

Influence of non-edible vegetable based oil as cutting fluid on chip, surface roughness and cutting force during drilling operation of Mild Steel

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Abstract

Friction between work piece-cutting tool-chip generates heat in the machining zone. The heat generated reduces the tool life, increases surface roughness and decreases the dimensional sensitiveness of work material. This can be overcome by using cutting fluids during machining. They are used to provide lubrication and cooling effects between cutting tool and work piece and cutting tool and chip during machining operation. As a result, important benefits would be achieved such longer tool life, easy chip flow and higher machining quality in the machining processes. Non-edible vegetable oils have received considerable research attention in the last decades owing to their remarkable improved tribological characteristics and due to increasing attention to environmental issues, have driven the lubricant industry toward eco friendly products from renewable sources. In the present work, different non-edible vegetable oils are used as cutting fluid during drilling of Mild steel work piece. Non-edible vegetable oils, used are Karanja oil (Honge), Neem oil and blend of these two oils. The effect of these cutting fluids on chip formation, surface roughness and cutting force are investigated and the results obtained are compared with results obtained with petroleum based cutting fluids and dry conditions.

Key words: Drilling operation, cutting fluid, Neem oil, Honge oil, Mild steel.

1. Introduction

Machining is a process designed to change the size, shape, and surface of a material through removal of materials that could be achieved by straining the material to fracture or by thermal evaporation. Machining offers important benefits such as excellent dimensional tolerances, sharp corners, grooves, fillets, various geometry, and good surface finish. The three principle machining processes are turning, drilling and milling. Other operations falling into miscellaneous categories include shaping, planing, boring, broaching and sawing.

Cutting fluid, as a component of machining industry, has been introduced and applied over 100 years. Cutting fluids are used in metal machining for a variety of reasons such as improving tool life, reducing work piece and thermal deformation, improving surface finish and flushing away chips from the cutting zone. Practically cutting fluids are classified into four categories such as Straight oils, Soluble oils, Semi synthetic fluids, Synthetic fluids.

Due to the importance of cutting fluids, significant issues have been raised in their application, recycling and disposal. Proper selection and application can reduce manufacturing cost and improve productivity on the other hand, manufacturing failure and wastes can be experienced by misuse of cutting fluids. And regarding to the environmental impacts and health hazards by



cutting fluids, recycling and disposal of cutting fluid are also of great importance. Improper disposal actions can cause severe health and environmental problems. These problems gave provision for the introduction of mineral, vegetable and animal oils. These oils play an important role in enhancing various aspects of machining properties, including corrosion protection, anti-bacterial protection, lubricity, chemical stability and even emulsibility. Vegetable oils can be classified in to various ways depending upon the source, application etc., oils can be edible or non-edible in nature. Compared to mineral oils vegetable oils in general possess high flash point, high viscosity index, high lubricity and low evaporative losses. Various researchers have proved the worth of edible vegetable oils viz., coconut oil, palm oil, soya bean oil, canola oil to be used as eco-friendly fluid in recent past. But in present situations harnessing edible oils for lubricants formation restricts the use due to increased demands catering the growing population worldwide and local availability. Non-edible vegetable oils and other tree borne seeds can prove to be an effective alternative, although limited research has been done on varieties like PongamiaPinnata (karanja), Jatrophacurcas (Ratanjyot) etc., prominently for biofuel applications and needs focused attention for fulfilling the environmental friendly lubricant need their full potential. Castor, Mahua and Neem also process certain properties which makes them a promising candidate for such formulations. Non-edible vegetable oils are renewable and biodegradable in nature.

1.1 Current Status — Non Edible Vegetable Oils

Being a tropical country, India is rich in forest resources having a wide range of trees, which yield a significant quantity of oilseeds. India is importing crude petroleum & petroleum products from Gulf countries. Indian scientists searched for an alternate to petroleum based lubricant to preserve global environment and to withstand economic crisis. Some Non-Edible Vegetable Oils Available in India.

1.2. Application of vegetable oil-based cutting fluids in various Machining operations

Many researchers have worked on various vegetable oils as cutting fluid on different work material. S.A.Lawal et.al [1] carried out a review on the applicability of vegetable oil based metal working fluids in machining of ferrous metal. The author focused on the performance and environmental impact of these vegetable oils as emulsion and straight oils for various materials and machining conditions. Finally concluded that Coconut oil showed the best performance when compared to mineral oil on turning of AISI 304 austenitic stainless steel. When vegetable oil was applied to turning of AISI 9310 alloy steel using MQL mode of application, there was remarkable improvement of metal removal rate (MRR). High productivity means that higher feed rate was achieved when vegetable-oil-based metalworking fluid was used.

SharafadeenKunleKolawale et.al [2] Evaluated performances of palm oil and ground nut oil when compared with that of mineral oil based cutting fluid during machining operation of mild steel. Palm oil gave the overall highest thickness of 0.27mm probably due to its better lubricating property. Based on these results, ground nut oil and palm oil are being recommended as variable alternative lubricants to the mineral oil during machining of mild steel. It was found that Viscosity of groundnut oil-based sample was lowest and the range was closest even at very high temperature. Low viscosity means high viscosity index and the tendency to be fluidic at high value of working temperature.

Jitendra Kumar Chandrakar et.al [3] showed that lubricants provide smooth operation between movable parts of all machines. It maintains the reliability of machine functions and reduces the risk of failures. Vegetable bio lubricants are non-toxic, degradable, and renewable also possess good lubricating properties. The author reviewed papers on edible oils as cutting fluids. While in few papers non-edible oils

such as castor, Karanja, Mahua were used and proved to have a great potential as lubricant for some of the machining operations.

Ahmad Fairuz Mansor et.al [4] Investigated Chip Formation and tool wear in drilling Process using various types of vegetable-Oil based Lubricants. This research paper represents the machinability of using several possible vegetable oils as cutting fluid in term of chip formation and tool wear during drilling operation on stainless steel, AISI 316. The performance of the vegetable oils; palm, sesame, olive and coconut oils were compared under minimum quantity lubrication (MQL) technique. The result reported that the coconut oil indicates the best machinability in term of highest and uniform chip thickness and least wear on the drill bit under same condition with others. These performances are followed by palm, olive and sesame oil. In additional, the viscosity measurement indicates that coconut oil has the lowest value which can possesses better fluidity and faster cooling capacity than other oils. Overall, coconut oil is recommended as viable alternative lubricants during drilling of stainless steel.

EmelKuram,et.al [5] studied the Effects of vegetable-based cutting fluids on the wear in drilling. This work focused on both formulation of vegetable-based cutting fluids (VBCFs) and machining with vegetable-based cutting fluids. Performances of three VBCFs developed from crude sunflower oil, refined sunflower oil, refined canola oil and commercial semi-synthetic cutting fluid are compared in terms of tool wear, thrust force and surface roughness during drilling of AISI 304 austenitic stainless steel with HSSE tool. Experimental results show that canola based cutting fluid gives the best performance due to its higher lubricant properties with respect to other cutting fluids at the constant cutting conditions. M.M.A. Khan et.al[6] investigated the effects of minimum quality lubrication (MQL) by vegetable oil based cutting fluid under turning operation of low alloy steel AISI 9310. The results were compared with completely dry and wet machine in terms of tool- chip interface temperature, chip formation mode, tool wear and surface roughness. Results show that MQL provides environmental friendliness and improves the machinability characteristics.

2. Experimental setup

2.1. Cutting fluids used

In the present work drilling of mild steel is carried out using the Vegetable based non-edible oils as cutting fluids and the results obtained are compared with SAE 20W40(Petroleum based cutting fluid) and dry cutting results. The Vegetable based non-edible oils used are Neem, Karanja, Blend of Neem and Karanja i.e. (50% neem-50% Karanja), (33.3%Neem- 66.6% Karanja), (66.65 Neem- 33.3% Karanja)

Table 1: Physical properties of cutting fluids used

Sl. No	Type of cutting fluid	Specific Heat (KJ/Kg. K)	Flash point (°C)	Fire point (°C)	Dynamic Viscosity (N-s/m ²)	Adhesiveness (g/m ²)
1)	Neem	1.6817	248	285	0.0345	687
2)	Karanja	1.6761	220	245	0.0266	412
3)	50%Neem 50%Karanja	1.6991	256	290	0.01648	359
4)	33.3%Neem 66.6%Karanja	1.6703	228	256	0.0135	257

5)	66.6%Neem 33.3%Karanja	1.6789	228	264	0.011271	367
6)	SAE 20W40	1.97	210	215	0.02172	319

Selection of good cutting fluid depends on its Viscosity, Flash and Fire Points and Adhesiveness. The cutting fluid should possess high flash and fire points, as it should not catch fire at high temperatures. From the above table, the blend of 50% Neem and 50% Karanja has got high flash and fire points of 256 °C and 290 °C respectively, but viscosity also matters. The viscosity of a lubricant is closely related to its ability to reduce friction. Generally, the least viscous lubricant which still forces the two moving surfaces apart is desired. If it is too viscous, it will require a large amount of energy to move. From the values obtained 50% Neem and 50% Karanja has got optimum Dynamic viscosity of 0.01648 N-s/m² which suits the best for machining. Adhesiveness is a property of cutting fluid to stick to the surface of work and tool during machining and maintain a later separating both the elements, so that friction is less. Adhesiveness also should be optimum. From the table 1 the blend of 50% Neem and 50% Karanja has got an optimum value of 359 g/m². So 50% Neem and 50% Karanja is considered as best cutting fluid.

2.2. Drilling conditions and experimental designs:

In this work constant speed of 800 rpm, constant feed rate of 10 mm/rev were taken. Drilling experiments were carried out for different cutting fluids and the results were investigated. CNC machine is used for drilling the holes of diameter 13mm to a drilling depth of 30mm.

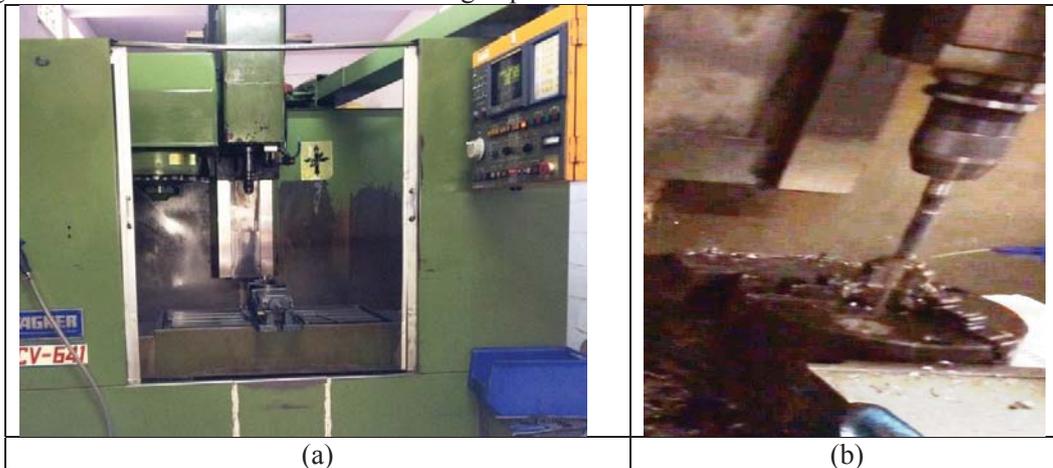


Figure 1: (a) CNC machine is used for drilling (b) continuous supply of cutting fluid during drilling

2.3. Work piece materials and cutting tools

AISI 1014 mild steel bar having diameter of Ø25mm with 75mm length was taken as work piece and drill bit of HSS with 10% cobalt with diameter of 13mm is used for drilling.

2.4. Chip and work surface Investigation

The chips were collected after machining for Neem, Karanja, blend of Neem and Karanja,SAE 20W40 and dry condition is as shown in figure 3 and the pitch, pitch height and chip length has been measured using profile projector. The machined surface roughness is measured using surface finish tester.

3. Results and Discussion

3.1. Study of chips

During Machining, chip formation usually depends on type of metal being machined i.e. weather ductile or brittle and temperature at the machining zone. This temperature is due to friction that exists between drill bit and the work piece. Chip may break due to chattering of work piece and due to overheating of work surface during the cutting process. The chatter in the material is avoided by strong work holding work element. Due to excessive heat produced during the machining, surface of work piece material gets converted from ductile to brittle and the chip becomes discontinuous [7]. This discontinues chips were observed for dry condition and when Karanja is used as cutting fluid. With petroleum based oil helped in reducing the heat but to a smaller extent. SAE 20W40 has better specific heat compared to other oils used hence acts as good coolant by absorbing heat ,but due less dynamic viscosity and adhesively, the petroleum based oil(SAE 20W40) does not lubricate hence friction is more as seen in work piece temperature. Compared to all the oils, it is observed that for blend of 50% Neem and 50%Karanja longer length continuous chips of 33mm are formed indicating that temperature at machining zone is less as shown in the figure 3. This can also be observed by the color of the chip, which is not dark like obtained for other cutting fluids. The results show that blends of 50% Neem and 50%Karanja has good lubricating and cooling property.

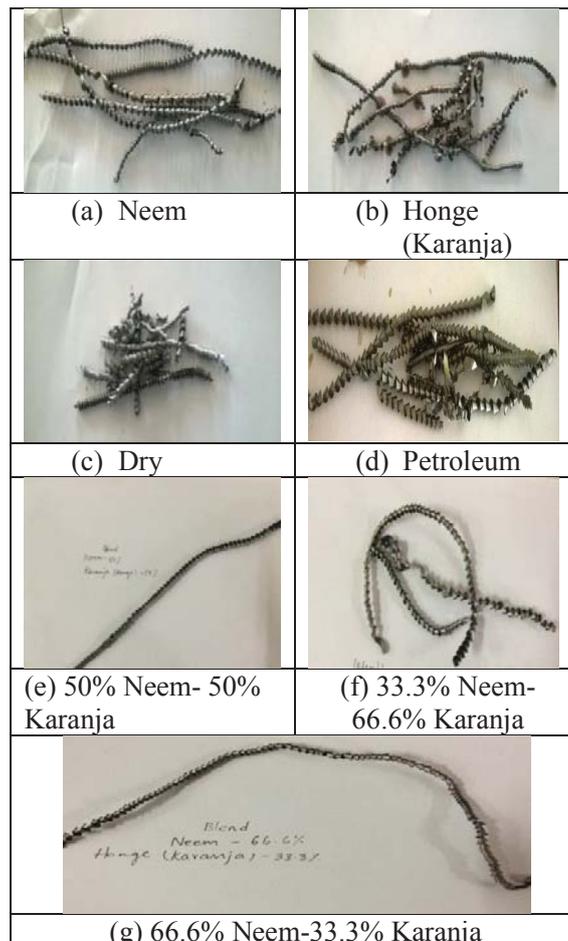


Figure 2: Chips formed during drilling operation on Mild steel with different cutting fluids
 Table 2: Chips length formed during drilling operation on Mild steel with different cutting fluids

Sl .No	Type of cutting fluid	Length (mm)
1)	Neem	24.5
2)	Karanja	25.7
3)	50%Neem 50%Karanja	33
4)	33.3%Neem 66.6%Karanja	20.5
5)	66.6%Neem 33.3%Karanja	30.7
6)	SAE 20W40	23.9
7)	Dry condition	9.1

From Figure 3 and Table 2 it is observed that continuous chips are produced from the lubrication of blend of 50% Neem& 50% Karanja. The chips from this blend are more uniform than others that indicate better cutting mechanisms. The greatest measurement of chip thickness is recorded when using Neem, blend of 50% Neem& 50% Karanja and blend of 66.6% Neem& 33.3% Karanja. These cutting fluids have higher oiliness that capable to reduce friction during drilling and it enables to achieve better condition of material removal.

3.2. Colour of the chips

The colour of the chip is taken as the measure of the temperature produced at the machining zone, due to friction between drill bit, work piece and the chip. Different coloured chips are obtained while machining with different cutting fluid and at dry condition as shown in figure 3. A blue temper colour on the surface of a chip formed in dry cutting is taken to mean that the tool point is hotter than when an uncoloured silvery chip is obtained when cutting with a fluid. The best uncoloured silvery chip is formed when Neem oil is used as cutting fluid. For dry condition the chips are completely burnt i.e. dark colour indicating that maximum heat is transferred to work piece during machining.

3.3. Surface roughness of machined surface

Surface profile measurement is made with a profile meter that will be in contact with the surface to be measured (typically a diamond stylus). When the diamond stylus comes in contact with the surface to be measured the surface roughness is measured in terms of μm .



Figure 3: Surface Roughness Tester.

Surface finish of machined part depends on temperature at machining zone, if the temperature is high the work surface will become brittle and the force required to cut the metal will be high leading very rough surface [8]. Figure 4 shows the surface obtained after drilling with different cutting fluids and at dry

cutting condition. Figure 5 shows Surface roughness measured with cutting fluid and at dry cutting condition. In dry cutting condition, the chips were discontinuous due to the friction in the tool and work interface. As the heat generated is high, the surface near the drill bit becomes brittle and due high cutting force, machined is very rough with highest value of 4.157 μm . During the use of non-edible oil we found that longer chips can be achieved due to the reduction. For Neem and blend of 50% Neem and 50% Karanja, the surface roughness measured 1.279 μm and 1.16 μm which is very less compared to other oils. This is due very low temperature at the machining zone and work surface will be ductile in nature leading to lesser cutting force and smooth removal of metal. In case of SAE 20W40 oil as cutting fluid the surface roughness measured is 3.5 μm , which is due to high friction between the drill bit and work piece.

	
(a) Neem	(b) Karanja/Honge
	
(c) Dry	(d) SAE 20W40
	
(e) 50%Neem 50%Karanja	(f) 33.3%Neem 66.6%Karanja
	
(g) 66.6%Neem ,33.3%Karanja	

Figure 4: Surface roughness of machined surface

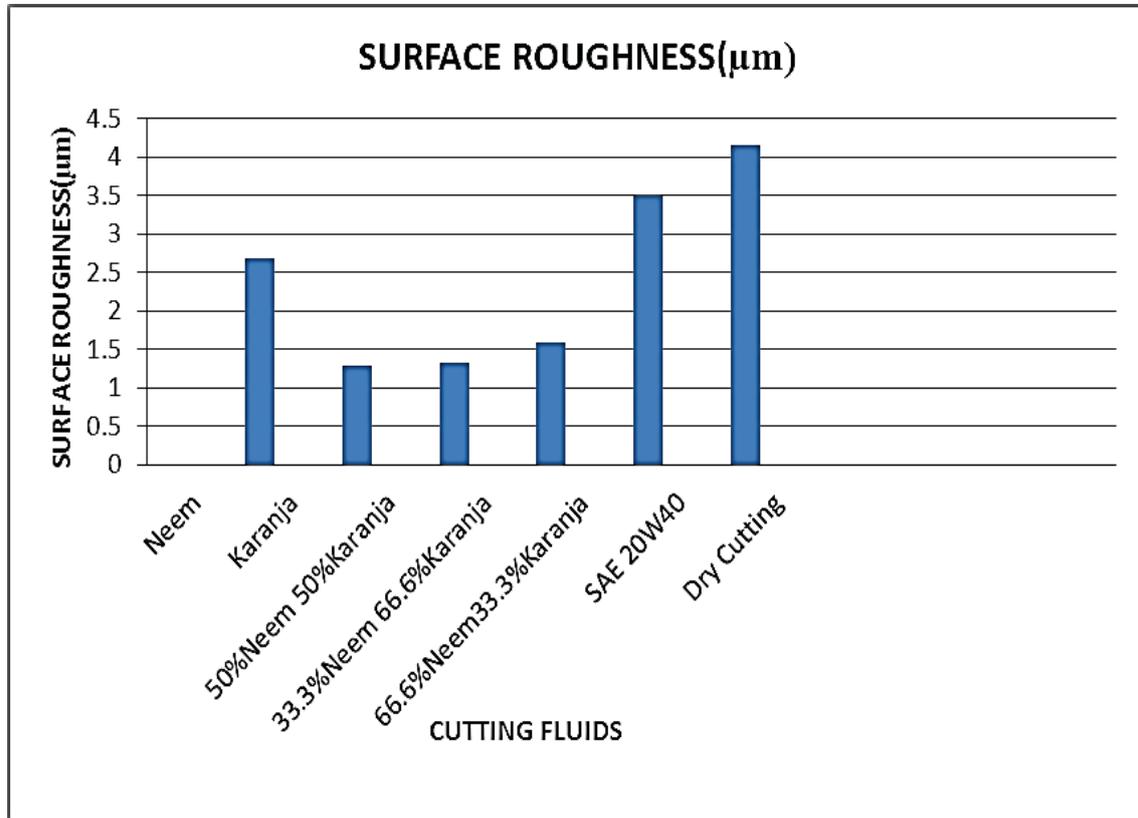


Figure 5: Surface roughness measured on work piece with different cutting fluids and at dry condition

3.4. Cutting Force

To know the performance of cutting fluid during drilling operation, it is essential to measure the cutting force. Cutting force helps in analysing [8]

- Effect of speed and feed during the cutting action,
- The effect of mechanical properties of work material
- Force exerted on the drilling machine parts

In the present work cutting speed, feed, and work piece are kept constant and different types / blends of cutting fluid are been used. So to know the efficiency of cutting fluid used Cutting force is considered as one of the measure. With respect to work piece, cutting force is the measure of resistance offered by the work piece during machining process. Smoother the drill bit enters the work piece, lesser will be the cutting force. Therefore a good cutting fluid should reduce the cutting force during the machining operation resulting in lesser mechanical stress in the work piece. Table 4.7 below shows the cutting force measured during drilling of mild steel at constant speed and feed using Drill tool dynamometer.

During machining process, cutting force depends on the friction between the tool and work piece. More cutting force accumulates more heat in the work material and makes it soft for further processing. This may adversely affect the quality of the material in terms of dimensional accuracy and surface finish.

A proper mechanism needs to be included in the process to control the heat generation in the heat zone during metal removal. Table 4 shows the cutting force for measured with different cutting fluid and at dry

cutting condition. It is being observed that during dry machining, the cutting force was increased due to excess heat generated by the friction. During petroleum based (SAE20W40) machining it is observed that the cutting forces 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 but not as lubricant. There was further decrease in cutting force with the use of non-edible oils. For 50% Neem & 50% Karanja as cutting fluid, the cutting force is 169.23 N, which is less compared to SAE 20W40 (petroleum based oil) and dry cutting condition. The cutting force is decreased at higher rate with the use of 50%Neem 50%Karanja, because of its high viscosity and Adhesiveness between work piece and tool and this nature of the oil helped in reducing the heat generated at the tool chip interface and also helped in reducing the cutting force.

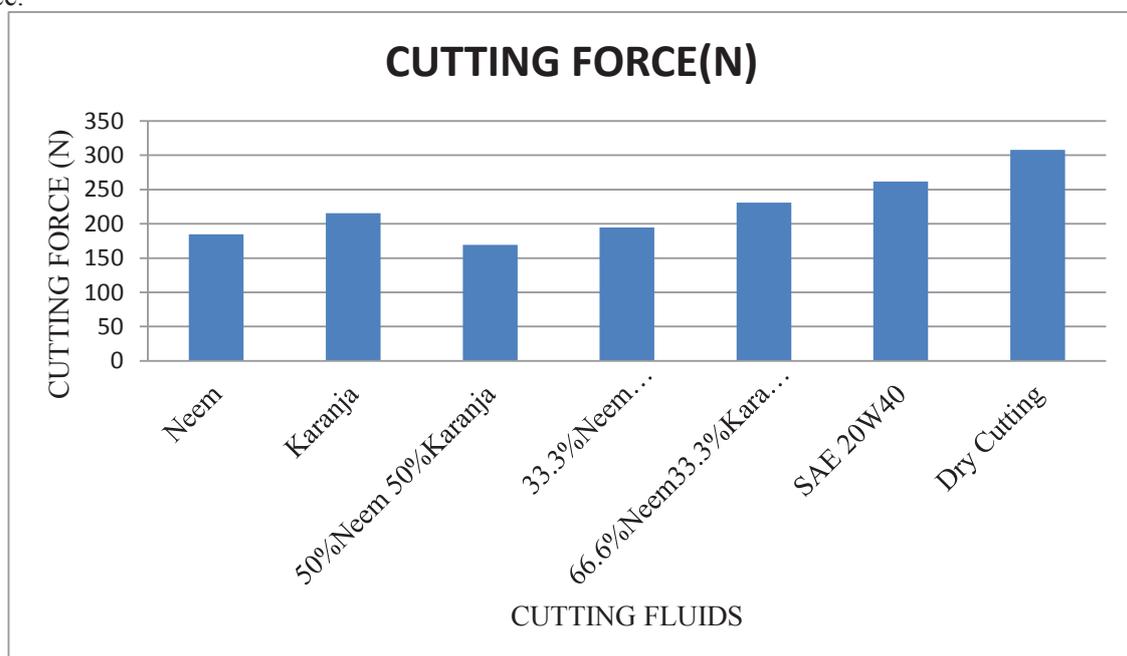


Figure 6: Cutting Force measured with different cutting fluid and at dry cutting condition

4. Conclusion

- A good cutting fluid should have high flash, fire point, specific heat, optimum dynamic viscosity and adhesiveness and all these physical properties were obtained for blend of 50% Neem- 50% Karanja.
- The surface of the work piece depends on the type of chip formed during machining; If the chips formed are uniform and continuous then the cutting fluid used is very good resulting in good surface finish. The continuous chips and uniform were formed for the blend of 50% Neem- 50% Karanja.
- The chips formed for the blend of 50% Neem- 50% Karanja were in uncoloured silver indicating that heat carried by the chip is less. This can also be observed by the length of the chip which is long and continuous. This type of chip is formed only when the cutting fluid used is very good.
- The cutting force should be less when a good cutting fluid is used. The cutting force of 169.23N was less for the blend of 50% Neem- 50% Karanja.

From the above results it was found that the blend of 50% Neem and 50% Karanja is the best cutting fluid compared to other cutting fluids used in this work. It is environmental friendly, bio-degradable, non-hazardous and economical.

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