EFFECT OF BIOLUBRICANT AS COOLING FLUID ON VERTICAL MILLING TOOL WEAR

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Abstrak

Dalam industri manufaktur, penggunaan cutting fluids sudah sangat dikenal. Namun, cutting fluid memiliki beberapa efek samping seperti mencemari lingkungan, dan pada beberapa kasus ada yang memiliki alergi terhadap cutting fluid konvensional tersebut. Tujuan dari penelitian ini adalah untuk mengetahui pengaruh biolubricant sebagai cairan pendingin terhadap keausan pada keausan pahat frais vertikal. Pada penelitian ini material yang digunakan adalah mild steel dan Endmill berbahan HSS dengan diameter 6 mm. Biolubricant dibuat dengan menggunakan proses pembuatan biolubricant menggunakan proses transesterifikasi dengan bahan; minyak jelantah, etanol (98%), dan kalium hidroksida. Pada proses pengambilan data menggunakan mesin milling, variasi yang digunakan adalah; tanpa menggunakan cutting fluid, menggunakan cutting fluid konvensional, dan menggunakan biolubricant. Dengan kecepatan 500 Rpm dan 930 Rpm. Pada uji Kromatografi-Spektrometri Massa (GC-MS) didapatkan hasil jumlah ester sebanyak 57,12%. Pada alat yang baru, didapatkan luas area alat sebagai berikut: titik (1.) 0,012 cm2, titik (2.) 0,013 cm2, titik (3.) 0,022 cm2, dan titik (4.) 0,22 cm2. Sudut pahat adalah 68,957° dan berat pahat 12,31 g. Pada proses milling dengan menggunakan cairan pemotongan konvensional, luas area yang diperoleh adalah: titik (1.) 0,008 cm2 , titik (2.) 0,007 cm2 , titik (3.) 0,012 cm2 , dan titik (4.) 0,16 cm2. Sudut pahat adalah 88,005° dan berat pahat adalah 12,16 g. Pada proses milling tanpa menggunakan cairan pendingin, luas area yang diperoleh adalah: titik (1.) 0,016 cm2 , titik (2.) 0,017 cm2 , titik (3.) 0,023 cm2 , dan titik (4.) 0,24 cm2. Sudut pahat adalah 96,670° dan berat pahat adalah 12,07 g. Pada proses milling dengan menggunakan biolubrication, luas area yang diperoleh adalah: titik (1.) 0,012 cm2 , titik (2.) 0,013 cm2 , titik (3.) 0,019 cm2 , dan titik (4.) 0,19 cm2. Sudut pahat 72,448° dan berat pahat 12,2 g. Dapat disimpulkan bahwa proses milling dengan menggunakan biolubricant dengan pemberian biolubricant pada proses milling lebih sedikit dibandingkan dengan menggunakan cutting fluid konvensional, mendapatkan hasil yang lebih memuaskan dibandingkan dengan proses milling tanpa cutting fluid dan dengan menggunakan cutting fluid konvensional dan tanpa cutting fluid, hal ini dapat dilihat dari data yang diperoleh.

Kata Kunci : Biopelumas, Mesin Milling, Transesterifikasi, Keausan

Abstract

In the manufacturing industry the use of cutting fluids is well known. However, cutting fluids have several side effects such as polluting the environment, and in some cases there are people who have allergies to these conventional cutting fluids. The purpose of this paper is to determine the effect of biolubricant as cooling fluid on the wear on vertical milling tool wear. In this study the material

used is mild steel and Endmill made from HSS with a diameter of 6 mm. Biolubricant is made using the process of making biolubricant uses a transesterification process with ingredients; wasteused cooking oil, ethanol (98%), and potassium hydroxide. In the process of taking data using a milling machine, the variations used are; without using cutting fluid, using conventional cutting fluid, and using biolubricant. With speeds of 500 Rpm and 930 Rpm. In the Chromatography-Mass Spectrometry (GC-MS) test, the results obtained the number of esters as much as 57.12%. In the new tool, the tool area is found as follows: point (1.) 0.012 cm^2, point (2.) 0.013 cm^2, point (3.) 0.022 cm^2, and point (4.) 0.22 cm^2. The tool angle is 68.957° and the tool weight is 12.31 g. In the milling process using conventional cutting fluid, the areas obtained were: point (1.) 0.008 cm^2, point (2.) 0.007 cm^2, point (3.) 0.012 cm^2, and point (4.) 0.16 cm^2. The tool angle is 88.005° and the tool weight is 12.16 g. In the milling process without using coolant, the areas obtained were: point (1.) 0.016 cm^2, point (2.) 0.017 cm^2, point (3.) 0.023 cm^2, and point (4.) 0.24 cm^2. The tool angle is 96.670° and the tool weight is 12.07 g. In the milling process using biolubrication, the areas obtained were: point (1.) 0.012 cm^2, point (2.) 0.013 cm^2, point (3.) 0.019 cm^2, and point (4.) 0.19 cm^2. The tool angle is 72.448° and the tool weight is 12.2 g. It can be concluded that the milling process using biolubricant with the provision of biolubricant in the milling process is less than using conventional cutting fluid, getting more satisfactory results compared to the cutting process without cutting fluid and using conventional cutting fluid and without cutting fluid, this can be seen from the data obtained.
Keywords: Biolubricant, Milling Machine, Transesterification, wear

1. INTRODUCTION

Biolubricants are made from natural resources, such as vegetable and animal oils, which are renewable, non-toxic to humans and other living things, and environmentally friendly. Biolubricants can be made from plants, such as vegetable oils that are edible or non-edible, jatropha, castor, rice bran, rapeseed, oil palm, sunflower, coconut, soybean, olive, and canola. The most potential sources of vegetable lubricants are plants(Mairiza et al., 2022).

Due to the high polarity, vegetable oils can interact well with the surface being lubricated, making them excellent boundary lubricants. Looked at how mineral and vegetable oil-based cutting fluids perform in various machining operations. They found that vegetable oil formulations performed in all operations on par or better than commercial mineral oil references. In addition, vegetable oils have many desirable properties that make them very attractive lubricants for many useful applications. (Lawal et al., 2012)

Lower cutting temperatures can increase tool life. Because of this, cutting fluids are used for cooling and lubrication purposes; wet cutting is standard in industrial production. The functions of lubricants are cooling and lubrication. The cooling effect increases tool life by keeping the temperature below the softening temperature of the tool material. The lubrication effect reduces mechanical wear, such as abrasion on the rake tool surface. And lubricants have the secondary function of transporting debris and cleaning the tool or workpiece. The characteristics of lubricants with water-dominant materials have excellent heat transfer, while oil-based lubricants are superior at higher lubrication levels.(Priarone et al., 2014)

Based on the description above, objective of this project is to study the effect of the use of cutting fluid on end mill.This study will examine the effect of using biolubricant as a substitute for ordinary cutting fluid to tool wear, using biolubricant made from used cooking oil as an effort to reduce used cooking oil waste which is not environmentally friendly and difficult to decompose.

2. METHOD

2.1 Research Flow

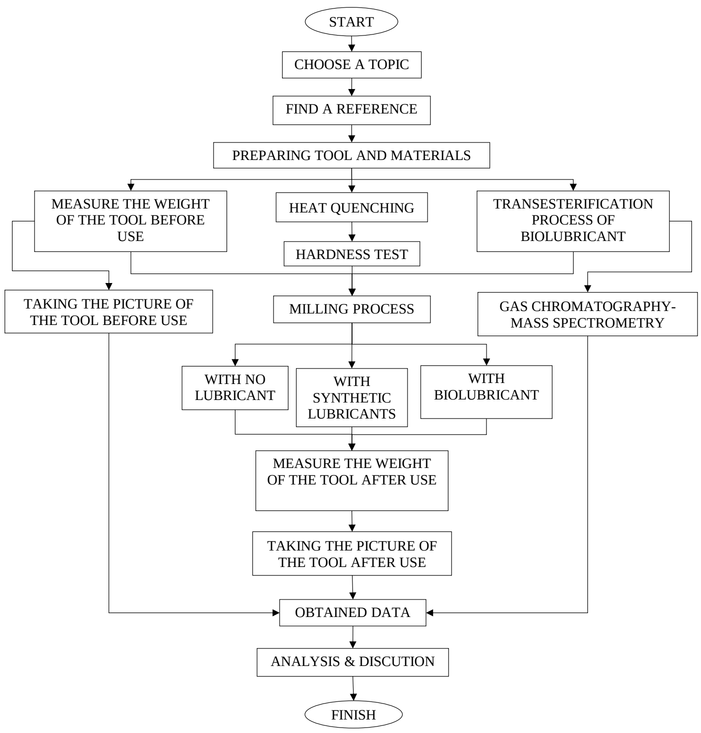


Figure 1. Research Flow

The workpiece in the milling process is as shown in Figure 2. The specimen size was made smaller to match the size of the endmill used

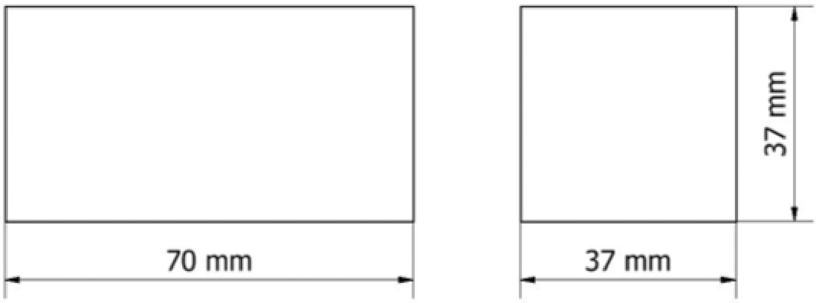


Figure 2. Research Design

2.2 Research Location

The experimental testing was conducted at the Mechanical Engineering Laboratory, Materials Laboratory, Universitas Muhammadiyah Surakarta

2.3 Material and Tools

2.3.1. Mild Steel

Specimens used in the milling process

Figure 3. Mild Steel

2.3.2. Waste Cooking Oil

The basic material used in the production of biolubricant is waste cooking oil obtained from the kitchen at home.

Figure 4. Waste Cooking Oil

2.3.3. Ethanol

The reagent used in the transesterification process is ethanol (98%)produced by PT Likuid Pharmalab Indonesia.

2.3.4. Potasium Hydroxide

Potasium Hydroxide Used as a catalyst in the transesterification process

2.3.5. Synthetic Cutting Fluid

Used as a cutting fluid in the milling process obtained from manufacture laboratorium.

2.3.6. Milling Macine

Using GUT universal milling machine as a tool to test biolubricant on mild steel surface.

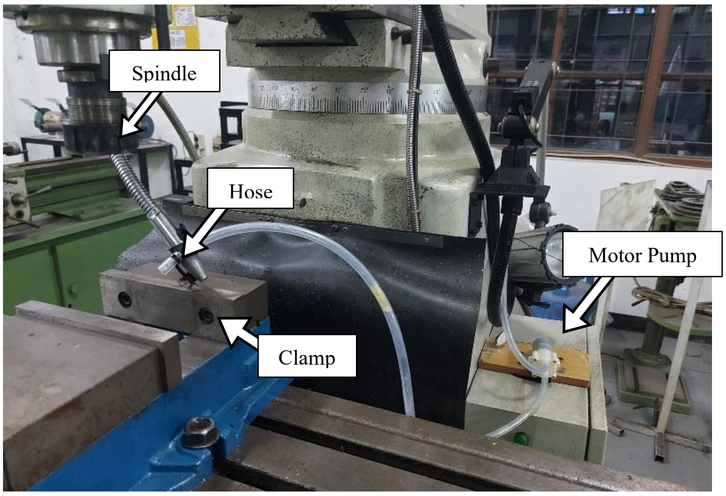


Figure 5. The Instalation Motor Pump in Milling Machine

Figure 6. Milling Machine

2.3.7. Surface Roughness Tester

Using Mitutoyo surftest SJ-210 series to measure the surface roughness of mild steel. This surface roughness test uses the ISO1997 standard.

Figure 7. Surface Roughness Tester

2.3.8. Gas chromatography–mass spectrometry (GC-MS) Instrument

Use for GCMS Test to determine the amount of fatty acid of biolubricant.

Figure 8. GC-MS Instrument

2.3.9. Hardness Tester

Using Mitutoyo Rockwell hardness tester to determine the hardness value of hardened mild steel. This hardness test uses the ASTM E92 standards.

2.3.10. Furnace

Using Wisetherm furnaces to carry out quenching method on the mild steel.

2.3.11. Viscometer

In accordance to ASTM D445-24 Standard Test Methods for Viscosity by Viscometer

2.3.12. Pycnometer

Pycnometer is used to measure the density

2.3.13. Pensky-Martens Closed Cup Tester

In accordance to ASTM D93-20 Standard Test Methods for Flash Point by Pensky-Martens Closed Cup Tester

2.4 Preparation Procedure

2.4.1 Transesterification Process

The transesterification process to make biolubricants is carried out in the following steps: First, prepare ethanol, KOH, and used cooking oil. A total of 20 mg of ethanol and 2 grams of KOH were weighed and put into a 125 ml flask. The ethanol and KOH solution was then heated to 60°C using a hot plate stirrer. Next, 200 mg of used cooking oil was weighed and put into a 125 ml flask, then heated to a temperature of 60°C. After reaching 60°C, ethanol and KOH solutions were added to the used cooking oil solution and stirred for 120 minutes at 60°C. After 120 minutes, the solution was transferred to a separating funnel and left overnight to separate the methyl ester phase and the glycerol phase. The glycerol phase (lower phase) was then discarded and stored in a separate container.

2.4.2 Chromatography-Mass Spectrometry (GC-MS) Test

GC MS testing of biolubricant samples was performed using a Shimadzu Gas Chromatography (GCMS-QP2010S) equipped with an Rxi™ -1 ms column (30 m x 0.25 mm x 0.25 µm thickness). The process began with the initial temperature of the column oven set at 80°C. This temperature was then gradually increased by 5°C per minute until reaching 200°C, where it was held for 2 minutes. Subsequently, the temperature was further raised to 280°C at a rate of 10°C per minute, with the GC injector temperature maintained at 270°C. Helium served as the carrier gas, flowing at a steady rate of 1 ml per minute. The identification of components was achieved by analyzing each peak from the chromatogram using a mass spectrometer. These results were then compared with a library spectrum to determine the types of substances present in the sample.

2.4.3 Milling Processes

The milling experiment began with setting the endmill on the machine spindle and placing the workpiece in the vise on the milling machine. In the first experiment, no cutting fluid was used. The zero point was set on the workpiece, and a depth of cut of 0.3 mm was entered. The machine was turned on with a spindle rotation of 500 RPM, and the feeding process was initiated. After completing this step, the workpiece and endmill were removed, and the endmill and the other side of the workpiece were installed. The zero point was set again on the workpiece, and the same depth of cut was input using a spindle rotation of 930 RPM.

For the second experiment, commercial cutting fluid was used. The endmill and workpiece were installed, the zero point was set on the workpiece, and a depth of cut of 0.3 mm was entered. The machine was turned on with a spindle rotation of 500 RPM, and commercial cutting fluid was applied during the feeding process. After this, the workpiece and endmill were removed, and the endmill and the other side of the workpiece were installed. The zero point was set on the workpiece, and the same depth of cut was input using a spindle rotation of 930 RPM.

In the third experiment, biolubricant was used as the cutting fluid. The workpiece and endmill were set up, the zero point was established, and a depth of cut of 0.3 mm was entered. The machine was turned on with a spindle speed of 500 RPM, and biolubricant was applied at a flow rate of 2.5 ml/min during the feeding process. After completing this step, the workpiece and endmill were removed, and the endmill and the other side of the workpiece were installed. The zero point was set on the workpiece, and the same depth of cut was input using a spindle rotation of 930 RPM, with biolubricant applied during the feeding process. After finishing all experiments, the endmill and workpiece were removed from the milling machine.

2.4.4 Hardness Test

The hardness testing procedure begins with cleaning the surface of the test piece to ensure accurate measurements. Then a 1/16 inch diameter ball indenter is mounted, and the load is set to 100 kgf. The test piece is then placed on a stand under the indenter. The start button is pressed, and the machine is allowed to run until the hardness test results appear on the information panel. Once the test is complete, the handle is returned to its original position. Finally, the test data is recorded.

2.4.5 Quenching

To increase the hardness of soft steel, the following steps are carefully taken: First of all, soft steel specimens are carefully prepared. Next, the furnace temperature is set at 550°C and a timer is set for 30 minutes to ensure the proper temperature and time required. After the 30-minute time has elapsed, the malleable steel specimens are carefully removed from the furnace and immersed in oil. Next, wait for the temperature of the malleable steel specimen to drop naturally and carefully dry it after it reaches a temperature that is safe for handling. These steps are designed to achieve an increase in the hardness of malleable steel through a proper heat treatment process and the use of quenching with oil to secure structural changes.

2.4.6 Wear Rate Measurement

The steps in the tool testing process begin with the preparation of the specimen to be tested. The weight of the tool is weighed before the cutting process and the data is recorded. Before starting the cutting, a photo of the tool edge is taken for initial documentation. After the cutting is complete, the weight of the tool is reweighed and a photo of the tool edge is taken. This process is carried out for all tools that perform different cuts. The weighing results were recorded for further evaluation of each tool's performance in the test.

2.4.7 Viscosity Test

To perform viscosity testing, the sample is first inserted into the viscometer by turning the viscometer upside down and slipping the measuring leg of the viscometer into the sample. The sample is sucked through the large diameter leg until it reaches the lower limit line. After cleaning the outside of the viscometer, the viscometer was returned to its normal position. Next, the viscometer was inserted into a holder and placed in a viscosity bath with a constant temperature. It was given 10 minutes to reach equilibrium at 40°C or 15 minutes at 100°C, or the time required for temperature equilibrium. Then, the solution is aspirated up to number one, allowing the solution to flow down to wet the inner surface of the viscometer. Flow time measurements from the upper boundary line to the lower boundary line were taken with an accuracy of 0.2 seconds to repeat the flow time measurements. These steps were taken to obtain accurate data on the viscosity of the tested sample.

2.4.8 Density Test

To perform Density testing using a pycnometer, the following steps must be followed carefully. First, ensure that the pycnometer and all other equipment are clean and dry before use. In the second step, weigh the empty and dry pycnometer, and record the result. Next, fill the pycnometer with the liquid whose density you want to measure, while ensuring that no air bubbles are trapped inside. Then, weigh the pycnometer that has been filled with the liquid and record the result. To ensure accuracy, repeat this process several times and calculate the average density. Finally, ensure that the temperature of both the liquid and the pycnometer are measured,

2.4.9 Flash Point Test

To perform flash point testing, prepare tools and materials such as the Pensky-Martens test kit, thermometer, heat source, timer, liquid sample, rags, and personal protective equipment. Make sure the equipment is calibrated to the standard. Take and homogenize the liquid sample, then fill the cup to the specified limit and attach the thermometer. Heat the cup at the specified rate while stirring the liquid constantly. Test the flash point periodically by lighting a small flame source over the cup at specified temperature intervals and record the temperature at which the flame first appears. After the test, clean the cup and other tools with a cloth. Use personal protective equipment during the process and ensure the test area is well ventilated. Record all test result data in a logbook.

3. RESULTS AND DISCUSSION

3.1 Gas Chromatography-Mass Spectrometry (GC-MS) Test Result

Gas Chromatography-Mass Spectrometry (GC-MS) test was conducted to determine the content of ester products formed from the biolubricant transesterification process.GC-MS test results for transesterification reaction products with a molar ratio of ethanol : waste cooking oil of 1: 10 using KOH catalyst with a reaction temperature of 60°C, shows that there is a chemical substance searched in biolubricant which is ester identified as 57.12%.

The amount of esters produced from the transesterification process of used cooking oil is not very high. This is because the results of the transesterification process can be influenced by several factors, such as the ratio of the ester ratio. such as the ratio of alcohol to used cooking oil that is less precise, the amount of free fatty acids contained in the oil. The transesterification process is a process to break down fatty acids in used cooking oil. If there are a lot of free fatty acids in used cooking oil, the esters produced are only a few.

3.2 Characteristic of Biolubricant

The following is the characteristic data of biolubricant that has been made by transesterification method from three repeated tests.

Table 1. Characteristic of Biolubricant

Viscosity		Density at 24°C	Flash Point
40°C	100°C		
19 cSt	3.825 cSt	0.836 g/ml	29.5°C

Based on the data results table above, it can be concluded that the viscosity at 40°C is 19 cSt indicating that the biolubricant has a medium viscosity and the viscosity at 100°C is 3.825 cSt indicating that the viscosity of the biolubricant decreases significantly as the temperature increases. Low viscosity at higher temperatures is typical of oils designed for lubrication. The density of a biolubricant is 0.836 g/ml, indicating that the lubricant is in liquid form. The lubricant in the liquid state allows the lubricant to flow and coat moving parts effectively, reducing friction and wear.The flash point of biolubricant is 29°C, this shows that the lubricant is very volatile and can burn at relatively low temperatures. So these biolubricants are not suitable for high temperature applications or environments where there is a risk of heat buildup.

3.3 Hardness test

The Rockwell hardness test is used to measure the hardness of hardened mild steel. In this work hardness test done in accordance with ASTM E92 standards,this test is carried out by applying pressure to the surface of the test specimen using a ball-shaped indenter with a diameter of 1/16 inch. The load used in this test is 100 kgf with a pressing time of 5 seconds.From the five readings, we found that the average hardness value of the mild steel sample was 75.3 HRB.

3.4 Tool blade wear test

3.4.1 Visual analysis

In this test use application ImageJ to know about the area and the angle of tools. This photo was taken using a cellphone camera with 8 times magnification.

Table 2. Area tool with biolubricant

	No	Area (cm^2)
With biolubricant	1	0.012
	2	0.013
	3	0.019
	4	0.019

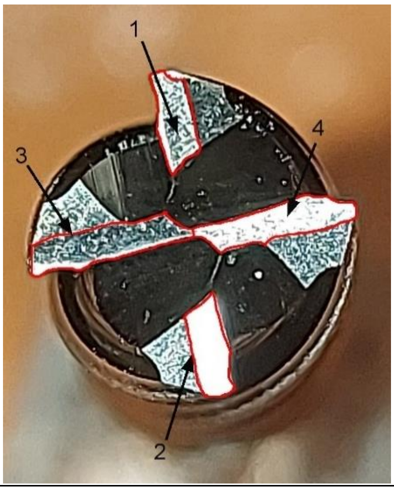


Table 3. Area tool Without Cutting Fluid

	No	Area (cm^2)
Without Cutting Fluid	1	0.016
	2	0.017
	3	0.023
	4	0.024

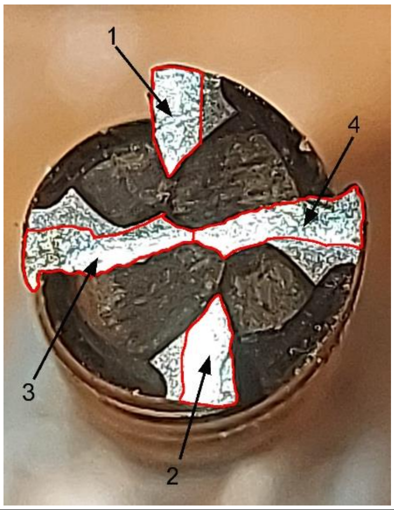
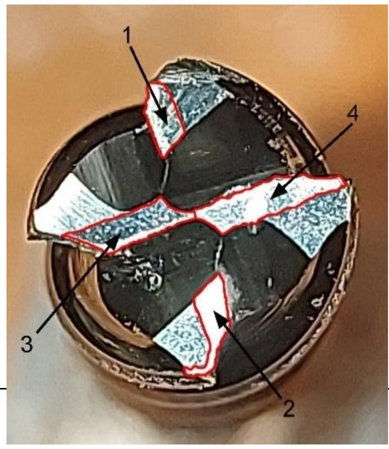


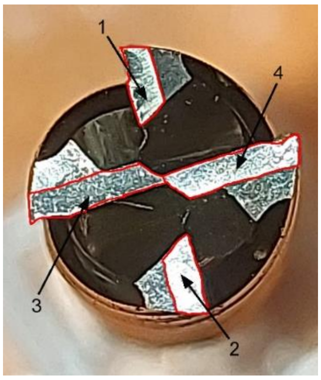
Table 4. Area tool with conventional cutting fluid

	No	Area (cm^2)
With Conventional Cutting Fluid	1	0.008
	2	0.007
	3	0.012



	4	0.016	

Table 5. Area new tool

	No	Area (cm^2)	
The New Tool	1	0.012	
	2	0.013	
	3	0.022	
	4	0.022	

This can be seen from the data in the table above. The area of the new end mill at point 1 is 0.012 cm^2, 2 is 0.013 cm^2 and at points 3 and 4 is 0.22 cm^2. The end mill area without using cutting fluid at point 1 is 0.016 cm^2, 2 is 0.017 cm^2 and point 3 is 0.023 cm^2, 4 is 0.024 cm^2, while the end mill area using commercial cutting fluid at point 1 is 0.008 cm^2, 2 is 0.007 cm^2 and point 3 is 0.012 cm^2, 4 is 0.016 cm^2. While using biolubricant, the area obtained at point 1 is 0.012 cm^2, 2 is 0.013 cm^2, points 3 and 4 are 0.019 cm^2. The reduction in endmill area is caused by the wear that occurs at the end of the endmill, this can be seen in the endmill data table using biolubricant and commercial cutting fluid. endmill tools that use commercial cutting fluid have more area reduction than in the data table that does not use cutting fluid, there is an increase in endmill area, the increase in area on the blunted tool occurs because the cutting edge of the tool, which initially has a small cross-sectional area, becomes wider due to wear and tear. As a result, the tool's ability to effectively cut materials decreases, the cutting force increases, the heat generated increases, and the quality of the cut surface decreases.

Table 6. Angle the tip of the tool with biolubricant

With Biolubricant	Point	Angle (°)	

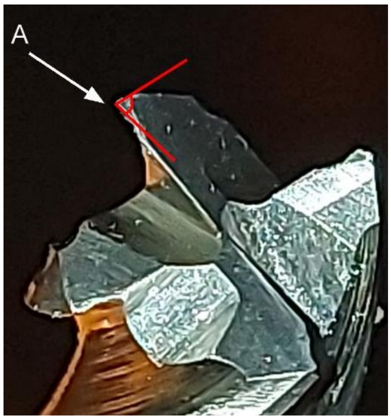
	A	72.448	

Table 7. Angle the tip of the tool Without Cutting Fluid

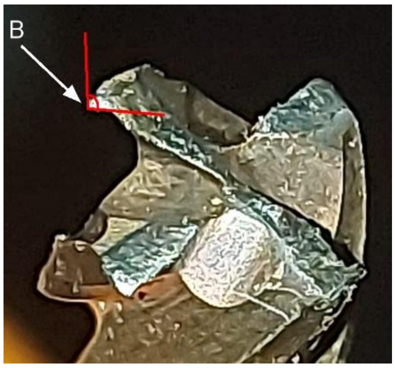
	Point	Angle (°)	
Without Cutting Fluid	B	96.670	

Table 8. Angle the tip of the tool with conventional cutting fluid

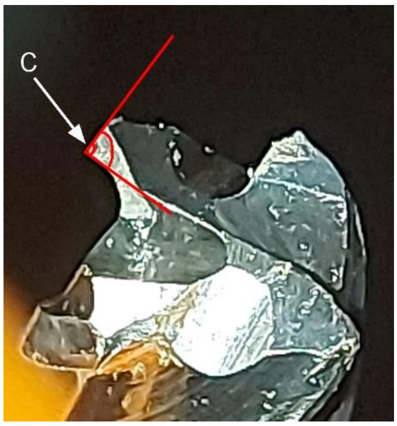
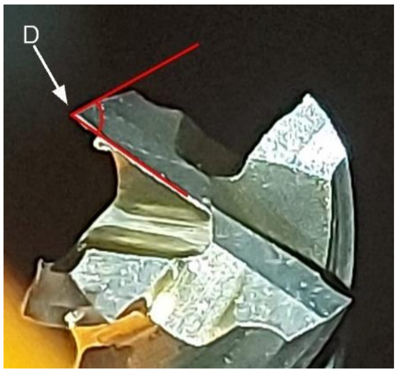
	Point	Angle (°)	
With Conventional Cutting Fluid	C	88.005	

Table 9. Angle the tip of the new tool

	Point	Angle (°)	
The New Tool	D	68.957	

From the data in the tables above, the following angles are obtained: point A is 72.448°, point B is 96.670°, point C is 88.005°, and point D is 68.957°. It can be concluded that the greater the angle of the tool, the greater the wear experienced by the tool. The angle on the tool using conventional cutting fluid has a value that is almost the same as without using lubricants because of the breaking at the tip of the tool. The following is an illustration of the milling process and a comparison chart of tool angle data

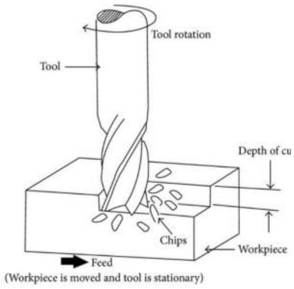


Figure 9. Ilustration Milling Process

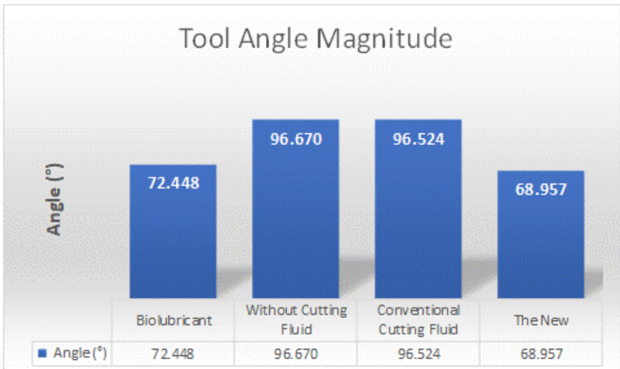


Figure 10. Histogram Tool Angle Magnitude

Table 10. The tip of the tools

The New Tool	With Biolubricant	With Conventional Cutting Fluid	Without Cutting Fluid
			

It can be seen from the figure that the new tool at points A and B is still a tool that has not experienced wear. The tool that uses biolubricant experiences wear at points A and B. The tool that uses conventional cutting fluid is broken at points A and B. The tool that does not use lubricant experiences wear until the tool becomes blunt, and at point C, the tool changes color from silver to golden brown.

3.4.2 weight test

This weight test is used to calculate the weight of the tool that is reduced because the wear.

Table11. Tool weight difference

No	Tool	Weight(g)
1	New Endmill	12.31
2	With Biolubricant	12.2
3	With Conventional Cutting Fluid	12.16
4	Without Cutting Fluid	12.07

Based on the data obtained, the endmill without cutting fluid lost weight by 0.24 g from 12.31 g. In the endmill using commercial cutting fluid the weight loss was 0.15 g from 12.31 g. Meanwhile, in the endmill using biolubricant, the weight loss was 0.11 g from 12.31 g. This indicates that biolubricants can prevent wear better than conventional cutting fluids and without cutting fluid.

3.5 Surface Roughness Test Result

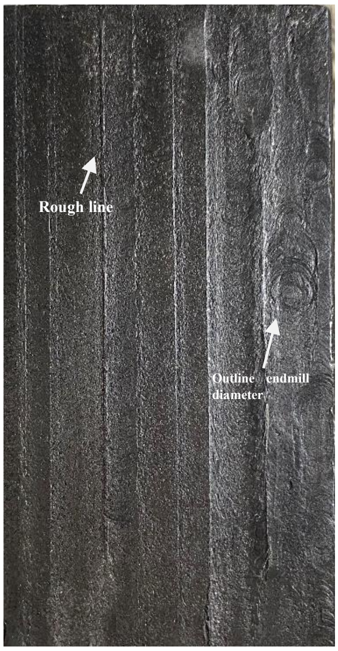
Surface roughness test in this research was conducted to determine the roughness value of mild steel after milling process with spindle speed of 500 Rpm and 930 Rpm with depth of cut 0.3 mm. This surface roughness test uses the ISO1997 standard and the roughness value is represented by Roughness Average (Ra).

Table 12. Surface roughness test results

e	N (Rpm)	f (mm/min)	a (mm)	Ra (µm)		
				Without Cutting Fluid	Commercial Cutting Fluid	Biolubricant
1	500 Rpm	50	0,3	0,887	0,862	0,637
2	930 Rpm			2,793	0,798	0,300

According to the test results data in table 12, the highest roughness value without cutting fluid is obtained at 500 Rpm with a value of 0.887 µm, and at 930 Rpm with a value of 2.793 µm. As for low value surface roughness, it can be observed that using biolubricant gives the lowest surface roughness value at 500 Rpm, which is 0,637 µm, and the lowest surface roughness value at 930 Rpm, which is 0,300 µm.

Table 13. Milling process specimen

<table>
<tr><td></td><td>500 Rpm</td><td>930 Rpm</td></tr>
<tr><td>Without Cutting Fluid</td><td>
</td><td>
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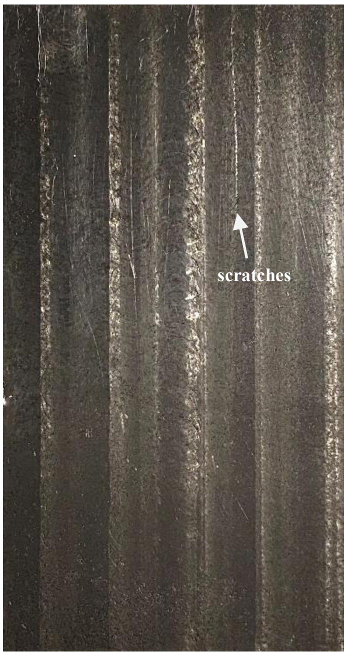
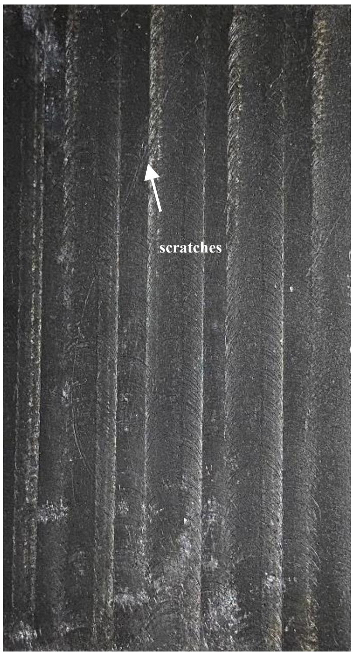
</table>

Commercial Cutting Fluid		
Biolubricant		

Based on table 13, the results of the milling process without using cutting fluid with a spindle speed of 500 rpm, the surface texture of the mild steel has several pores and at a spindle speed of 930 rpm it looks very rough with several rough lines and the outline of the diameter of the endmill used. Meanwhile, the milling process by using commercial cutting fluid, at a spindle speed of 500 rpm, there are several textures are from the endmill diameter and at a spindle speed of 930 Rpm there are several scratches at several points. In the milling process by using biolubricant, a rough surface texture was visible when using a spindle speed of 500 Rpm with a few small scratches at several points, whereas at a spindle speed of 930 Rpm there are a few smaller scratches.

Minimal quantity lubrication (MQL), which uses a small amount of cutting fluid to provide cooling and lubrication between the cutting tool and surface in a MQL-based machining process, is showing greater potential to produce a high-quality surface and better overall machining performance when compared to conventional cooling methods. Applying MQL (Minimum Quantity Lubrication) allows for four times more cutting than wet machining when it comes to the cutting fluid utilized in the cooling and lubrication process between the cutting tool and the surface. During the milling process, the MQL approach helps reduce temperature, friction, cutting forces, and tool wear. (Kumar et al., 2022)

Adhesive, abrasive, surface fatigue, and tribochemical wear are examples of wear types. Particles from the surface of a weak substance are transferred to a harder material, causing adhesive wear. Abrasive wear is the result of a tougher material wearing away at its surface, leaving behind two and three body abrasions. Frequent and sporadic surface fatigue wear leads to increased shear stress and crack development. The expansion of the area on the tool is caused by the tool becoming dull due to wear. Tribochemical wear is the result of a mix of thermal and mechanical processes that happen on an object's surface and in its surroundings over time, which causes abrasion and crack propagation. Because of the presence of reactive materials, this kind of wear leads to rapid corrosion of the metal, starting with adhesive wear. (Syafa’at ., 2008).

4. CLOSING

Based on the data analysis and discussion of test results, several conclusions can be drawn. The transesterification process of used cooking oil into biolubricant with a molar ratio of ethanol to used cooking oil of 1:10 using a KOH catalyst resulted in an ethyl ester content of 57.12%. The free fatty acid (FFA) content in the used cooking oil affects the ethyl ester content in the biolubricant, as the saponification reaction occurring during the transesterification process, driven by the FFA content, can reduce the ethyl ester content. The hardness test on mild steel samples at five points showed an average hardness of 75.3 HRB, classifying the mild steel as quite hard due to the quenching process. The wear on endmills using biolubricant showed fewer defects compared to those using commercial cutting fluid and those without any cutting fluid, which exhibited more defects. The weight reduction after milling was lowest for the endmill with biolubricant (0.11g), compared to those with commercial cutting fluid (0.15g) and without cutting fluid (0.24g). The decrease in the endmill area is attributed to wear at the end of the endmill, as seen in the data for both biolubricant and commercial cutting fluid. Without cutting fluid, an increase in endmill area was noted due to the tip being used up during the cutting process. The surface roughness of the mild steel samples was affected by the coolant used. The highest surface roughness was achieved without cutting fluid, with values of 0.887 μm at 500 Rpm and 2.793 μm at 930 Rpm. In contrast, the lowest surface roughness was achieved using biolubricant, with values of 0.637 μm at 500 Rpm and 0.300 μm at 930 Rpm. Biolubricant produced better surface roughness compared to commercial cutting fluid and no cutting fluid, with fewer scratches and textures, particularly at higher speeds. The biolubricant prepared had a viscosity of 19 cSt at 40°C and 3.825 cSt at 100°C. Its density at 24°C was 0.836 g/ml, and it had a flash point of 29.5°C, indicating the minimum temperature at which its vapor can ignite. This data is crucial for understanding the behavior of biolubricants under various temperature conditions and for evaluating their performance and safety aspects. Based on the research conducted, the following suggestions are provided: use a comparative scale in determining the composition of biolubricant to easily ascertain the amount of ingredients needed, utilize oils with low FFA content to produce high ethyl esters in the esterification process, and conduct the biolubricant manufacturing process in a well-ventilated area.

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