Research Article

Influence of Nano Boric Acid Material in Bio-Diesel Blends to Enhance the Surface Quality with Minimum Quality Lubrication

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Received 18 June 2022; Revised 11 July 2022; Accepted 18 July 2022; Published 10 August 2022

Abstract

Machining with conventional process of lubrication is a general industrial practice for diminishing cutting forces, high temperature, and friction. During the machining process, cutting fluid characteristics plays a crucial role in enhancing machining performance when it is properly chosen. The harmful gases during machining process are often hazardous to individuals and the environment. It is also economically unviable if the cutting fluid cost, method of application, and flow rate is underestimated. Due to chip obstruction and poor absorption, a high amount of heat is liberated and as a result high quantity and high quality of lubricant or coolant are need to be supplied between the chip-tool interfaces consistently. This process becomes costly and degrades the environment. In the current work, nano powder of boric acid is chosen as solid type lubricant in turning process, which is blended with bio-diesel consisting of coconut oil as base oil. The outcomes of nano powder mixed bio-diesel cutting fluids exhibited significant enhancement in machining characteristics when it is compared with wet and dry machining. And also, Taguchi method of orthogonal representation is considered to determine the optimum weight percentage of the bio-diesel blends at different conditions of the machining process. The optimum machining conditions were obtained at high machining operation with a feed of 0.04 mm/min, speed of 600 rpm, and toll diameter of 0.5 mm.

1. Introduction

In metal cutting process high temperatures are produced at the tool-chip interface due to friction. This heat has an impact on machining performance in terms of dimensional accuracy, surface finish, machining cost, and tool life. Various techniques have been used to reduce the heat. In the beginning, water was used as a coolant to reduce the heat, but it caused issues such as corrosion. Different cooling and lubrication techniques have emerged as a result of technological advancement.

Flood coolant, cryogenic coolant, and minimum quantity lubricant (MQL) are some of the substitute techniques used to diminish or eradicate heat from the machining region. MQL principles are thus important because it supplies the required amount of lubrication and metal-working coolants to cutting zone and diminishes the heat liberations at the chip-tool interface [1, 2]. Petro-oils, which have been popularly used for generations, are non-sustainable, conventional, and nondecomposable. However, the key aspects are decreasing as a result of extremely high consumption of fuel. These elements have caught the interest of researchers in exploring alternative green energy materials as lubricating oils to replace petro-coolants. In the context of viable expansion, the petroleum metal-working fluid used in the machining process should be replaced with an eco-sustainable lubricant, such as a vegetable oil-based emollient, as an alternative [3, 4]. It has also been identified that the vegetable oil-based lubricants enhances the proficiency of metal-working lubricant particularly in assessment.

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Advances in Materials Science and Engineering
Volume 2022, Article ID 3819774, 10 pages
https://doi.org/10.1155/2022/3819774
with the petro-oil [5, 6]. Furthermore, stirring of appropriate nano-type particles in vegetable oil-based lubricants considerably enhanced the competency of metal-working fluids [7–9]. In comparison to other types, vegetable oil-based lubricant is typically considered as a substitute in the production of designated lubricants with green and environment friendly properties and reduced toxicity.

Vegetable-based lubricants, in particular, are easily manufactured because they are derived from renewable resources. The long-chain fatty acids, significant amounts of polar-ester, and polyunsaturated category of constituents in vegetable oils are generally attributed to better lubricating measures. But, most of the researchers believe that the frictional coefficient is restricted and the wear rate is substantial. The metal solvent layer has been observed to be swept away at sliding, resulting in nonvolatile cleaning elements that increase the wear-rate on sliding surfaces [10]. Their research is mainly focused on the bio-chemical reaction on the sliding-surface, when a fatty-acid is used as a lubricant, which is derived from vegetables. And the scientific proof suffers from a high deterioration rate, despite its small coefficient. Even so, vegetable oil-type lubricating oils have not contributed to adequate scientific advancement. The main reason for this is edible type lubrication oils were not properly prepared.

The previous forms of the vegetable-type oils consist of procedural solvents that were identical to mineral-type oils. So these approaches were not suitable because the characteristics of the vegetable-type oils differ from those of hydrocarbon oils. The restrictions of vegetable-type lubricants as simple stocks, like lack of reserved hotness, elastomer resistance, and oxidative protection have been widely studied by most of the researchers. Triglyceride appears to have high degrees of temperature in vegetable-type lubricants, but few appear to be tougher than the others. Several vegetable-type lubricants have a maximum operating temperature of −60°C, although some can provide shields up to a temperature of 104°C [11]. Hence, vegetable oils need to be prepared as per their specific behaviors. Lubricant additives are frequently used to reserve and enhance the effectiveness of lubricant oils. To improve its properties, vegetable lubricants containing a preservative must be added to its composition. This enhances the physico-chemical properties and exceptional lubrication features connected with triacylglycerol materialization. According to reports, the additive has a positive effect on the frictional force, slowly minimizes the wear, diminishes the cutting-force, and also decreases temperature [12, 13]. The coolant proportion is dependent on the base oil and their extracts. A favorable range of extracts, as well as their interaction with vegetable lubricant solution, must be carefully examined [14]. Nano additives interaction in lubrication oils must be liquefied or distributed consistently in the transferor medium. In the turning of EN-31 steel, general flood-type lubrication is replaced by vegetable lubricant MQL, indicating that surface quality of vegetable lubricant is almost the same as that of the inorganic oil [15]. MQL by vegetable oil-based cutting fluid allows for a 10% reduction in chip-tool interface temperature [16]. The chip-tool interface temperature reduces dining when machining Steel (EN–31) with 10% of Nano boric acid stirred with SAE-40 lubricant oil [17]. To strengthen the current research, coconut oil is blended with additives and the wear resistance is assessed in order to achieve the better tribological characteristics [18]. Coconut oil originally belonged to a distinct group of vegetable-based oils known as lauric oils, which have the lowest weight gain, a predictor of antioxidant capacity in an oxidizing atmosphere, and the maximum viscosity of any vegetable oil [19].

The variation of metal cutting temperature changes, mean flank wear, and surface roughness with cutting speed and depth of cut were investigated in the turning of AISI-1040 steel with a carbide-tool using 50 nm particle size boric acid powder as solid lubricant suspensions in coconut oil and SAE40 [20]. The influence of boric acid particle size and coconut oil concentration on surface wear and friction exhibited good performance characteristics [21]. Similarly, soybean blended oil is tested but performance decreased due to a high amount of unsaturated fatty acid content and predisposition to oxidation [22]. Along with experimental results, optimization also plays a crucial role in identifying the most appropriate input parameters. For that the Taguchi method of orthogonal representation is considered to determine the optimum weight percentage [23]. The Taguchi technique was used to optimize the cutting parameters in order to maintain optimal surface roughness attributes when turning SCM steel-alloy [24]. In the present research, a set of experiments were conducted to examine the surface roughness and temperature of tool-chip interface of mild steel work piece and HSS tool. Nano particles of boric acid are blended in coconut oil and bio-diesels at different weight percentage ratios to diminish the environmental effects caused due to petro-oils.

According to the review of literature, minimum quantity lubrication offers several advantages in machining over dry-machining and conventional flood lubrication. The current experiment was carried out to compare the performance of coconut oil and nano particle-blended Bio-Diesel, which contains coconut oil as the base oil. The primary goal of this research is to determine the effectiveness and appropriate machining characteristics when compared with wet and dry machining.

2. Materials and Methodology

2.1. Materials

2.1.1. Mild Steel as Specimen. In the current research mild steel material is chosen as a cylindrical shaped work piece of dimensions 150 mm in length and 25 mm in diameter as shown in Figure 1. Chemical composition of mild steel in terms of weight % is carbon(C), 0.12 (max.); manganese(Mn), 0.30–0.60 (max.); silicon(Si), 0.40 (max); phosphorus(P), 0.04 (max); sulfur(S), 0.04 (max.); and ferrous(Fe) is the base material as shown in Table 1.

2.1.2. HSS as a Tool. For metal removal process, HSS is considered as a tool material which has better characteristics during cutting operations. The chemical composition of HSS...
2.1.3. Bio-Diesel Preparation. Bio-diesel is prepared by choosing coconut oil as the base oil. During the process of preparing bio-diesel acid treatment, base treatment and water treatment plays crucial role. In acid treatment, one liter of coconut oil (base oil) is heated up to 60°C after that 100 ml of methanol is added to base oil along with 2–3 ml of H₂SO₄. The entire mixture is proportionality mixed by using magnetic stirrer and left for 1 hr to settle to complete the acid treatment. In base treatment, again the prepared solution is heated up to 60°C and then it is mixed with sodium methoxide and again settled for about 6–7 hrs. The acid and base treatments are done to remove the glycerin as a byproduct from the solution. Now the water treatment is conducted with approximately five liters of water to remove any dirt or waste from the oil. Then it is heated up to 100°C to remove the water bubbles formed during water wash. The physical properties of the bio-diesel are shown Table 3.

2.1.4. Boric Acid as an Additive. To prepare bio-diesel blends into a wet lubricant, nano boric acid as an additive must be added to the base oil, which is coconut oil. The addition of additives is done to improve the performance of the bio-diesel blend, and the characteristic performance is heavily affected by the extracts. Boric acid powder is one of the additives used in this formulation. Particle size is less than 10 µm, this size was suggested by the previous literature [25]. Table 4 shows the physical characteristics of the nano boric acid powder chosen in this study. The additives used in this formulation are carefully chosen, and also it is confirmed that the outcomes of the machining elements are not harmful to workers and the atmosphere.

2.2. Methodology. For the current study, the most common combination of HSS tool and mild steel cylindrical bar of 150 mm length and 25 mm diameter is used to conduct experiments at several dry machining operations and wet machining operations. The entire machining operation is conducted on CNC Turning machine with a M.No. of DX 200. It is controlled by a SIEMENS 828-D and has an 8-station tool post with a bidirectional servo type turret, as shown in Figure 2. At tool-chip interaction, temperatures and surface quality of steel are examined using a CNC Turning machine and plain turning of mild steel material at several dry machining operations as shown in Figure 3(a) and experimental input parameters are shown in Table 5. Different tools like surface roughness-measuring device are shown in Figure 3(b), and thermometer of noncontact type is utilized to measure tool-chip interaction temperatures and variation in surface roughness.

The Taguchi approach is used to DOE (Design of Experiments), which were classified as low, medium, and high machining [26]. Experimental input parameters are considered in 4 different levels for feed (F), depth of cut (D), and speed (S) and their combinations are shown in Table 6. For each experiment, the tool-chip interface temperatures and quality of surface roughness were measured. Figures 3(a) and 3(b) depict the CNC turning machine and a surface roughness tester used in the experiment.

Experiments on lathe machine are carried out in three phases, that is, dry machining operation, wet machining operation (without any solid lubricant), and wet machining operation (with boric acid)—MQL. In this machining process the lubrication is explored on the surface with a constant velocity of 1 L/min which is the preferable velocity of lubrication specified in ref [27]. Up to 5% of boric acid addition in the lubricant causes a decrease in the temperature, but the remaining output parameters like surface roughness and wear gradually increase. At 3% addition of boric acid the temperature decreases and wear and surface roughness are constant (stable). The same type of output is observed in the literature [25].
Throughout the investigation, the optimal weight of 3% boric acid powder blended bio-diesel is used as coolant. For this experiment the nano boric acid is mixed with coconut oil using a magnetic stirrer. The solution was stirred for 30 minutes with a speed of 1200 rpm so that all the components get mixed properly [25]. In each phase, temperature of tool-tip and surface roughness were measured and plotted. The whole experimental input parameters are divided into three levels of machining operations that is low, medium, and high machining operations. And their input parameter combinations are represented in Table 7. The feed rate is taken from the range of 0.04 mm/min to 0.16 mm/min and 0.5 mm to 2 mm, respectively. Similarly with the same range of feed and depth of cut, medium machining and high machining operations are considered as 300 r.p.m–450 r.p.m and 600 r.p.m, respectively.

3. Results and Discussion

Surface quality is an analytical variable that is widely used in determining machine component surface roughness and is essential for mechanically connected elements. Accomplishing the required surface superiority is crucial for the practical performance of machine elements. There are numerous ordered and disordered aspects that influence surface roughness. As a result, selecting the most appropriate controllable process variables is critical for effective management system.

3.1. Effect of Surface Roughness under Dry Machining Operations

Surface roughness of the mild steel material is measured under dry machining operations at the three different levels of machining operations that is low, medium, and high. L1–L6, M1–M6, and H1–H6 represent the low speed operations that is 150 r.p.m with a feed rate and depth cut of 0.04 mm/min to 0.16 mm/min and 0.5 mm to 2 mm, respectively. Similarly with the same range of feed and depth of cut, medium machining and high machining operations are considered as 300 r.p.m–450 r.p.m and 600 r.p.m, respectively.
machining operations of low, medium, and high, respectively. During these machining operations the tool-chip interaction temperatures and average surface roughness’s for three trials are tabulated in Table 8.

In dry machining operation the data for average surface roughness (R) and temperature Vs cutting speed at feed rates of 0.04 and 0.16 mm/rev are shown in Figure 4. When comparing surface roughness and temperature to examine the effect of feed in the mild steel material with an HSS tool during turning operation, it is clear that the surface roughness’s and temperature increased as the feed increased in each and every level of machining. A maximum of 98°C is observed at a speed of 600 r.p.m. at 0.16 mm/rev and maximum surface roughness is observed at a speed of 300 r.p.m. at low feed that is 0.04 mm/rev.

From the results it is identified that surface roughness increases at low feeds. And at the same time temperature gradually rises which may result in producing harmful gases during machining. Because surface roughness and temperatures are extremely reliant on feed rate, it increases with the increment in feed rate [28], and thus no unexpected outcomes are observed. In terms of cutting speed, the surface roughness’s value decreases slowly with increased cutting speeds. But when cutting speeds are related to temperature, it increases with increased cutting speeds. This is related to the earlier interaction of cutting into the wear process that results in increase in cutting. In order to reduce the temperature and increase the surface finish the machining process is conducted by introducing coolants. The current study’s primary goal is to investigate the effect of coolants on mean surface roughness and temperatures.

### Table 7: Experimental turning parameters at different machining operations.

| Level of Machining | Low machining operations | Medium machining operations | High machining operations |
|--------------------|--------------------------|-----------------------------|-------------------------|
|                    | F (mm/min) | S (R.P.M) | D (mm) | F (mm/min) | S (R.P.M) | D (mm) | F (mm/min) | S (R.P.M) | D (mm) |
| L1                 | 0.04       | 150       | 0.5    | M1        | 0.08       | 300       | 1      | H1        | 1.2        | 450       | 1.5    |
| L2                 | 0.08       | 150       | 1      | M2        | 0.12       | 300       | 1.5    | H2        | 0.16       | 450       | 2      |
| L3                 | 0.12       | 150       | 1.5    | M3        | 0.16       | 300       | 2      | H3        | 0.04       | 600       | 0.5    |
| L4                 | 0.16       | 150       | 2      | M4        | 0.04       | 450       | 0.5    | H4        | 0.08       | 600       | 1      |
| L5                 | 0.04       | 300       | 0.5    | M5        | 0.08       | 450       | 1      | H5        | 0.12       | 600       | 1.5    |
| L6                 | 0.08       | 300       | 1      | M6        | 1.2        | 450       | 1.5    | H6        | 0.16       | 600       | 2      |

### Table 8: Surface roughness (R) of dry machining operation.

| Level of Machining | Low machining operations | Medium machining operations | High machining operations |
|--------------------|--------------------------|-----------------------------|-------------------------|
|                    | R (μm) | Avg.R (μm) | L | R (μm) | Avg.R (μm) | L | R (μm) | Avg.R (μm) |
|                    | R1 | R2 | R3 | L | R1 | R2 | R3 | L | R1 | R2 | R3 |
| L1                 | 38 | 7.12 | 7.64 | 7.83 | 7.53 | M1 | 56 | 7.32 | 7.35 | 7.41 | 7.36 | H1 | 79 | 6.23 | 6.49 | 6.63 | 6.45 |
| L2                 | 41 | 7.52 | 7.33 | 7.38 | 7.41 | M2 | 59 | 9.76 | 10.3 | 10.54 | 10.2 | H2 | 83 | 7.7 | 7.2 | 7.25 | 7.15 |
| L3                 | 45 | 8.65 | 8.97 | 8.18 | 8.6 | M3 | 63 | 9.89 | 10.32 | 10.54 | 10.25 | H3 | 87 | 4.26 | 4.31 | 4.33 | 4.3 |
| L4                 | 48 | 8.5 | 9.1 | 8.8 | 8.8 | M4 | 69 | 5.78 | 5.63 | 5.54 | 5.65 | H4 | 90 | 4.39 | 4.52 | 4.59 | 4.5 |
| L5                 | 53 | 7.32 | 7.35 | 7.41 | 7.36 | M5 | 73 | 5.64 | 5.68 | 5.69 | 5.67 | H5 | 94 | 5.1 | 5.23 | 5.27 | 5.2 |
| L6                 | 56 | 7.32 | 7.35 | 7.41 | 7.36 | M6 | 79 | 6.23 | 6.49 | 6.63 | 6.45 | H6 | 98 | 5.67 | 5.63 | 5.74 | 5.68 |

3.2. Effect of Surface Roughness under Wet Machining Operations (without Adding Solid Lubricant). In order to reduce the effects of dry machining process, bio-diesel blends are introduced in between the cutting interface which acts as a coolant. In the bio-diesel blend, 20% of coconut oil is considered as the base oil. During the wet machining operations it is observed that there is a reduction in temperatures and surface roughness with increased feed rate and cutting speeds. The effect of surface roughness under wet machining operations (without adding solid lubricant) is tabulated in Table 9. From the outcomes it is identified that the temperatures are reducing with increased speed due to the intermediate element (bio-diesel blend) between the cutting interfaces. When compared with dry machining, in wet machining operation 54.08% of temperature is reduced.
Temperature (°C)  48  44  40  36  32  28  24  20  16  12  8  4  0
Figure 5: Surface and temperatures at different levels of cutting speed in wet machining.

This is due to the reduction of heat between the cutting interfaces with coolants.

As shown in Figure 5, the minimum surface roughness (4 μm) in turning of mild steel material was obtained with bio-diesel blend lubrication at 600 r.p.m cutting speed and 0.08 mm/min feed rate. When it is compared with dry machining an improvement of 9.8% is attained. From the study, the behavior and performance of HSS tools under wet machining was unlike carbide inserts. Surface quality with bio-diesel blends has been recognized for its physical properties and lubricating properties, which diminish friction force and permits to clench strongly at machining region. The current study discovered an exciting result: surface roughness is reduced with wet machining while turning of mild steel material outperformed. Therefore, it is recognized that the effect of MQL on the machined surface of material against the dry machining operation is more efficient.

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### 3.3. Effect of Surface Roughness under Wet Machining Operations (with Boric Acid)

By mixing boric acid in bio-diesel blends the temperatures and surface roughness is decreased further when it is compared with dry machining and wet machining (only with bio-diesel blend). At various levels of machining operations with boric acid mixed wet machining, the surface quality and temperatures are tabulated in Table 10.

Boric acid is an environmentally friendly lubricant. When nano boric acid solid lubricant is added to the coconut oil it reduces the friction which may lead to a reduction in the temperature at the machining zone, and the surface roughness is also improved. The same effect is observed in the literature [25]. When compared to dry and wet machining, the addition of boric acid to bio-diesel reduces surface roughness and temperatures regardless of feed rate and cutting speed. Recently reported studies clearly indicate this even when carbide inserts are being used. Variable rates of progress in surface quality have just been accomplished under varying nano-cutting fluids [29, 30]. Similarly, a few researchers noted that graphite has high stability throughout the machining process [31, 32]. Another research indicated that the combination of graphite nano powders improves the lubricating characteristics of traditional lubricants by lowering the contact resistance [33]. The minimum surface roughness is observed at 600 r.p.m cutting speed and 0.08 cutting feed which is 40% more efficient than dry machining and 18% more efficient than wet machining (without solid lubricant) as shown in Figure 6.

Boric acid, as a stabilizing agent, can also be used itself to reduce the temperature at the interaction between both the work piece and the cutting edges. As a result, introducing boric acid to a bio-diesel blend will further enhance its lubricating oils efficiency. It is because boric acid material has a high heat capacity and a low thermal expansion coefficient. Thermal resistance of boric acid particles in the lubricating oil helps to boost thermal performance which is trying to build up at the machining zone. As a result, heat is dissipated more quickly than with lubricating oil which does not include boric acid particles. Furthermore, the size of the particles of the boric acid influences the heat transfer rates. Because the surface area of the boric acid powder is larger at the micro size of particles, more heat energy is transferred. Improved surface finish could be accomplished as heat is released out from machining zone.

#### 3.4. Comparison of Temperatures and Surface Roughness with Cutting Speeds

Compared to dry machining, in wet machining, the temperature of machining zone was reduced due to the act of coconut oil lubricant, which may lead to absorb the cutting temperature. From Figure 7(a) it is identified that the temperatures are gradually reducing from dry machining operations to wet machining operations (without additive and with nano particles of boric acid).

With the inclusion of coolants during machining operations...
Table 10: Surface roughness ($R$) of wet machining operation (with solid lubricant).

| Low machining operations | Wet machining operation (20% of coconut oil + bio-diesel with solid lubricant) | High machining operations |
|--------------------------|--------------------------------------------------------------------------------|--------------------------|
| $L$ $T$ ($^\circ$C) $R$ ($\mu$m) | $L$ $T$ ($^\circ$C) $R$ ($\mu$m) | Avg.$R$ ($\mu$m) | $L$ $T$ ($^\circ$C) $R$ ($\mu$m) | Avg.$R$ ($\mu$m) | $L$ $T$ ($^\circ$C) $R$ ($\mu$m) | Avg.$R$ ($\mu$m) |
| L1 33 6.9 7 6.8 6.9 | M1 38 4 4.1 4.2 4.1 | H1 44 5.3 5.6 5.7 5.53 |
| L2 34 6.7 6.8 6.9 6.8 | M2 39 8.1 8.4 8.5 8.33 | H2 44 6.1 6.2 6.2 6.16 |
| L3 34 7.9 8.1 8.1 8.03 | M3 39 8.3 8.9 8.7 8.63 | H3 45 3 3.2 3.1 3.1 |
| L4 35 7.8 8.3 8.1 8.06 | M4 41 4.8 5 4.9 4.9 | H4 46 3.7 3.8 3.8 3.76 |
| L5 36 4.8 4.9 5 4.9 | M5 42 4.8 5.1 5 4.96 | H5 47 4.2 4.3 4.2 4.23 |
| L6 38 4 4.1 4.2 4.1 | M6 44 5.3 5.6 5.7 5.53 | H6 48 4.9 5 5 4.96 |
the machining parameters of the materials are enhanced impressively. The addition of nano boric acid to coconut oil has a greater impact on the friction force produced between the tool and workpiece interface. Nano boric acid reduces the friction between the mating surfaces which may lead to reducing the temperature of the cutting zone. Similarly with the aid of nano particles of boric acid in bio-diesel blend coolant, the surface quality also improves which can be observed from Figure 7(b) when compared with dry machining operations.

4. Conclusion

This study compared the machining operations under dry, wet, and wet with nano lubricants and it has been detected that the temperature and surface roughness are highly minimized with combination of wet lubrication (with boric acid) when it is compared with dry and wet machining (with Bio-diesel blends). The minimum surface roughness is observed at 600 r.p.m cutting speed and 0.08 cutting feed which is 40% more efficient than dry machining and 18% more efficient than wet machining (without solid lubricant).

As a result, the investigation has provided an excellent alternative in discovering eco-friendly lubricating oil, which is by using a boric acid powder enabled bio-diesel blend. The lubricant produced is safe because the materials used to make it are biocompatible and nontoxic to the ecosystem. Moreover, the use of minimum quantity lubrication decreased the amount of lubricating oil used, which really is favorable in the machining operation. And it is suggested because it eradicates harmful environmental effects while also limiting the risk of workers’ health within the machining sector.

The present research encourages manufacturers and researchers to use eco-sustainable vegetable oil coolants or lubricants in machining operations instead of using...
commercially existing coolants or lubricants. This certainly can minimize the impact of toxic gases released through machining on workers and environment.

Data Availability

The data utilized to back up the study’s findings are supplied in the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest to declare.

Acknowledgments

The authors appreciate the support from Samara University, Ethiopia. The authors thank GMR Institute of Technology, Rajam, Andhra Pradesh, and Swamy Vivekananda Engineering College, Bobbili, Andhra Pradesh, for the technical assistance to complete this experimental work.

References

[1] M. H. A. Bakar, S. S. N. Ahmad, R. I. R. Abdullah et al., “Evaluation of the surface integrity when machining LM aluminum metal matrix composites using coated and uncoated carbide cutting tools,” Applied Mechanics and Materials, vol. 465–466, pp. 1049–1053, 2014.

[2] R. M. N. Murad, A. I. Azmi, and I. Shyha, “Effects of minimal quantity lubricants reinforced with nano-particles on the performance of carbide drills for turning nickel-titanium alloys,” Tribology International, vol. 136, pp. 58–66, 2019.

[3] M. A. M. Au, A.-I. Azmi, M. N. Murad, M. Z. M. Zain, A. N. M. Khalil, and N. A. Shuaib, “Roles of new bio-based nanolubricants towards eco-friendly and improved machinability of Inconel 713 alloys,” Tribology International, vol. 144, Article ID 106106, 2020.

[4] K. C. Wickramasinghe, G. I. P. Perera, S. W. M. A. I. Senevirathne, H. K. Punchihewa, and H. Sasahara, “Surface quality evaluation of 0.2 % C and AISI 304 steels in turning with sustainable lubricant condition,” Journal of Mechanical Science and Technology, vol. 33, no. 12, pp. 5753–5759, 2019.

[5] S. A. S. Amiril, E. A. Rahim, N. Talib, K. Kamdani, and M. Z. Rahim, “Performance evaluation of palm-olein TMP ester containing hexagonal boron nitride and an oil miscible ionic liquid as bio-based metalworking fluids,” Journal of Mechanical Engineering, vol. 4, no. 1, pp. 223–234, 2017.

[6] A. S. Abdul Sani, E. A. Rahim, S. Sharif, and H. Sasahara, “The influence of modified vegetable oils on tool failure mode and wear mechanisms when turning AISI 1045,” Tribology International, vol. 129, pp. 347–362, 2019.

[7] N. Talib, R. M. Nasir, and E. A. Rahim, “Tribological behaviour of modified jatropha oil by mixing hexagonal boron nitride nanoparticles as a bio-based lubricant for machining processes,” Journal of Cleaner Production, vol. 147, pp. 360–378, 2017.

[8] M. Sayuti, A. A. D. Sarhan, and F. Salem, “Novel uses of SiO2 nano-lubrication system in hard turning process of hardened steel AISI4140 for less tool wear, surface roughness and oil consumption,” Journal of Cleaner Production, vol. 67, pp. 265–276, 2014.

[9] K. C. Wickramasinghe, H. Sasahara, E. A. Rahim, and G. Perera, “Green Metalworking Fluids for sustainable machining applications: a review,” Journal of Cleaner Production, vol. 257, Article ID 120552, 2020.

[10] F. P. Bowden, F. P. Bowden, and D. Tabor, The Friction and Lubrication of Solids, Vol. 1, Oxford University Press, Oxford, England, 2001.

[11] M. Mark, Additives for Bio-Derived and Bio-Degradable Lubricants, pp. 445–454, Lubricant Additives, Boca Raton, FL, USA, 2009.

[12] O. N. Celik, N. Ay, and Y. Goncu, “Effect of nano hexagonal boron nitride lubricant additives on the friction and wear properties of AISI 4140 steel,” Particulate Science and Technology, vol. 31, no. 5, pp. 501–506, 2013.

[13] G. S. Goindi, S. N. Chavan, D. Mandal, P. Sarkar, and A. D. Jayal, “Investigation of ionic liquids as novel metalworking fluids during minimum quantity lubrication machining of a plain carbon steel,” Procedia CIRP, vol. 26, pp. 341–345, 2015.

[14] L. R. Rudnick, Synthetics, Mineral Oils, and Bio-Based Lubricants: Chemistry and Technology, CRC Press, Florida, FL, USA, 2013.

[15] G. Singh, M. Singh, and A. Kurnar, “Experimental investigation of vegetable and mineral oil performance during machining of EN-31 steel with minimum quantity lubrication,” International Journal of Renewable Energy Technology, vol. 2, no. 6, 2013.

[16] N. R. Dhar and M. W. Islam, “The influence of minimum quantity of lubrication (MQL) by vegetable oil-based cutting fluid on inachinability of steel,” in Proceedings of the International Conference on Mechanical Engineering, pp. 1–5, ICME, Bangladesh, Asia, July 2005.

[17] N. R. Dainera mid, V. K. Pasarn, Performance profiling of bone acid powder as lubricant in machining,” Journal of the Brazilian Society of Mechanical Sciences and Engineering, vol. 30, no. 3, 2008.

[18] N. H. Jayadas, K. P. Nair, and G. Ajithkuniar, “Tribological evaluation of coconut oil as an environment-friendly lubricant,” Tribology International, vol. 40, no. 2, pp. 350–354, 2007.

[19] N. H. Jayadas, K. P. Nair, and G. Ajithkuniar, “Tribological evaluation of coconut oil as base oil for industrial lubricants- evaluation and modification of thermal, oxidative and low temperature properties,” Tribology International, vol. 39, no. 9, pp. 873–878, 2006.

[20] P. V. Krishna, R. R. Srikant, and D. N. Rao, “Experimental investigation on the performance of nanoboric Acid Powder suspensions in SAE-40 and coconut oil during turning of AISI1040 steel,” International Journal of Machine Tools and Manufacture, vol. 50, no. 10, pp. 911–916, 2010.

[21] T. Hisakado, T. Tsukizoe, and H. Yoshikawa, “Lubrication mechanism of solid lubricants in oils,” Journal of Lubrication Technology, vol. 105, no. 2, pp. 245–252, 1983.

[22] J. K. Mannekote and S. V. Kailas, “Studies on boundary lubrication properties of oxidised coconut and soy bean oils,” Lubrication Science, vol. 21, no. 9, pp. 355–365, 2009.

[23] K. S. Geethanjali, C. M. Ramesha, and B. R. Chandan, “Comparative studies on machinability of MCLA steels EN19 and EN24 using Taguchi optimization techniques,” Materials Today Proceedings, vol. 5, no. 11, pp. 25705–25712, 2018.

[24] S. Thanhnhanh, S. Saparudin, and S. Hasan, “An experimental study for analyses of surface roughness by turning process using Taguchi method,” Journal of Achievements in Materials and Manufacturing Engineering, vol. 20, no. 1-2, pp. 503–506, 2007.
[25] M. Muaz, R. Kumar, and S. K. Choudhury, “Enhancing tribo-rheological performance of solid lubricants mixed bio-based emulsions applied through minimum quantity cooling lubrication technique,” Sadhana, vol. 47, no. 3, pp. 110–115, 2022.

[26] P. N. L. Pavani, R. Pola Rao, and S. Srikiran, “Performance evaluation and optimization of nano boric acid powder weight percentage mixed with vegetable oil using the Taguchi approach,” Journal of Mechanical Science and Technology, vol. 29, no. 11, pp. 4877–4883, 2015.

[27] M. R. Lovell, M. A. Kabir, P. L. Menezes, and C. F. Higgs, “Influence of boric acid additive size on green lubricant performance,” Philosophical Transactions of the Royal Society A: Mathematical, Physical & Engineering Sciences, vol. 368, pp. 4851–4868, 2010.

[28] S. Sirin and T. Kivak, “Performances of different eco-friendly nanofluid lubricants in the milling of Inconel X-750 super-alloy,” Tribology International, vol. 137, pp. 180–192, 2019.

[29] O. Ondin, T. Kivak, M. Sankaya, and L. V. Yildirim, “Investigation of the influence of MWCNTs mixed nanofluid on die machinability characteristics of PH 13-8 Mo stainless steel,” Tribology International, vol. 148, Article ID 106323, 2020.

[30] T. Kivak, M. Saiikaya, V. Yikliiim, and S. Siri, “Study on turning performance of PVD TiN coated AOs+TiCN ceramic tool under cutting fluid reinforced by nano-sized solid particles,” Journal of Manufacturing Processes, vol. 56, pp. 522–539, 2020.

[31] P. Shall, N. Khanna, K. Zadafiya, M. Bhalodiya, R. W. Maruda, and CM. Krolczyk, “In-house development of eco-friendly lubrication techniques (EMQL, Nanopanicles + EMQL and EL) for improving machining performance of 15-5 PHSS,” Triboi. Int vol. 151, Article ID 106476, 2020.

[32] Y. Su, L. Gong, and D. Chen, “Dispersion stability and thermophysical properties of environmentally friendly graphite oil–based nanofluids used in machining,” Advances in Mechanical Engineering, vol. 8, Article ID 168781.401562797, 2016.

[33] C. G. Lee, Y. J. Hwang, Y. M. Choi, J. K. Lee, C. Choi, and J. M. Oh, “A study on the tribological characteristics of graphite nano lubricants,” International Journal of Precision Engineering and Manufacturing, vol. 10, no. 1, pp. 85–90, 2009.