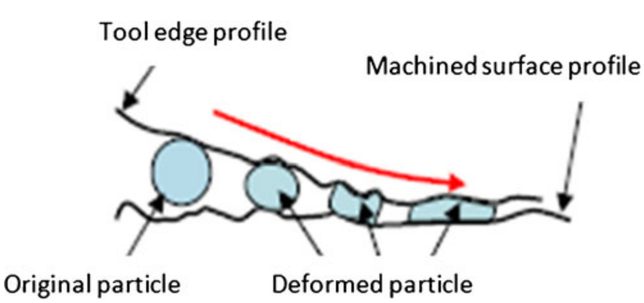

Fig. 2 Mechanism of nanoparticle lubrication [15]

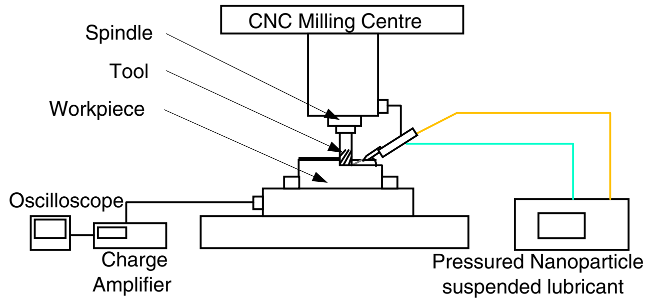

Fig. 3 Experimental setup

In order to develop advanced machining processes with less power consumption and pollution using less lubrication, it is clear that a multi-pronged approach must be used [12, 13]. In this paper, the authors will explore the development of nanolubrication in machining. Nanolubrication facilitates to reduce costs, extends tool life, and improves the performance of the machining process [14]. It has been reported that the cutting force and power has been reduced considerably using a nanoparticle lubricant as such lubricant works as billions of rolling elements in the tool chip interface, as shown in Fig. 2 [15]. For example, in grinding, the use graphite nanoplates as lubricants has been investigated in order to reduce the cutting force and power [16–18]. The graphite (nanoparticle lubricant) has also been evaluated as a lubricant while grinding SiC. The results showed that the tangential force component and energy are reduced considerably.

In another study, comparisons have been made with respect to turning performance using different lubrications, namely, dry, graphite, and MoS_2 lubricants. It is found that the power consumption by nanoparticle lubricants is again lower than that of dry in hard turning process [19].

SiO_2 nanoparticles are well known as hard and brittle materials. It can be easily found in the market at an affordable price. These nanoparticles have very good mechanical properties, especially in terms of hardness (Vickers hardness, 1,000 kgf mm^{-2}). They can also be found within a size range of 5 to 100 nm.

Table 1 Mechanical properties of aluminum (AA6061-T6)

Ultimate tensile strength (Mpa)		0.2% proof stress (Mpa)		Webster hardness tester (model B)		Vickers hardness (HV)
Min	Typical	Min	Typical	Min	Typical	
260	310	240	275	8′	15′	105