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Use of Boric Acid Powder Aided Vegetable Oil Lubricant in Turning AISI 431 Steel

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Abstract

There has been a great demand for environmentally benign lubricant due to stricter regulation imposed on the use of conventional lubricant made from mineral oils, as it is not safe to the health of workers and to the environment. Following to this, vegetable oil as based lubricant offers the suitable solution for an environmentally friendly lubricant as it is non-toxic and biodegradable. Furthermore, the performance of vegetable oil base lubricant can be enhanced by adding micro/nano-particle with the lubricant. The present study focus on the use and the performance of boric acid powder with palm kernel oil in comparison to conventional oil as a means of lubrication in machining AISI 431 steel with minimum quantity lubrication. A 2^4 full factorial design of experiment has been conducted with cutting speed, feed rate, depth of cut and types of lubricant as the input process variables. Surface finish has been evaluated in each of the machining conditions. It has been found that the feed rate and type of lubricant are the only factors that have significant effect on the surface finish and boric acid powder aided lubricant machining outperformed conventional lubricant. The average improvement in surface finish with boric acid powder aided vegetable oil lubrication is observed to be 7.21%. The cutting speed and depth of cut apparently do not have any significant effect on surface roughness in minimum quantity lubrication, of conventional and vegetable oil on lubrication.

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Keywords: Vegetable oil; micro-particle; Lubricant; Machining; AISI 431

1. Introduction

In a high precision machining operation, lubricant is extensively needed to remove the heat at the tool-workpiece interfaces. High heat is generated at the interface due to friction between the tool and the workpiece, which can lead to a very poor workpiece surface quality and tool wear. For that reason, report showed that approximately 320,000 tons of lubricant were used per year in the European Union [1] proving the importance of lubricant in machining application. Lubricant is divided into three categories that are neat oil, water-soluble fluids, and gases [2], where the most common type of lubricant in machining application is the water-soluble fluids. This type of lubricant is made of water mixed with oil with a certain ratio depending on the types of application being used. However, the oil used in the water-soluble fluid are typically mineral-based oil, which is known to be harmful to the worker and to the environment.

Studies have proven that mineral-based lubricant can be hazardous to the workers and to the environment. Thus, operational workers that are exposed to machining lubricant are prone to dermatitis, respiratory ill health and cancer [3–7]. Mineral-based

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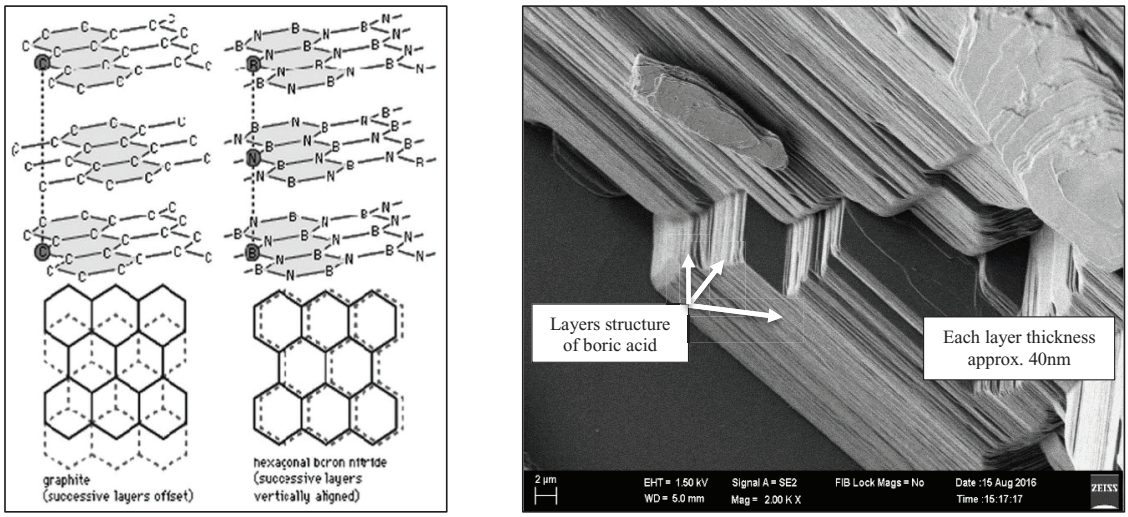
lubricant can generate the formation of nitrosamines (carcinogenic) [8], which is a substance capable of causing cancer if it enters human bodies. Even though mineral oil in lubricant has been refined or treated from any carcinogenic, it is not sufficient to categorised it as harmless [9]. In terms of the environment, mineral-based lubricant are not biodegradation friendly, where it is shown that it exhibit toxic product when it degraded in soil [10]. Moreover, with the shortage of mineral-based oil in the coming future, there will be a shortage in the production of lubricant. Hence, another greener alternative lubricant needs to be explored that should offer the same performance as mineral-based lubricant, non-toxic and biodegradable [11].



a) b)

Fig. 1. a) Layered structure of graphite and boric acid particle [12]; b) The layered structure of boric acid shown from using FESEM (magnification 2000x)

Suggestion of implementing dry machining conditions in machining application can eliminate the use of lubricant and consequently exterminate the bad effect of using mineral-based lubricant. However, dry machining cannot lead to high quality surface when machining at higher cutting speed and feed rate. Therefore, the best approach to creating a greener lubricant is by replacing the mineral oil with vegetable oil as the base oil of a lubricant. Most of the vegetable oil has triglycerides in its composition [13], which consists of three long chains of fatty acid in their structure that give vegetable oil the properties of good lubricity [14]. Other than that, vegetable oil commonly known to have a high viscosity index, meaning that its viscosity is stable at high temperature [15]. This is beneficial, as during the machining process, high temperature will be detected in the cutting zone, thus a stable liquid viscosity is needed. Furthermore, the most important properties of vegetable oil to become a lubricant is that it is non-toxic and biodegradable.

As established vegetable oil can perform as lubricant in machining application. Lawal et al. [16] have done an evaluation of the performance of vegetable oil in turning process in comparison to mineral oil. The investigation found that the vegetable oil surpasses conventional oil-in-water performance in turning process. Likewise, Babur et al. [17] have concluded that vegetable oil is effective in producing better surface quality and tool wear than synthetic cutting fluids during turning process. Nevertheless, improvement on the performance of vegetable oil can be done by utilising powder particles such as MoS_2, graphite, boric acid, etc. Improvement can be seen from using powder particle aided lubricant in terms of surface finish, coefficient of friction, wear and cutting force [18]. This is because powder particle has lattice layered structure (Fig. 1), relatively high load carrying capacity and low steady state coefficient of friction [19]. Moreover, powder particle such as boric acid are environmentally friendly and do not pose threat to operational workers, according to the Environmental Protection Agency, which is desirable in creating a greener lubrication in machining application [20].

The objective of the experiment is to assess the use and the performance of boric acid powder aided vegetable oil-in-water lubricant in turning AISI 431 steel. The boric acid powder is mixed with palm kernel oil due to its properties having high in saturated fatty acid, making it more stable in oxidation in comparison to other vegetable oils. Boric acid powder with <8µm particles size and 1.0 %wt. concentration is to be used in minimum quantity lubricant condition in machining AISI 431 steel. A performance comparison between boric acid powder aided vegetable lubricant with conventional lubricant is made based on the surface roughness with respect to cutting conditions.