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Experimental Studies On Cutting Parameters During Turning Of Aluminium 6082-T6 Alloy Using Non Edible Oils As Cutting Fluid

Alam Radhika[1], Shailesh Rao A[2], Napa Hemanth[3]

Dept. of ME, KSSEM, Bangalore-109

Abstract:

With the use of cutting fluids in machining provides cooling and lubrication to improve tribological characteristics of machining processes. Though, Petroleum based cutting fluids are effectively involved itself in the process of lubrication, there is a vital need to identify environmental friendly and hazard free cutting fluids as lubricant. The objective of this work is to introduce Non-edible oils such as Karanja and Neem oils as cutting fluid, which is an environmental friendly for turning of Aluminium 6082-T6 Alloy. Further, an attempt has to been made to identify the influence of Non-edible oils by various rotation speeds with constant depths of cut and Feed rate. The machining parameters studied are Surface finish, cutting force and cutting temperature. The results indicate that the use of Karanja oil have superior surface finish at lower speed of 500 rpm compared to petroleum based oil and also dry cutting machining as discussed in detail.

Key words: *Aluminium 6082-T6 Alloy, Turning operation, Non-Edible Oils, Physical Properties, Surface finish, cutting force, Cutting Temperature*

1. Introduction

In any industries machining is very important aspect and the industries like aerospace, textile, and other manufacturing industries has restriction on tolerance for proper fit on the component. During machining, heat are generated between the work piece and tool which due to the generation of friction between them. In order to reduce the errors in manufacturing process, the cutting fluids are used for cooling and lubricating purpose. With the increase in the demand for the components in day to day life, the demand for good machine tools, cutting tools and the cutting fluids that would enhance the operating life of a tool reached skies. The cutting fluids plays a dominant role in removing the heat from the parts of the cutting tool that are subjected to friction during machining operation and also helps in better lubrication between the rubbed surfaces. Thus, selection of a good cutting fluid is very vital to involve a cutting tool in machining process for a longer period of time, without bringing any halt to the machining process.

There were many experimental works that are carried out by the different researchers in this arena. The petroleum based cutting fluids has become much more popular and are used as Metal Cutting fluids on a trial basis. Though Petroleum based cutting fluids effectively involved itself in the process of lubrication and cutting action in the long run, man learnt that these oils were not operator friendly, environmental friendly and resulted in many health hazards, toxic and found many skin diseases among the workers.

The challenge of modern machining industries is focused mainly on the achievement of high quality, in terms of work piece dimensional accuracy, surface finish, high production rate, less wear on the cutting tools, economy of machining in terms of cost saving and increase the performance of the product with reduced environmental impact.

1.1 Vegetable oil as Cutting Fluids

Vegetable Oil based metal working fluid are plant based product. They are cultivated and refined for specific performance properties and technical requirements. Vegetable oils cutting fluid has some superior features compared to petroleum based cutting fluids.

The influence of vegetable oil as cutting fluids on tool wear and surface roughness during turning of AISI 304 austenitic stainless steel with carbide tool using different types of cutting fluids (coconut oil, soluble oil and straight cutting oil) was investigated by Xavier and Adithan **[1]**.The metal working fluids that are widely employed to increase the machining productivity and quality of metal cutting, but the usage poses great threat to the ecology health of workers in industry. Therefore a need arose to identify eco-friendly and hazard free alternatives to convention mineral oil based material working fluid. In this review paper an effort has been undertaken to provide highlights of vegetable oils over petroleum based oils. Many research works showed that vegetable oils have promising scope of their emergence as metal working fluid **[2].**

Edward **[3]** showed the method of removing or preventing carbon fouling on a mechanical component of a device, comprising depositing a vegetable oil composition on the mechanical component of the device, wherein the vegetable oil composition comprises at least one vegetable oil having a smoke point above 200F, where in the at least one vegetable oil is present in an amount of at least about 25% by volume of the total volume of the oil composition and where in operation of the device deposits carbon on the mechanical component. Babur Ozcelik Emel kuram **[4]** focused on both formulation of vegetable based cutting fluids and machining with these cutting fluids. For this purpose characterization of chemical and physical analyses of these formulated cutting fluids are carried out. Experimental results show that Canola based cutting fluid gives the best performance due to its higher lubricant properties with respect to other cutting fluids with constant cutting conditions

1.2 Edible & Non Edible oils as Cutting Fluids

The performances of palm oil and groundnut oil as cutting fluid were studied by Odusote **[5],** where the obtained results were compared with that of mineral oil-based cutting fluid during drilling operation of mild steel. The temperature of the work piece when groundnut oil was used as the cutting fluid was very close to that of the conventional oil, which was the lowest. The Palm oil gave the overall highest chip thickness of 0.27 mm probably due to its better lubricating property. This was followed by that of the groundnut oil and the conventional oil as compared with dry machining of 0.17 mm thickness. Anil Raj **[6]** explored the various effects of vegetable oil such as soya bean oil, Sun Flower, Rapeseed, Coconut oils with minimal application of cutting fluid on hard turning of AISI4340 steel. The results obtained from the experiments clearly indicated that the soya bean oil used as cutting fluid has highest cutting force and contributes assured outcomes on comparing with wet and dry turning and reduced the cutting fluid quantity to a greater extent. Swarup Paul **[7]** investigated the performance of different types of cutting fluids (Karanja oil, Neem oil, conventional fluid) as compared to dry cutting condition during turning of mild steel. The use of vegetable based cutting fluid improved the surface quality as compared to the dry turning and conventional cutting fluids. They explained that the lower temperature of Neem vegetable oil than that of Karanja vegetable oil with the lower viscosity of Neem oil with respect to Karanja oil.

1.3 Machining in Non-ferrous Metals

An investigation has been carried out on 6061 aluminium alloy **[8]** which was subjected to the various cutting condition using uncoated carbide as a cutting tool conducted under orthogonal cutting condition in order to study the effect of cutting speed to tool wear and surface roughness and find which condition contribute more tool wear and surface roughness. It was observed that aluminium had a tendency to melt during cutting process and work material adhere on tool rake face especially at low speed. A review on Application of vegetable oil-based metalworking fluids in machining ferrous metals was carried out by S.A. Lawal **[9].**The advantages of metal working fluids and its performances with respect to cutting force, surface finish of the work piece, tool wear, and temperature at the cutting zone have been reviewed. The review focuses on the performance and environmental impact of this vegetable oil as emulsion and straight oils for various materials and machining conditions. Ojolo **[10],** investigated the effect of cutting speed, feed rate, depth of cut and rake angle on cutting force when cylindrical turning mild steel, brass, and aluminium rods with high speed steel tool using palm-kernel oil as cutting fluid. The impact of lubrication on the coefficient of friction between the chip and rake face during turning operation, assuming a negligible friction between the flank and cut surface was measured. The reduction in coefficient of friction at cutting speed of 4.15 m/s and rake angle 9^o for aluminium was 33.3 % and an increase of 13.8 % was recorded for brass. At a cutting speed of 4.15 m/s and depth of cut of 1.5 mm, there were 9.79 % reduction in coefficient of friction for brass and increment of 46.7 % for aluminium. While a reduction of 9.2% coefficient of friction was recorded for brass and an increase of 30.4 % coefficient of friction was recorded for aluminium at cutting speed of 4.15 m/s and feed 1.8 mm/rev. similar trends were observed by varying the cutting conditions on the work parts through different selected values. The effect of palm-kernel oil as a metal cutting lubricant was more pronounced on aluminium than brass. The study established palm-kernel oil as a good metal cutting lubricant.

In the view of the above, it is observed that less work has been carried out on influence of non-edible oils on machining non-ferrous materials like Aluminium and copper and its effect on machining parameters. To bridge this gap the present work focused on studying the machining parameters by turning of Aluminium 6082-T6 alloy using Non-edible Oils as Cutting Fluids.

2. Materials and Methods

The materials used in this research work were: Aluminium 6082-T6 alloy used as the work piece. Karanja and Neem oils are non-edible oils used as the cutting fluids for the study.

Aluminium 6082-T6 alloy

The Non-ferrous material used in this research work was Aluminium 6082-T6 alloy used as the work piece. Aluminium 6082-T6 alloy having diameter of 25mm with 120mm length was taken for our experiment which is shown in Figure 1. Aluminium is one the most common metals in Earth's crust, and the second in manufacturer industry. Aluminium alloy 6082 T6 is a medium strength alloy with excellent corrosion resistance. It has the highest strength of the 6000 series alloys. Aluminium alloy 6082-T6 is widely used in the industry such as transportation components, Aircraft Spare Parts, machinery equipment, bicycle frames, and fly fishing reels. As a relatively new alloy, the higher strength of 6082 has seen it replace 6061 in many applications. The addition of a large amount of manganese controls the grain structure which in turn results in a stronger alloy The mechanical properties of 6082-T6 depend greatly on the temperature or heat treatment of the material. The Young's Modulus, Ultimate tensile strength and Yield strength are 69 GPa, 300 MPa and 241 MPa respectively. T651 temper has similar mechanical properties. The typical value for thermal conductivity for 6082-T6 at 77°F is around 152 W/m^{0}K. A material data sheet defines the fatigue limit under cyclic load as 100 MPa for 500,000,000 completely reversed cycles using a standard RR Moore test machine and specimen. The chemical composition of aluminium alloy is shown in Table 1

Fig. 1 Turned Aluminium 6082-T6 Alloy Work pieces

Table 1: Chemical Composition of Aluminium 6082-T6 Alloy

Constituents	**Min (in %)**	**Max (in %)**
Silicon	**0.4**	**0.8**
Iron	**0.5**	**0.7**
Copper	**0.15**	**0.4**
Manganese	**0.4**	**0.15**

Magnesium	**0.6**	**1.2**
Chromium	**0.04**	**0.35**
Zinc	**0.2**	**0.25**
Titanium	**0.1**	**0.15**
Other Elements	**No more than 0.05% each, 0.15% total**	
Remaining Aluminium	**95.85**	**98.56**

3. Experimental set up and procedure

The experimental study is carried out on a BALAJI medium lathe machine and the work piece work is firmly held in a 3-jaw chuck at 2 cutting speeds i.e. 500 and 1200 rpm respectively carried for all the experiments are shown in table 2. The depth of cut is taken as 1mm for 25mm diameter with constant feed rate of 0.6mm/rev. HSS INDIAN TOOL having 12.3mm square section 50mm length was used with 10^0 back rake angle and 1.5mm nose radius cutting tool for the entire operation. The cutting tool was mounted on the tool holder on the Lathe tool dynamometer of Contech make and fixed to the cross slide of the lathe. The lathe tool dynamometer was calibrated precisely as per standard before checking cutting force during the operation. The forces in X, Y and Z directions are recorded in the dynamometer and the Cutting forces (value recorded in Z direction) are taken as values for our experiments. The experimental setup is shown in Figure 2.

Table 2: Experimental Conditions

Machine tool: BALAJI lathe machine (Model 215 Super Series)
Work material: Aluminium alloy 6082-T6
Tool material: HSS INDIAN TOOL
Tool geometry: 5-10-5-6-9-4-1.5
Method of Applied Coolant: Flood Method
Process parameters:
1. Cutting speed (v) = 500 and 1200 rpm
2. Feed rate (f) = 0.6mm/rev
3. Depth of cut (d) = 1mm

Environment:
1. Dry Condition
2. Petroleum based product (SAE20W40 Lubricant).
3. Non-Edible oils as Karanja and Neem oil

Fig. 2 Machining Setup in Lathe

To measure the surface roughness (R_a) of the work material a portable surface roughness tester was used. The probe is moved over the surface and according to the surface profile the values are displayed directly in terms µm as shown in Figure 3. The five values are taken at different locations and its average value is taken as R_a for our study.

Fig. 3 Surface Roughness Tester

The temperature developed is an important factor which has a dominant influence to the mechanism of transformation of the work piece machined layer into chip. Also it has effect on the phenomenon that occurs in the process of cutting tool wear. Pyrometer as shown in Figure 4 is used to measure the temperature because it is simple and reliable to use. A pyrometer is a device that is used for the temperature measurement of an object. The device actually tracks and measures the amount of heat that is radiated from an object. The thermal heat radiates from the object to the optical system present inside the pyrometer.

Fig. 4 Infra-Red Pyrometer

4. Results and Discussion:

4.1 Physical Properties of Cutting fluids

Flash and Fire Points

Flash point is used to characterize the fire hazards of liquids. Every liquid has a vapour pressure, which is a function of that liquid's temperature. As the temperature increases, the vapour pressure increases. At flash point, a substance will ignite briefly vapour might not be produced at a rate to sustain the fire. The fire point is the lowest temperature at which the vapours of the lubricant oil burn continuously for at least five seconds, when a tiny flame is brought near it. Higher the fire point greater will be the resistance to ignite. The Neem has highest flash and fire point of 250^{0}C and 260°C which is very high compared to other cutting fluids i.e. Karanja and petroleum based oil as shown in Table 3.The flash and fire points are calculated by using Cleave land's Apparatus as shown in Figure 5.

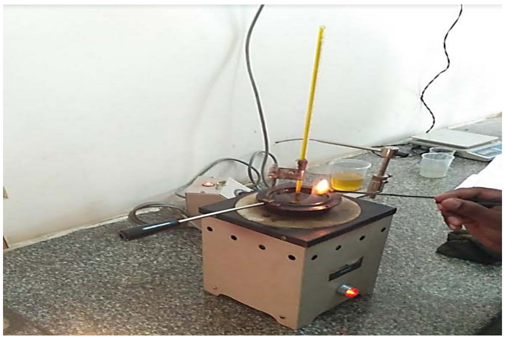

Fig. 5 Cleveland's Apparatus

Table 3: Flash and Fire Points for Different Cutting Fluids

Sl. No.	Type of cutting fluid	Flash point (°C)	Fire point (°C)
1	Neem	**250**	**260**
2	Karanja	**220**	**230**
3	Petroleum based Oil (SAE 20W40)	**210**	**215**

Viscosity

A good cutting fluid should have optimum viscosity i.e. if it is high then oils does not carry away heat and chip from machining zone and it will stick the chip in the machining area effecting machining efficiency. If it is low then it will just pass away from machining zone without lubricating the tool and work piece. Viscosity of selected oils is measured by using say bolt viscometer and values obtained are tabulated in Table 4.Since viscosity related to motion of oils is important, dynamic viscosity plays an important role, from the table below is it seen that Neem oil has highest value of 0.0491 N-s/m² compares to other oils. The viscosity of the cutting fluids are calculated by using Say bolt viscometer as shown in figure as shown in Figure 6.

Fig. 6 Say bolt Viscometer

Table 4: Viscosity for Different Cutting Fluids

Sl. No	Type of cutting fluid	Kinematic viscosity in (m²/s)	Dynamic Viscosity in (N-s/m²)
1	Neem	**5.896×** $\mathbf{10^{-5}\frac{m^2}{sec}}$	**4.91×** $\mathbf{10^{-3}}$**N-sec/**$\mathbf{m^2}$
2	Karanja	**4.354×** $\mathbf{10^{-5}\frac{m^2}{sec}}$	**3.40×** $\mathbf{10^{-3}}$**N-sec/**$\mathbf{m^2}$
3	Petroleum based Oil (SAE 20W40)	**3.721×** $\mathbf{10^{-5}\frac{m^2}{sec}}$	**2.67×** $\mathbf{10^{-3}}$**N-sec/**$\mathbf{m^2}$

Effect of Cutting Force

During the machining process, there was some changes in the cutting force due to the friction between the tool and work piece. If more cutting forces are there it affects the surface finish and dimensional accuracy of the work piece. From Table 5 & 6 shows the variation in cutting force, for varying dry and lubricating conditions. During dry machining, the cutting force was increased due to more friction between tool and work piece. During petroleum based (SAE20W40) machining, the cutting forces are gradually decrees because of it act as a coolant. There was more decrease in cutting force with the use of non-edible oils. For Neem oil the cutting force was less compared with petroleum and dry cutting. The cutting force was decreased at higher rate with the use of Karanja oil, because of its high viscosity and oil contact time is more between work piece and tool. Due to this there is less cutting force by using non edible oils as cutting fluids

a) Speed 500rpm

Table 5: Table Showing Cutting Force with different Lubricating Conditions for 500rpm Speed

Sl. No.	Lubrication Condition	Cutting Force (in N)
1	Dry	410
2	Petroleum based Oil (SAE20W40)	409
3	Neem	407
4	Karanja	406

Cutting force graphs have been plotted as shown in Figure 7 and Figure 8 for lower and higher cutting speed. The depth of cut and feed rate were constant at 1mm & 0.16mm/rev respectively. As seen from Figure 7, the lower cutting speed at 500 rpm the rake angle was determined based on uniform cutting zone.

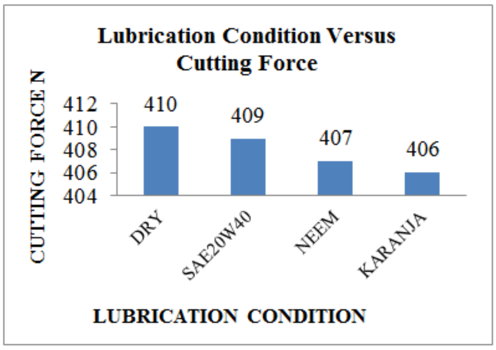

Fig. 7 Graph Showing Cutting Force with Different Lubricating Conditions for 500rpm Speed

b) Speed 1200rpm

Table 6: Table Showing Cutting Force with different Lubricating Conditions for 1200rpm Speed

Sl. No.	Lubrication Condition	Cutting Force (in N)
1	Dry	410
2	Petroleum based Oil (SAE20W40)	409
3	Neem	408
4	Karanja	407

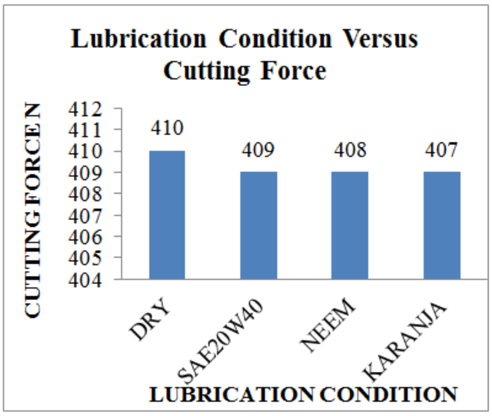

Fig. 8 Graph Showing Cutting Force with Different Lubricating Conditions for 1200rpm Speed

It was observed that from Figure7 for lower cutting speed at 500 rpm, there was a gradual decrease of cutting force compare to larger cutting speed of 1200rpm by using Karanja and Neem as cutting fluids compare to dry cutting machining. The largest decrease was observed in lower speed of 500 rpm by using Karanja as cutting fluid compare to others. The cutting force decreases for lower speed at constant feed rate higher speed.

Effect of Surface Roughness

Surface roughness was observed for the entire range of work piece during machining process. From Table 7 & table 6 displays that surface finish is the maximum in case of dry machining process.

a) Speed 500 rpm

Table 7 Table Showing Surface Roughness of Specimen with Different Lubricating Conditions for 500rpm Speed

Sl. No.	Lubrication Condition	Surface Roughness (in µm)
1	Dry	3.05
2	Petroleum based Oil (SAE20W40)	1.71
3	Neem	1.10
4	Karanja	1.06

During dry machining process, the surface roughness is high due to more friction between tool and work piece. By using petroleum based lubricant, there is a gradually decrease in surface finish. Further, it was observed that the non-edible oils such as Neem and Karanja oil as cutting fluids have good surface finish compared with the other two cutting conditions.

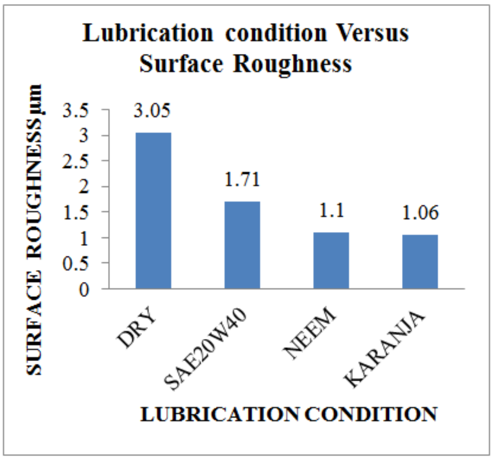

Fig. 9 Graph Showing Surface Roughness of Specimen with Different Lubricating Conditions for 500 rpm Speed

The above results from Figure 9 display that surface finish for low speed 500 rpm and 1200rpm. The surface finish is maximum in case of dry machining process. With petroleum based lubricant, there is a gradually decrease in surface finish. By using Neem as cutting fluid ,there is a gradual decrease in surface finish Further, it was observed that the Karanja oil have superior surface finish for low speed at 500 rpm. It was observed that the average surface roughness decreases with the increase in spindle speed from 500 to 1200 rpm as shown in Figure 9 and Figure 10.

b) Speed 1200 rpm

Table 8: Table showing Surface Roughness of Specimen with Different Lubricating Conditions for 1200rpm Speed

Sl. No.	Lubrication Condition	Surface Roughness (in µm)
1	Dry	3.44
2	Petroleum based Oil (SAE20W40)	3.11
3	Neem	2.64
4	Karanja	2.24

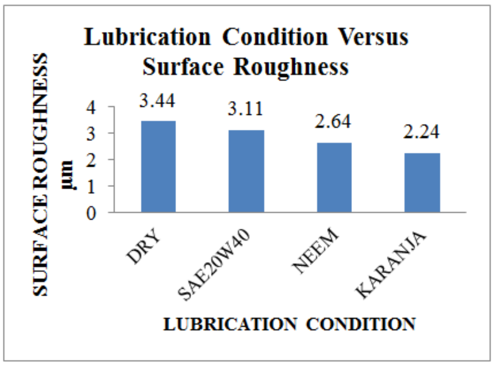

Fig. 10 Graph Showing Surface Roughness of Specimen with Different Lubricating Conditions for 1200rpm Speed

However, the highest surface quality was obtained using Karanja oil as cutting fluid and the lowest surface quality occurred in dry condition. This is due to more viscosity in non-edible oils. The Neem oil used as cutting fluid reduced the surface roughness compared to dry turning and petroleum based oil cutting fluid respectively. With the use of petroleum based cutting fluids, there was decrease in the value of surface finish compared to dry machining process This is due to less contact time between tool and work piece and also petroleum based products act as a lubricant, but not as coolant. For high speed 1200rpm, the Neem oil used as cutting fluid reduced the surface roughness by 76% and for low speed of 500 rpm reduced 36% compared to petroleum based oil and dry machining process. For high speed 1200rpm, the Karanja oil used as cutting fluid reduced the surface roughness by 65% and 35% for low speed of 500 rpm as compared to petroleum based oil and dry machining process.

Effect of Cutting Temperature

Chip-tool interface temperature is closely connected to cutting speed. With increase of cutting speed, friction increases, this induces an increase in temperature in the cutting zone. The cutting speed was found to be the most effective parameter in assessing the temperature rise. A pyrometer is a device that is used for the temperature measurement of an object. The device actually tracks and measures the amount of heat that is radiated from an object. The thermal heat radiates from the object to the optical system present inside the pyrometer. The optical system makes the thermal radiation into a better focus and passes it to the detector.

a) Speed 500 rpm

Table 9: Table Showing Tool and Specimen Temperature with Different Lubricating Conditions for 500rpm Speed

Sl.No.	Type of cutting Lubrication condition	Tool Temperature (in ^{0}C)	Specimen Temperature (in ^{0}C)
1	Dry	38.6	36.2
2	Petroleum based Oil (SAE20W40)	33.2	35.6
3	Neem	23	24.5
4	Karanja	22	23

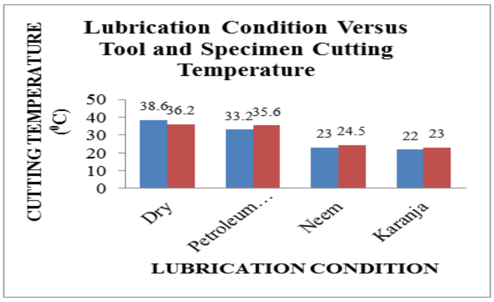

Fig. 11 Graph Showing Tool and Specimen Temperature with Different Lubricating Conditions for 500rpm Speed

Table 9 and Table 10 shows, Temperature measured for tool and work piece with cutting fluid and at dry cutting condition for lower speed at 500rpm and high speed 1200rpm.For dry condition temperature of tool and work piece is 38.6 °C and 36.2 °C which is very high in low speed rpm. This is due to transfer of whatever heat generated to tool and work piece as no coolant is used and also due to high friction between tool and work piece as no lubricant is used. For petroleum based oil the temperature between the both tool and the work piece is 35.4 °C and 40.2°C, which is less compared dry cutting but higher than non-edible oils used, this due to its lower adhesiveness and lower dynamic viscosity. For Neem and Karanja the temperature of tool and work piece is 23°C and 22°C very less value compared to other conditions. This is due more viscosity as shown in figure 11 & Figure 12.

b) Speed 1200rpm

Table 10: Table Showing Tool and Specimen Temperature with Different Lubricating Conditions for 1200rpm Speed

Sl. No.	Type of cutting Lubrication condition	Tool Temperature (in ^{0}C)	Specimen Temperature (in ^{0}C)
1	Dry	42.3	44.1
2	Petroleum based Oil (SAE20W40)	38.7	39.6
3	Neem	28.3	29.7
4	Karanja	26.8	27.9

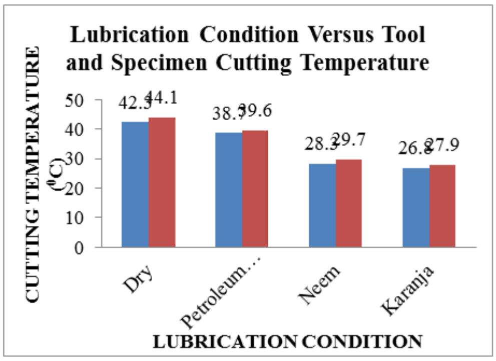

Fig. 12 Graph Showing Tool and Specimen Temperature with Different Lubricating Conditions for 1200rpm Speed

From Table 9, the temperature measured for tool and work piece with cutting fluid and at dry cutting conditions are high compare to low speed. This is due to high speed of rotation of spindle. In the Table 10, it is observed that for dry condition, the highest temperature of tool and work piece is 42.3 °C and 44.1 °C are recorded. This is due to more friction between the tool and work piece at high spindle rate. During petroleum based oil (SAE20W40) machining it is observed that the cutting temperature of tool and work piece is 38.7 °C and 39.6°C were gradually reduced due to the interface of petroleum based lubricant in between tool and work piece and in this process the petroleum based oil acts as coolant. There was further decrease in cutting tool and work piece temperature with the use of Neem and Karanja as a cutting fluid shown in Figure 12. This is because of its high viscosity nature of the oil helped in reducing the heat generated at the tool chip interface and also helped in reducing the cutting force.

It indicates that from Figure 11 & Figure 12 for lower cutting speed at 500rpm, there was a gradual decrease of cutting tool and work piece temperature, when non edible oils such as Neem and Karanja oil used as a cutting fluid compare to high spindle speed. Thus, non-edible oil has better cooling and good lubricating property for lower speed at constant feed rate and depth of cut.

5. Conclusion

The main objective of the present research was observed the experimental studies on cutting parameters during turning of Aluminium 6082-T6 alloy using non edible oils such as Neem and Karanja oil as cutting fluid by selected parameters such as feed rates, and depths of cut for different Spindle speeds. The non-edible oils as cutting fluid in turning operation of Aluminium 6082-T6 alloy by HSS tool with 1.5mm tool nose radius for 500rpm and 1200rpm and also compared the performance of non-edible oils with dry and petroleum based oil machining process in terms of Cutting force, Surface roughness, Cutting temperature analysis experimentally summarized as follows

1. The performance of cutting fluid depends on the physical properties. The cutting fluids used in the present work are Neem, Karanja and Petroleum based oil. The physical properties are been determined for these oils and are given below.

- **Flash point:** The highest flash point of 250^0C was recorded for the Neem.
- **Fire point:** The Neem used as cutting fluid has got highest fire point of 260^0C.
- **Viscosity:** The Optimum Kinematic and Dynamic viscosities are $5.896X10^{-5}$ N-s/m² and $4.91X10^{-3}$ N-s/m² was obtained for Neem used as cutting fluid.

2. The Surface roughness results obtained much better using non edible oil as cutting fluid compared with other two machining process. It was observed that the Karanja oil have superior surface finish at lower speed of 500rpm compare to high speed of 1200rpm.This indicates that there is a lesser friction between tool and work piece using Karanja oil as cutting fluid.

3. Karanja and Neem oil as cutting fluid exhibited that there was a gradual decrease in cutting force, with smoother surface finish compared with other two machining process. It was observed that there was less reduction in cutting force at lower speed of 500 rpm and more reduction at higher speed of 1200 rpm

4. The temperature of cutting tool and work piece was very less by using non edible oils as cutting fluids i.e when Karanja was used compared to petroleum based oil and dry cutting process. The temperature of tool was 22^0C and the temperature of work piece was 23^0C for lower speed and 26.8^0C for tool and 27.9^0C in work piece for higher speeds which is less heat dissipated between tool and work piece.

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