

# Evaluation of Rubber Seed Oil as Cutting Fluid using Minimum Quantity Lubrication in the Turning Process of AA6061

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**Abstract** - At this time, a cooling technique has been developed in the machining process, namely the minimum of drop lubrication, to save the use of cutting fluid. The existence of cutting fluid as a lubrication medium can reduce the friction force between the tool and the workpiece so that the tool life can be extended and decrease the surface roughness value. This study uses the minimum drop lubrication technique and rubber seed oil as a cutting fluid. The turning process is done with carbide inserts and varying flow rates. The results showed that the greater the flow rate of cutting fluid (rubber seed oil), the lower the surface roughness value and the continuous and thinner chip shape. This is in accordance with the flow rate of 0 ml / s cutting fluid has an average roughness value of 2  $\mu\text{m}$  with a continuous chip shape and tends to be thick, the tool experiences cracks and wear. At the cutting fluid flow rate of 192 ml / s, it has an average surface roughness value of 1.729  $\mu\text{m}$  with a continuous and thin chip shape, the tool wears out but does not experience cracks.

**Keywords** — cutting fluid, flow rate, drop lubrication, rubber seed oil, surface roughness, chip

## I. INTRODUCTION

In this era of globalization, the development of the manufacturing process is increasingly rapid, which must produce high-quality products. In the machining process, where objects are formed by removing part of the material from the workpiece, the machining process obtains an accurate product compared to other processes [1-4]. The turning process is a production process that involves a variety of machines, which in principle reduce the diameter of the workpiece [5-7]. This type of machine varies and is the most widely used machine tool in the world and produces the most various forms of components in the piping industry. An example is the pipe flange manufacturing process. In this component's manufacturing process, the material that is widely used is aluminum alloy 6061 [7-10]. This material was chosen because this material has good corrosion resistance, excellent formability, minimal maintenance, and a fairly excellent conductor of electricity and heat conductor.

One of the impacts that can arise from the machining process is unevenness on the machined surface. The unevenness creates roughness on the surface of the material. Surface roughness itself is a deviation of a surface texture, one of which is the production process or the machining process [11-12]. A machining process is carried out to achieve good product quality, which is a turning process to reduce the workpiece's dimensions by determining machining parameters such as spindle speed, depth of cut, and feed rate, which affect the surface roughness value. The characteristics of a surface roughness play an important role in designing machine components because it is related to friction, wear, and gluing of two or more components [13-16].

The chip resulting from the machining process is formed because of the microcrack that appears right at the end of the chisel on the workpiece when the cutting process begins [17]. Metals, in general, have ductile properties; when under pressure, stress will arise in the area of the cutting edge's compression force. If this shear stress exceeds the metal's strength, it will cause plastic deformation that shifts and breaks the workpiece material at the end of the tool in a flat plane [18-20]. The surface area can be influenced by the result of chip formation. In general, the shape of the chip is divided into three, including the shape of the built-up edge chip, the continuous chip, and the non-continuous chip; the three chips can affect the material's surface roughness results being tested [21-22].

The cutting fluid usage methods are atomized, sprinkled, and sprayed [23-24]. This method is less efficient in use and cost; the lubrication method is the minimum quantity of drop lubrication [25-27]. The minimum quantity of drop lubrication fluid is between 50-500 ml/hour in the method. The minimum quantity of drop lubrication method is one of the lubrication techniques, which is the latest technology in machining which is useful for gaining advantages in environmental and economic safety by reducing cutting fluid use. This method utilizes gravity force so that the cutting fluid will come out trickling between the chisel and the workpiece [28]. In the turning process, the cutting fluid flow rate greatly affects the surface area's value;



with the increasing of the cutting fluid flow rate, the area affected by lubrication increases and causes a decrease in the surface area's value.

A cutting fluid is a liquid fluid flowed during the machining process; cutting fluid aims to reduce friction between the tool and workpiece, reduce the cutting temperature, and help remove chips in the cutting area [29-31]. Several types of cutting fluids are used in the machining process: straight oil, synthetic fluid, soluble oil, and bio cutting fluid [32]. Cutting fluid types such as straight oil, synthetic fluid, and soluble oil can damage the environment and pollution along with continuous use; on the one hand, these types of cutting fluid are very difficult to maintain by nature and cause environmental damage. A good type of cutting fluid that is environmentally friendly and biodegradable. Bio cutting fluid from vegetable oil can decompose naturally in the soil around 98%, but in cutting fluid, straight oil, synthetic fluid, and soluble oil, it decomposes 20% -40%.

Rubber is one of the agricultural products that support the economy. Apart from producing latex, rubber plantations also produce rubber seeds that have not been utilized optimally [33]. By looking at the high oil content in the rubber seed meat, which is 45%, this oil can be used in the bio cutting fluid. Taking rubber seed oil can be done in two ways: pressing (pressing) and solvent (solvent). Two methods that are commonly used, namely mechanical pressing, include hydraulic pressing and threaded pressing. The results showed that rubber seed oil had good capabilities, namely viscosity and resistance to high temperatures.

This study aims to determine the effect of the cutting fluid flow rate of rubber seed oil on-chip shape and surface roughness in the turning process using the minimum quantity of drop lubrication method.

## II. EXPERIMENTAL METHOD

The material used in this study is aluminum alloy 6061, which has a chemical composition as shown in Table 1 below

**TABLE 1. AA 6061 chemical composition**

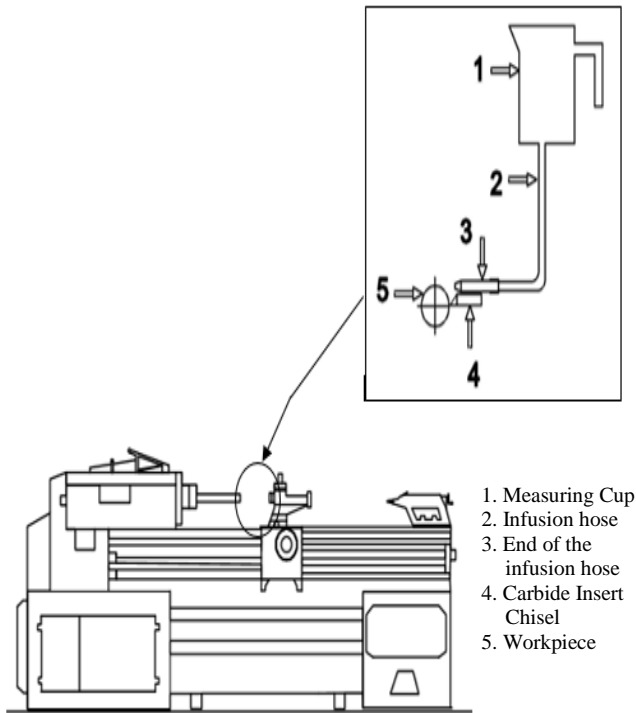
Element	Composition (%Wt)
Si	0,4
Fe	0,7
Cu	0,15
Mn	0,15
Mg	1
Cr	0,2
Zn	0,25
Ti	0,15
Others	0,05
Al	Balance

The manufacture of rubber ore oil begins by opening the rubber seeds first using a hammer. After getting the core from the rubber seeds, the core is dried in the sun first not to contain water and sap. After that, the seeds are then blended to obtain a uniform mesh size. Furthermore, the rubber seeds that have been blended are pressed using a 20 ton Melzer Hydraulic Press to get the oil. The oil obtained has the composition as listed in Table 2 below.

**TABLE 2. Chemical composition of rubber seed oil**

Element	Composition (%Wt)
Oleic Acid	39,45%
Palmitic Acid	13,11%
Stearic Acid	12,66%
Arachidic Acid	0,54%
Linoleic acid	33,12%

The lathe used is KW45-185, which has previously been installed, as shown in Figure 1. A tool holder is a support tool for the process of flowing cutting fluid drops to the chisel and workpiece. The location of the tool holder is set to fit so that the flow rate measurement process can run properly. Furthermore, a measuring cup is used to accommodate the cutting fluid and to measure the discharge of the cutting fluid, then the infusion hose is used to drain and adjust the flow rate of the cutting fluid, and a stopwatch is used to measure the flow of the cutting fluid so that it does not take more than 1 minute. The measuring cup is attached to the tool holder at the top and the infusion tube at the bottom of the measuring cup. Rubber seed oil acts as a cutting fluid in a measuring cup with a constant volume of 250 ml when the valve is closed. Flow rates were measured by cutting fluid at speeds of 0, 60, 120, 192 ml / s. the flow rate measurement process begins by opening the valve slowly for 1 minute. Cutting fluid that comes out is then accommodated in the measuring cup. The spindle speed of 330 rpm, infeed length of 10 mm, depth of cut 0.5, feed rate 0.231 mm / rev, and tool angle 90°.

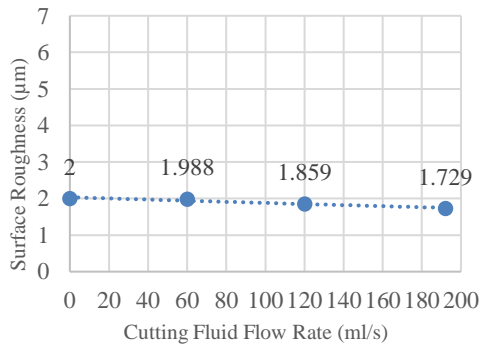


**Figure 1. Tool Mechanism**

Surface roughness was measured using the Mitutoyo Surface Roughness MJ301. Meanwhile, the analysis of tool wear was analyzed using Phenom G2 Scanning Electron Microscopy (SEM). Meanwhile, the shape of the chip is analyzed using the Canon EOS 850 D.

**III. RESULTS AND DISCUSSION**

Figure 2 below shows the relationship between rubber ore oil's flow rate using the MQL method to the surface roughness of the AA 6061 turning process. The process of taking surface roughness data is carried out at 3 points on each material.



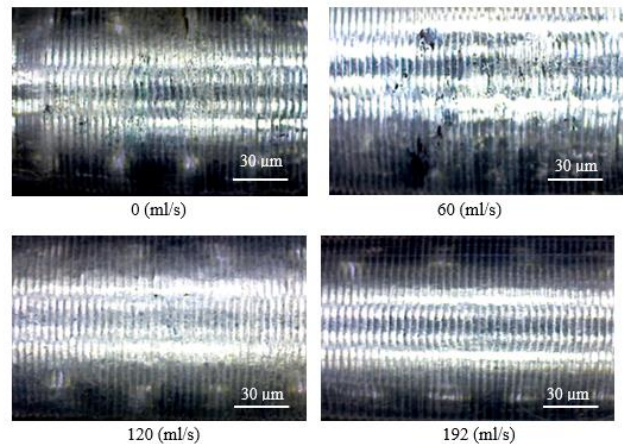
**Figure 2.** The relationship of the cutting fluid flow rate to the mean surface roughness of the cutting results using the turning machine

According to ISO 1302 - 1978, surface roughness is meant by the arithmetic to mean deviation from the mean profile line. This definition is used to determine the value of the average surface roughness. In the industrial world, the needs that are desired by each company are different, according to the desired needs. The surface roughness value itself has a different quality value.

The surface roughness values obtained also have almost uniform values, ranging from 1.729 - 2 µm. The value obtained is in accordance with the tolerance of roughness values in the turning process, namely 0.4 µm to 50 µm.

In the process of forming and cutting, there will be high heat partly due to friction, so the metal surfaces tend to stick together. Therefore cutting fluid is needed. It can be seen in Figure 2 that shows a graph of the relationship between the flow rate of cutting fluid on the average surface roughness value of aluminum alloy 6061.

In Figure 3, which shows the results of the surface roughness test on the turning surface, it appears that the increasing flow rate of the cutting fluid causes a decrease in the surface roughness value because an increase in the flow rate of cutting fluid causes the cutting fluid to be exposed between the tool and the workpiece, the more heat is absorbed. The cutting fluid is also increasing so that the cutting temperature decreases and the tool performance becomes optimal, which causes the surface roughness of the workpiece to decrease.



**Figure 3.** AA 6061 surface after turning process

It can be seen that the constant cutting variation, which differs the flow rate for the cutting conditions with a flow rate of 0 ml / s (without using the cutting fluid rubber seed oil), shows an average roughness value of 2 µm. At a flow rate of 60 ml / s, the average roughness value was 1.988 µm while at a flow rate of 120 ml / s, it had an average roughness value of 1.859 µm and at a flow rate of 192 ml / s had a surface roughness value of 1.729 µm. So it can be concluded

that when the flow rate of the cutting fluid of rubber seed oil is added, it causes the surface roughness value to decrease. The cause of the decrease in the surface roughness value is because when the flow rate is increased, the amount of cutting fluid flow from the rubber seed oil that is exposed to the contact area with the workpiece and the chisel is also increasing, the heat absorbed by the cutting fluid is also increasing so that it can reduce the cutting temperature by decreasing the cutting temperature causing performance the chisel becomes optimal, and the surface roughness value decreases, so as to improve product quality.

Analysis of tool wear using the Scanning Electron Microscope (SEM) method to determine the surface of the object directly with a magnification of 300 x as seen in Figure 4. Based on the research results, the chisels analyzed are chisels without cutting fluid and chisels using cutting fluid rubber seed oil with a flow rate of 192 ml / s. It can be analyzed that the chisel before the test does not experience changes in the top or side sides, in the process of cutting conditions without using cutting fluid rubber seed oil can be seen in Figure 4. The chisel experiences cracks and wears on the top and sides; this happens because, in the absence of cutting fluid, the chisel rubber seed oil in the cutting process experiences excess temperature due to friction in the absence of cutting fluid rubber seed oil, in the cutting process it causes between the two sides the tool becomes cracked even with a longer cutting time which can cause fracture and wear on the tool which results in an increased roughness value. The absence of cutting fluid rubber seed oil in the cutting process resulted in significant wear and reduction in tool weight volume.

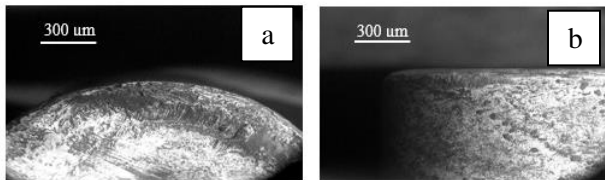


Figure 4. tool section (a) top view (b) side view

The rubber seeds used in this study were other products besides natural rubber from rubber plants (*Hevea brasiliensis*), which were underutilized. Rubber seeds are large and have hard skin or shell. The color is dark brown with distinctively patterned patches, seen from the chemical composition, and it turns out that the protein content of rubber seeds is high. Besides having a high protein content, the amino acid pattern of rubber seeds is also very good. All the essential amino acids needed are contained therein. Rubber in the form of three or four squares. After four months of age, the rubber fruit will ripen and break, so the rubber seeds will come off from the shell. Rubber seeds are round, 2.5-3 cm long, weighing 2-4 g. Inner rubber seeds consist of 40-50% hard brown skin and 50-60% yellowish-

white carnelian. Rubber seeds need to be dried before taking the oil because they contain a lot of water

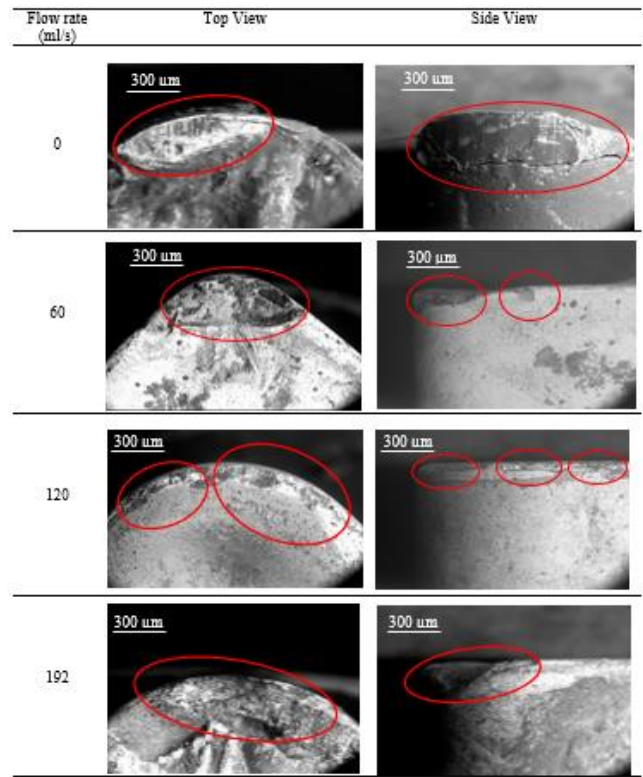


Figure 5. tool wear section is based on the flow rate of the cutting fluid

In the machining process, cutting fluid is used in metal cutting or machining processes to extend tool life, reduce deformation of the workpiece due to heat, improve the quality of machined surfaces, clean burrs from cutting surfaces, maintain temperature, and protect components from corrosion.

In general, it can be said that the main role of the cutting fluid is to cool and lubricate. With the presence of high temperature, cooling liquid on the outer layer can be reduced so that it does not change the metallographic structure of the workpiece. The chemical process is also expected to occur in the turning process. This cooling can be in the form of liquid that is sprayed on the workpiece that is turned and on the chisel; this cooling serves to reduce the excess heat that arises on the workpiece and the tool blade.

By reducing the cutting temperature, it can affect the tool wear rate, which will affect the roughness value and chip shape. There are several functions of the cutting fluid, including reducing cutting forces and energy, reducing friction and wear, thus increasing tool life, helping to remove chips in the cutting area, and reducing cutting temperatures. Meanwhile, the cooling liquid should have characteristics to support its function, such as not damaging the workpiece,



and not being harmful to the operator, being reusable and not clogging the circulation system, transparent which is needed to make it easier to see dimensional precision and has good lubrication properties, does not settle, heat resistant and easy to flow.

For the conditions of the cutting fluid flow rate of 60, 120, and 192 ml / s, it can be seen in Figure 3 that the chisel experiences better wear from the top and side of the tool blade and does not experience cracks on the top and side of the tool, and this is due to the method. The use of cutting fluid with the minimum quantity of drop lubrication method where the method drips with a minimum quantity that does not completely lubricate the part between the tool and the workpiece resulting in not maximum heat transfer and wear, where the use of cutting fluid will reduce friction and reduce the cutting temperature, so work the tool will be maximized, and the tool is not susceptible to wear and increase tool life and increase the yield of a product. Most of the carbide chisel structure is a fairly hard type of material; in each test, the wear reduction and tool volume did not increase significantly.

Based on the data tested, the shape or morphology of the chip is observed using a macro photo. For cutting conditions with a flow rate of 0 ml / s up to the cutting conditions with the greatest flow rate of 192 ml / s, it can be observed that the shape of the chip formed has a continuous geometry.

Chip formation is caused by the appearance of a very small crack that appears on the workpiece right at the end of the tool when cutting begins, as shown in Figure 5. As the tool pressure increases, the cracks advance so that a chip forms. Metal, which is generally ductile when under pressure, will result in stress in the area where there is a concentration of pressure from the cutting edge of the tool. The stress on the metal has a complex orientation, and in one direction, the maximum shear stress occurs. If this shear stress exceeds the strength of the metal concerned, there will be plastic deformation (change in shape), which shifts and breaks the workpiece material at the end of the chisel on a flat plane.

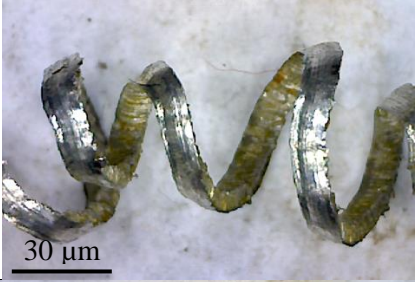


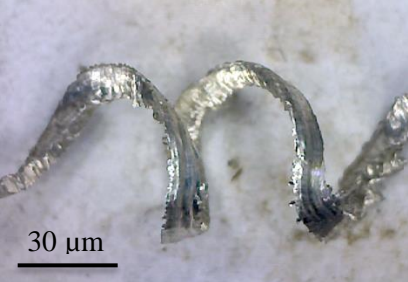
60		22
120		28
192		31

Figure 5. chip shape and size

The vertical cutting system is a simplification of the oblique system, where the force is broken down into components in a plane. Some of the assumptions used in the analysis of the model include deformation occurring in only two dimensions, the cutting edge of the tool is very sharp, so it does not rub or scratch the workpiece, the distribution of stress is evenly distributed in the shear plane, the action force and the reaction of the tool to the chip plane are equal and in line so that it does not cause a coupling moment.

Because the force system is seen in only one plane (not space), the net force can be broken down into two perpendicular components of the force. Depending on the way the description, in this case, can be put forward three ways, namely the total force (F) in terms of the deformation process of the material can be broken down into two components,  $F_s$ : The sheer force that transforms the material in the shear plane so that it exceeds the elasticity limit and  $F_{sn}$ : Normal force on the shear plane that causes the tool to stick to the workpiece. In addition, the total force (F) can be expressed the direction and magnitude by making a dynamometer (a force measuring device where the chisel is attached to it and the tool is mounted on a machine tool) which measures two components of the force, i.e.,  $F_v$ : Cutting force at the same direction as cutting speed and  $F_f$ : The style of eating is at the same direction as the speed of

Flow rate (ml/s)	Chip cut shape	Total length (cm)
0		17

eating. The last one is the total force (F), which reacts on the chip plane (Ay, face, where the plane on the tool where the chip flows) is broken down into two components to determine the chip friction coefficient against the tool, i.e., Fy: The friction force on the chip plane and Fyn: Normal force on the chip plane.

When the cutting takes place, the cutting force Fv will increase, the area in front of the cut will cause shear stress with varying orientations and prices. One of the planes will cause the largest shear stress, and with the increase in the cutting force, the shear stress in that plane (the shear plane) will exceed the elastic limit causing plastic deformation, which causes the formation of chips. If this happens, the cutting force has reached the maximum value (it is not possible to increase it again). Based on the geometric analysis of the force circle, the basic formula for the cutting force Fv can be derived.

The results of the analysis of the chip shape in aluminum 6061 material, along with the increasing flow rate of the cutting fluid, the more flat chip shape tends to be continuous, this is because the use of cutting fluid can reduce plastic deformation and reduce friction between the cutting tool and the workpiece so that the cutting temperature will decrease. And optimal tool performance, which causes the workpiece to become smoother and reduces the surface roughness value.

## VI. CONCLUSIONS

The use of rubber seed oil cutting fluid in the turning process can reduce the surface roughness value of the machined object. Surface roughness with the smoothest level of smoothness is obtained undercutting conditions with the cutting fluid flow rate of rubber seed oil 192 ml / s with an average surface roughness value of 1.729  $\mu\text{m}$ , the chip shape analysis has a flatter geometry and tends to be continuous, while in the analysis the chisel form undergoes wear only. At the cutting fluid flow rate of 0 ml / s rubber seed oil (without using the cutting fluid rubber seed oil) with a surface roughness value of 2  $\mu\text{m}$ , the chisel experienced cracks and wear. Along with the increasing flow rate of the cutting fluid, the chip shape rubber seed oil has a flatter geometry and tends to be continuous.

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