

# ME352:- MANUFACTURING SCIENCE -2

## TERM PAPER PROJECT

### VEGETABLES OIL BASED CUTTING FLUID IN MACHINING - A CASE STUDY

By-RAHUL PAMMINA(11940960),VIPEEN KUMAR(11941360)

**Abstract:** *This research paper mainly deals with the cutting fluid, which are mostly used as a lubricant and coolant that increases machining productivity in most of the metal cutting industries. This also shows how the cutting fluid influences cutting tool, tool wear and cutting forces. Though these show innumerable number of advantages in the respect of machining they have an adverse effect on the environment, as mineral oil cutting fluids are non-biodegradable and have more amount of toxicity, even harmful to the operator. In order to sort this out we have to use some of the eco-friendly cutting fluids and here vegetable oil cutting fluid into the existence. The way it benefits the most of the metal cutting industries, the way sorting the cons of the mineral oil cutting fluids is one of the main objective of this research paper.*

#### ❖ Introduction:

Cutting fluids or Metal working fluids play a very crucial role in order to ensure the economy of metal cutting operations. Cutting fluid is typically a type of lubricant and also used as a coolant which are specifically used for metal working processes and optimises them. There are several kinds of cutting fluid which basically includes aerosols, oil water emulsion, oils, pastes, gel, air and other gases. Animal fat, plant oils, water and air, petroleum and raw ingredients are the main constituents of cutting fluid in machining. The conditions and environment of cutting tools play an important role for the machining process for getting desired quality and doing it in controlled manufacturing cost.

#### ❖ Objectives of cutting fluid:

- Lubricating the cutting environment
  - Once we lubricate the cutting surfaces there may be a chance to prevent the friction so that the chip will not get stuck and thereby we can even prevent the formation of built up edge formation.
- Cutting force can be reduced
  - As the friction is reduced thereby lubricating, cutting force will reduce and thereby we can even minimise the power consumption rate.
- Elimination of heat.
  - As cutting fluid acts as a coolant too it can cool the interface of the tool, chip and workpiece by conduction process.

- Prevents the rise in temperature
  - As we have earlier discussed that cutting fluid acts as a coolant this helps to decrease the temperature rise and it can even prevent the built up edge formation. As the temperature gets decreased, there won't be any material adhesion and even affinity between chip and rake surface
- Improve surface finish.
  - Since the cutting fluid flushes away the chip there wouldn't be any melt of the chip.
- To protect the finished surface from the corrosion
  - It prevents the corrosion between the workpiece and the atmosphere.
- Prevent the formation of BUE (chip welding).
  - By using cutting fluid we can reduce friction and thereby we cannot have any virtual negative rake angle and thereby we can reduce the cutting force and power which is utmost favourable and tool life can be improved.
- Reduce wear and tear and to aid smooth machining operation.
  - Cutting tool takes away the heat and reduces the pressure which in turn reduces wear and tear.
- Removal of chip to prevent adhesion on workpiece.
  - This takes away the chips from the work area else due to the heat the chips get melt and even may be a chance of increase in surface roughness.
- Improves the tool life
  - The cutting force and power decreases which helps to improve the tool life.

Till now we have gone through the advantages of cutting fluid, there are disadvantages even like wise when we use the synthetic and mineral cutting fluids they directly get involved with the damage of the ecosystem (river pollution, soil pollution) as these have high levels of toxicity. They have adverse effects not only on mankind but even on the environment. Typically water miscible metalworking fluids are used as a metal working solution or fluids by diluting with water in machining tools. Even this type of cutting fluid damages the environment when the pH is too high or low. We need to monitor the corrosion resistant test, viscosity periodically and even the toxicity levels. The main reasons for the disposal are basically contaminations with excess solids, oxidation, mixing of substances. There can be even biological and chemical degradations due to compositional difference between any two forms of the liquids. Even the disposal of these degraded cutting fluids is a troublesome task.

Now the other alternative we have is that we need to find some eco friendly/sustainable cutting fluids which should have the properties as follows:

- No harm to be done to the ecosystem
- Non corrosive to work.
- Ph neither too high nor too low
- Toxicity levels need to be as little as possible.
- No contamination of bacteria or fungus.

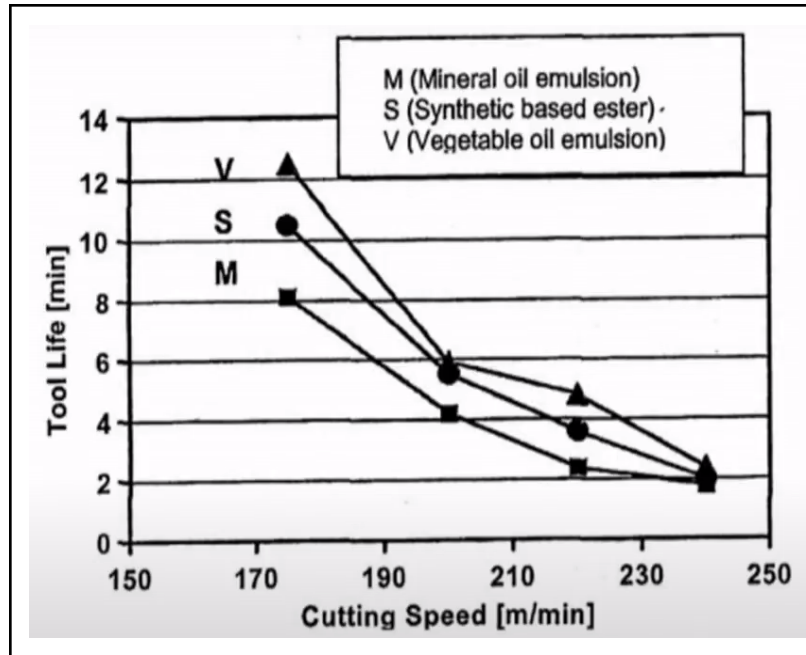
### ❖ **Eco friendly Metal working fluids:**

These are the cutting fluids which are essentially used by companies as they are satisfying the pros

of the synthetic,mineral,water miscible cutting fluids and replacing the cons with the satisfactory needs by not causing any harm to the environment.

Some of the examples of eco friendly cutting fluids are as follows:

- Vegetable Oil Cutting fluids
- Semi Synthetic Cutting fluids
- Dielectric Fluid
- Bio cutting fluids
- Liquid  $N_2, CO_2$
- Water vapour as a cutting fluids



**Fig1.0** The above plot shows a relation between cutting speed and tool life Of three different kinds of oils

- From the above graph it is very clear that the tool life can be increased by using vegetable oil as the cutting fluid rather than mineral oil or synthetic oils .

Now from here on we mainly focus on VBCF which serves as an alternate cutting fluid.

### ❖ Vegetable Oil Cutting fluids:

These fluids are those which are directly produced from the plants and other cash crops. As these are biodegradable and renewable we can use this preferably. These are also good substitutes for petroleum based oils. If we want to discard and dump these cutting fluids into the water bodies it can be taken care by the microorganisms. These mainly consist of Glycerol and triglycerides (which basically contains a long chain of carboxylic acids). Triglycerides have a good boundary of lubrication. Boundary here in the sense is that there will be a solid to solid contact and has a fine lubrication which works perfectly. It needs to be less volatile as whenever there is an exposure to low temperatures or atmospheric conditions there won't be any sort of catch of fire else they may catch fire. These triglycerides also have high structural stability over even with a high temperature. If we have a good structural stability even it falls in a machining region it is not

destroyed. Comparison of vegetable oil with mineral oil:- vegetables oil have high viscosity index, low evaporative loss, much lubrication and high flash points. Vegetables oil can be classified as edible and non edible depending upon their application, source, etc.

- **Edible vegetable oil:-** Naturally occurring oils from vegetables and animal fats. Examples are coconut oil, soya bean oil, palm oil, etc . Edible vegetable oil is Eco friendly in nature but restrictions on use now due to increased demand of a growing population.
- **Non- Edible vegetable oil:-** jatropha, karanja, neem, mahua, rubber, polanga are some examples of the non edible vegetable oils which are effective alternatives of Edible vegetable oil. They are biodegradable and renewable in nature. India is Rich in a variety of oilseed trees which can fulfill the need of non edible vegetable oil.

Some of the examples of vegetable oil cutting fluids:

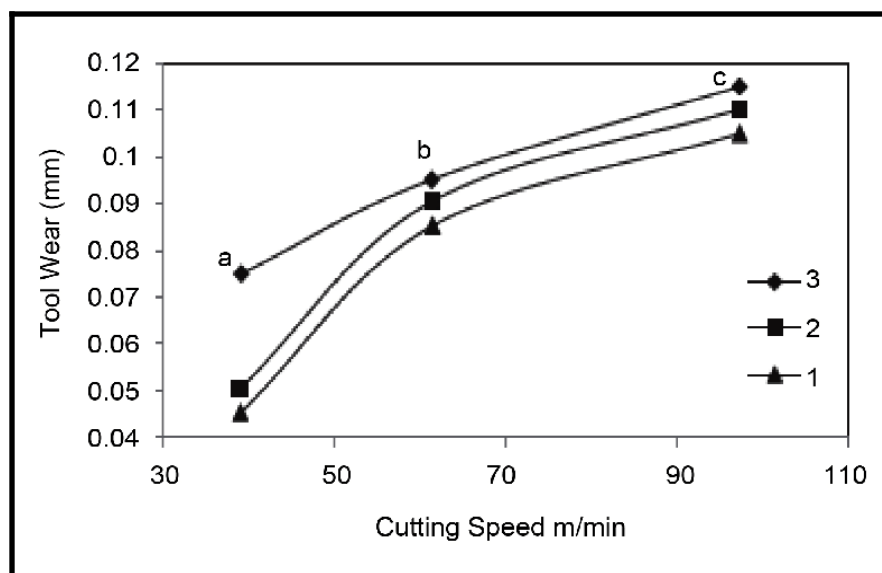
- Coconut Oil
- Karanja Seed oil
- Soybean Oil
- Castor Oil
- Sunflower Oil
- Jatropha Oil
- Rapeseed Oil



Here we will discuss some of these oils as cutting fluids. *Fig 1.1 shows some of the examples of VBCF*

#### ❖ **Coconut Oil as a Cutting fluid:**

- This consists of more saturated acids like lauric acids, caprylic acids and some amount of unsaturated acids.
- This shows an incredible performance of having a depth of cut of nearly 1mm and cutting speed of 90m/min. This is very good in ecological point of view
- Quality of product by using coconut oil as the cutting fluid is much better compared to the other mineral oils taken as the cutting fluids.



*Fig 1.2 The above graphs indicates a plot between cutting speed and tool of different kinds of vegetable oil cutting fluid*

- ❖ 1,2,3 represents coconut soluble and straight cutting oils as cutting fluids respectively.
- ❖ In general due to the increase in cutting speed there may be an increase in tool wear.
- ❖ The above fig 1 clearly indicates that though there is an increase in tool wear but out of those 3 oils, the tool wear of coconut oil is less compared to the other two.
- ❖ This indicates that mechanical performance is better compared to others.
- ❖ Hence it will be better to use coconut oil as a cutting fluid.

#### ❖ **Sunflower Oil as a Cutting fluid:**

- This consists of more amount of linoleic acid which is polyunsaturated and some amount saturated fatty acids like palmitic and stearic acids.
- It has a good kinematic viscosity of 40.05m<sup>2</sup>/sec at 40°C.
- It has a viscosity index of 206
- As it has good kinematic viscosity and even contains waxes(which helps in lubricating) it is preferred as a metal cutting fluid which helps to reduce the friction between the tool and workpiece.

#### ❖ **Karanja Seed oil as a cutting fluid:**

- This consists of a major amount of oleic acid, linoleic acid and palmitic acids.
- It has kinematic viscosity of 43m<sup>2</sup>/sec at 40°C and viscosity index of 172
- Here as we have a good kinematic viscosity it can be used as a good lubricating fluid.



***Fig 1.3 Karanja seed***

- It also acts as a coolant in the machining process.
- This has many benefits in the medical field. It can even cure “Rheumatism” which is typically a joint pain.
- When we use mineral oil as a cutting fluid there might be a chance that the cutting fluid may fall on our skin, but here in this case though Karanja Seed oil falls on our skin it doesn't have any impact on the skin.
- The chip thickness even found to be less using this Karanja based soluble cutting fluid when compared to the conventional cutting fluid.
- This is highly capable of providing support for the cutting parameters like feed, depth of cut and cutting velocity.

### ❖ Jatropha oil as a cutting fluid:

- This oil basically includes the majority content of unsaturated fatty acids like oleic, linoleic acids and some amount of palmitic and stearic acids.
- This oil is biodegradable and hence it doesn't cause any harm to the environment
- This oil possesses low toxicity levels.
- It is a better way of flushing away the chips
- Has a good lubricating and cooling property
- Coming to the cost point of view it is preferable.
- Hence this is one of the alternative cutting fluids that can be used in the place of mineral oil cutting fluids.

### ❖ Effect of Cutting fluid on cutting force and tool wear:

The resultant force ( $F_r$ ) in cutting operation is

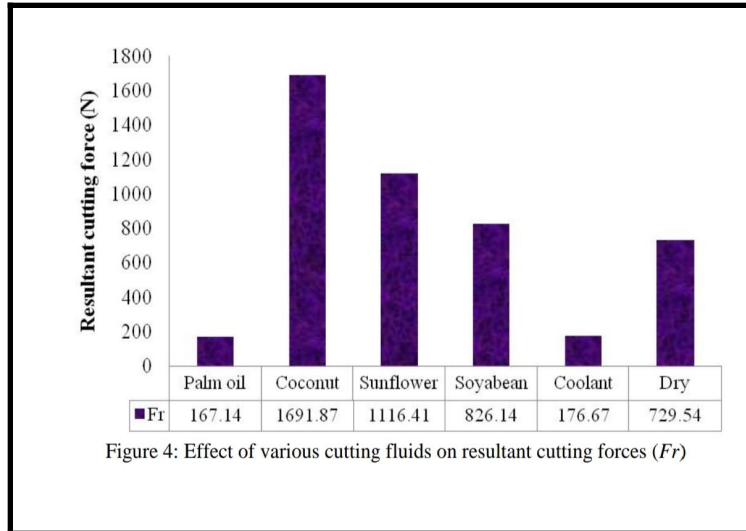
$$F_r = \sqrt{F_x^2 + F_y^2 + F_z^2}$$

Where  $F_z$  is the main cutting force.

$F_x$  is the feed force.

$F_y$  is the radial force.

So for the effect of cutting fluid on cutting force we have an experiment with palm oil, coconut oil, sunflower oil, soybean oil, coolant and dry cutting during milling operation



**Fig 1.4 Shows a plot between various vegetable cutting fluids on the resultant cutting force**

Here is a graph on the effect of cutting fluid on the Resultant cutting force.

The performance of coolant (commercial cutting fluid) is better than other vegetable based cutting fluid. The effect of palm oil is better than other vegetable based CFs and also from dry conditions because of highest viscosity. Palm oil exhibits the lowest cutting force after coolant. More stable lubricity is provided by VBCFs than mineral based CFs across the machining temperature range due to higher viscosity. Except from mineral based CFs, viscosity of VBCFs is decreased gently with rise in temperature. Reduction of friction between tool and workpiece after the involvement of VBCFs which



reduces the heat at the work tool interface and hence reduces the cutting force . Minimal surface roughness and tool wear are reduced. Friction is the major contributor for the cutting force between tool and workpiece and cutting force mainly produced due to spindle speed. Cutting fluid reduces the friction between tool and workpiece, so cutting force is minimized. Cutting fluid is necessary for reduction of cutting force after providing lubrication and a cool environment in the cutting area to reduce cutting force. VBFCs having High quantities of unsaturated fatty acid with high viscosity will generate excessive strength lubricant film acting as a boundary lubricant. Whereas commercial cutting fluid with mineral and chemical particles will lower the cutting force even after having lower viscosity.

## ❖ Conclusion:

Cutting fluid is essential for lubrication and cooling of tools - work interface. There are various kinds of cutting fluid that are synthetic, semi-synthetic, soluble , straight, water , mineral oil. Main objectives of cutting fluid are lubrication to cutting area, cooling, reducing tool wear, surface finish, cutting force reduction, chip flush away, no bue formation, and protection from corrosion. Vegetables oil is a straight oil produced from vegetables and animals fat and classified on edible and non edible on their sources ,applications,etc. Vegetables oil are biodegradable and renewable so it is achieved as an excellent replacement of mineral oil cutting fluid. VBCFs are eco-friendly in nature and provide. Coconut oil, palm oil, soybean oil etc are examples of edible oil CFs, jatropha, karanja, neem, mahua, etc are examples of non Edible CFs. Cutting fluid is used to reduce cutting force and tool wear. VBCFs have high lubrication which reduces the friction between the tool and workpiece interface, so it reduces its cutting force. Higher viscosity of VBCFs is used for lubrication in the cutting area. Viscosity of mineral oil is decreased faster with increase in temperature than Vegetables based cutting fluid. Along with these advantages VBCFs are vastly used nowadays causing reduction of environmental disbalance. So we need to go indeed use VBCFs.

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