Comparative experimental analysis of non edible vegetable oil as cutting fluid - a review

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Abstract - *Cutting fluids have three main benefits: they remove chips during machining processes, lubricate at the chip-tool contact, and evacuate heat. However, there is rising worry regarding the sustainability, biodegradability, safety, and health of operators when using regular mineral oils as cutting fluids. Because of its environmental benefits, including resource renewal, biodegradability, and sufficient performance for a variety of applications, vegetable oil can now be employed as a lubricant in industrial settings Vegetable oils have generally been shown to be a good replacement for conventional mineral oil as working fluids when it comes to machining temperature, surface roughness, force, tool wear when performing various machining processes.*

Key Words: **Drilling operation, cutting fluid, Used oil,Blend of oils ,neem oil ,jatropha oil.**

1. INTRODUCTION

The process of machining involves removing material to alter its size, shape, and surface. Materials that can be synthesized through heat evaporation or by exerting pressure until the material cracks. A smooth surface, precise geometry, sharp corners, grooves, fillets, and excellent dimensional tolerances are just a few of the many important benefits of drilling ,turning , grinding, machining are the three most used types of machining. The term "Miscellaneous Activities" also refers to the following operations: planning, drilling, broaching, and cutting [1].

Various machining processes play an essential part in the production sector. Cost-cutting measures have been taken into account in every manufacturing process. In this regard, it's crucial to choose the right machining settings, such as, cutting speed, feed rate and depth of cut. By choosing the best machining parameters, longer surface finish, increased tool life, and a greater rate of material removal can be attained.

1.1 Function of cutting fluid

Cooling and lubricating are two of cutting fluid's primary functions in temperature control. By removing metal shavings and other particles from the tool and cutting area, cutting fluid also improves the quality of the workpiece. As the cutting fluid is applied during the machining operation, it drains heat from the cutting tool-workpiece interface. Tools maintain themselves within their critical temperature range by the coolant's cooling effect, which keeps the tool from softening and wearing out quickly. The use of cutting fluid also lessens the likelihood of built-up edges. Metal particles that stick to the tool's edge during the machining of particular metals are referred to as built-up edges. In certain procedures, fluid transparency or clarity may be the desirable property in a cutting fluid.

1.2 Cutting fluid

In the manufacturing industry, cutting fluids are employed as lubricants and coolants for metalworking applications. They may also be known as lubricants, coolants, cutting oils, machining fluids, or metal working fluids as well as the machining processes. For both tools, cutting fluid is used to reduce the harmful effects of heat and friction as well as the task item F. Taylor really published the first paper on the use of cutting fluids in metalworking in 1894. He discovered that by strongly misting the cutting zone, it is feasible to achieve a cut speed of up to 33% without shortening the tool's lifespan. Three practical advantages of cutting fluid are that it helps with machining, chip tool contact lubrication, heat evacuation chip removal.

Types of Cutting fluids:

Cutting fluids are often divided into four groups: water soluble oils, synthetics, semi-synthetics, and straight oils.

1) Straight Oil

These are essentially mineral-based petroleum oils, so named because they don't contain any water. They might contain additives intended to bring forth specific qualities in them. The superior lubrication that straight oils provide over the workpiece and cutting tool is one of their main advantages. However, these are particularly useful for low-speed, low-clearance tasks when a superior surface polish is required. They are applied directly and aren't diluted possess excellent lubricating qualities, strong corrosion resistance, and biodegradation resistance, yet there. The cooling properties of this type of metal working fluid are not quite as effective as those of other varieties.

2) Soluble Oil

The terms "emulsions," "watersoluble oils," or "emulsible oils" refer to entities that simulate soap. Typically, they consist of emulsifiers, additional additives, and 60–90% mineral or petroleum oil. Once the emulsifiers are mixed together and the oil is dispersed throughout the water, a stable oil emulsion is produced. Because soluble oils combine with water to form a lubricant, they have a higher cooling capacity. They can leave a protective oil layer on the moving elements of equipment and tools, and they frequently have the ability to emulsify grease or friction oils. On the other hand, soluble oils are more vulnerable to bacterial development and degradation, evaporation oil contamination, and oil loss when there is water present.

3) Synthetics Fluids

Alkaline inorganic and biological elements constitute synthetic fluids rather than the base of mineral oil or petroleum. Based on their chemical composition, natural fluids can also be classed as simple, complex, or emulsifiable substances. Light duty grinding processes are the main applications for simple synthetic concentration, also referred to as a real solution. Emulsifiable synthetics can handle heavy-duty grinding and cutting operations on tough, challenging-to-machine, and high-temperature metallic materials by virtue of their wettability, excellent cooling, and lubricity. Synthetics can still foam or form fine mists under moderate to high agitation conditions, even if they are less immune to issues with oil-based fluids.

4) Semi-synthetics Fluids

Semi-chemical fluids, also known as semi-synthetic fluids, are essentially composed of a blend of soluble oils and synthetic materials. Small mineral oil dispersions are present in a water-dilutable concentrate, typically ranging from 2 to 30 percent. Semisynthetic lubricants are far lower maintenance than soluble oils and are useful in a wide range of machining applications.They have superior wetting and cooling qualities over soluble. oils that provide effective lubrication for heavy duty applications with a moderate rate of consumption by enabling users to reduce and feed faster. Because semisynthetics are made of less smoke and oil mist, they are superior at preventing bacterial Hard water deposits, however, can occur as a result of the stability of silicones being altered by water hardness. They also have a longer life expectancy than soluble oils and are typically sold at a lower price for lubricating less oil than pure or liquid oils because of how easily they froth due to their cleaning ingredients. strong resistance to corrosion.

1.3 Standard Mineral Oils

Eco-friendly lubricants were expected to grow at a pace of 7% to 10% annually in 2002. US market for a few years, although the overall growth rate of the lubricant business was only 2%. In the Journal of Scientific and Engineering Research, Mbishida MA et al. reportedly published a paper in 2018. In 2005, the world's lubricant consumption was estimated to be 38 million tonnes, with an expected growth rate of 1.2% per year over the next ten years. Metal working fluids (MWFs) are becoming more used in the machining sector due to their benefits. At least two thirds of the 320,000 tonnes of MWFs that are consumed yearly in the European Union alone need to be disposed of. Growing awareness of the potential negative effects of using mineral oil-based lubricants has led to the implementation of laws prohibiting their use in countries such as the Austrian Empire, Canada, Budapest, Japan, Poland and Switzerland.

1.4 The existing challenges related to conventional cutting fluids

Conventional metalworking fluids have challenging chemical compositions that are used to complete various machining process activities. Despite their widespread usage, they represent a significant risk to the environment and public health. Hazards during their entire life cycle.

1. Human hazard

Skin contact with metalworking fluids (MWFs) was linked to over 80% of all occupational diseases reported by operators, according to research findings. It is believed that between 70,000 and a million workers in the US are vulnerable to MWFs. Cutting fluids may be unpleasant or allergic due to their complex chemical composition. The bacteria and fungi present can also create microbial toxins, particularly in watersoluble MWFs that pose a greater risk to operators [14]. Inhaling aerosols from process fluids can cause a variety of health problems for metalworking machine workers, including allergies, skin diseases, cancer, hypersensitivity pneumonitis, and chronic bronchitis [15].To address these concerns, tribologists and scientists are currently looking into a variety of alternatives to mineral-based MWFs. About 85% of all lubricants used worldwide are mineral-based oils [16].

2. Ecological Risk and Biodegradability

The ability of each component to break down through the action of microorganisms determines how biodegradable it is. If the percentage of breakdown of an oil passes a predefined level in a standard test, it is deemed biodegradable [16]. The extensive use of mineral oils has had a number of negative effects on the environment. Their use has several negative effects, including air pollution, soil erosion, groundwater and surface water contamination, and the following degradation of agricultural and food products [17]. Public interest in environmentally friendly lubricants is rising as a result of the connection between conventional mineral oil-based lubricants and environmental issues [14]. Numerous additives, such as antiwear, detergents, dispersants, antifoams, severe pressure agents, friction modifiers, and viscosity improvers, are included with mineral oil-based lubricants. Certain chemicals pose a threat to wildlife and human health due to their toxicity and negative effects on the environment. The environment's toxicity Issues with mineral oil-based lubricants and the additives they contain, as well as growing costs due to a global shortage Once again, vegetable oils such as canola, coconut, sunflower, and soybean oil are becoming more and more popular. Sesame oil, castor oil, and so on.

1.5 Additional challenges consist of:

1. Unrenewability: This is the fluid's propensity to diminish herself after use and not replenish.

2. Foaming: Usually, it is produced by mechanical, chemical, or air-blocking processes in the fluid. For any conventional fluid to remain biostable, effective corrosion prevention, and cutting performance, it must meet a minimum concentration level. For the fluid to function, a specific concentration range is required. The minimum may fall below this concentration level for an extended length of time if this is the case for a number of reasons, including low pH, emulsion cracking, corrosion of ferrous alloys (red rust), bio-instability and bio-mass formation, poor cutting performance, and, lastly, the handling of metal removal fluid.

2. The effect of fluid cutting on the parameters for machining

Numerous scholars have examined the impact of conventional and non-edible oils on machining parameters such as cutting force, working shape creation, machine temperature, and tool wear. This report highlights the primary findings from these investigations.

Ademoh, et al., (2016) [1] Additionally, in a light steel turning operation, the efficacy of soluble oils, water melon seed oil, and neem seed oil as metal cutting fluids has been evaluated. Moreover, consideration has been given to certain physicochemical properties of cutting fluids. 37.33 C was the lowest temperature measured when making an emulsion consisting of 25% neem seed oil and 75% water. Unlike conventional cutting oil, all ratios of oils to water emulsions performed admirably as coolants.

SharafadeenKunleKolawale et.al [2]. The effectiveness of groundnut and palm oils in comparison to mineral oil cut fluid was assessed while a soft steel was being machined. Because palm oil has the best lubricating qualities, it has produced the largest total thickness (0.26 mm). Based on these findings, powdered nut oil, palm oil are suggested a flexible substitute for mineral oil for machining mild steel. The sample based on groundnut oil has the lowest viscosity, and at extremely high temperatures, ranges are closest. Low viscosity results in a high viscosity index and a propensity to flow at high temperatures during operation.

Jitendra Kumar Chandrakar et.al [3] All machinery with moving parts can run smoothly, as demonstrated by lubricants. It guarantees the dependability of machines' operations and lessens the likelihood of their failure. Vegetable bio lubricants provide excellent lubricating qualities in addition to being non-toxic, biodegradable, and renewable. The study on edible oils as a cutting agent was reviewed by the author. In a few articles, it was used and demonstrated to be beneficial as a lubricant for some oils that weren't edible, including castor machining operations.

Obi, et al., (2013) [4]. Confirmed the effectiveness of a few vegetable oils as an aluminium cutting fluid, including palm, groundnut, shear butter, and cotton seed oil. Each oil needs to be used as lubricant in a turning process with varying spindle speeds, feed rates, and cutting depths. The surface temperature, surface quality, and chip thickness ratio must all be checked. They have performed remarkably well when compared to conventional clear oils. It has been demonstrated that machined components are capable of performing the same tasks as imported ones.

According to **Lawal et al.** [5], MWFs made from bio-based oil have been modified to work with a variety of materials and machining settings. Their research shows that MWFs made of palm, coconut, and sunflower oils have superior lubricating characteristics and perform on par with mineral oils in terms of cutting force, temperature, surface finish, and tool wear.

Emel-Kuram et al [6]. We investigated the effects of vegetable-based cutting fluids on drilling wear. This initiative was focused on developing vegetable cutting fluids, or VBCFs, and machining procedures that make use of them. When drilling 304 AISI steel with an HSSE tool, the following parameters will be assessed: tool wear, thrust strength, and surface roughness. The efficacy of the three VBCFs—commercial seamless cutting fluid, refined canola oil, refined sunflower oil, and refined canola oil—will be assessed. The testing findings show that the canola-based cutting fluid performs better due to its enhanced capacity. The lubricating properties under continuous cutting conditions are superior to those of other cut fluids.

Bello and Yakubu [7]. Neem oil has produced aluminium manganese alloy by a range of machining processes. They examined how well Neem seed oil machined in comparison to soluble oil and dry turning under various cutting conditions. Compared to soluble oils, the investigators found that neem seed oil had a 39% smoother surface. The research also found that using neem oil lowers tool wear by 56% when compared to soluble oils. It follows that neem oil performs better as a cutting fluid than mineral oil.

Table -1: Report of various articles about non edible vegetable oil as metalworking fluid

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Sr.no	Author	Title	Type of Machine	Cutting Fluid	W/P material	O/P parameters	I/P parameters
1.	Sharafadeenkunlekolwale et.al	fluid during the evaluation of groundnut and palm oil performances in comparison to mild steel cutting and machining operations based on mineral oil	CNC drilling machine	mineral oil-based cutting fluid, palm oil, and groundnut oil	Mild steel	cutting depth (mm), feed rate (mm/rev), and cutting speed (rev/min)	Temp Surface roughness Chip formation
2.	M.Susmitha et.al	Impact of non-edible vegetable-based oil as a cutting fluid on the force and roughness of the chips during mild steel drilling	CNC drilling machine	Neem oil,karanja oil Blend of neem and karanja	AISI 1014 Mild steel		Chip creation roughness of the surface cutting power
3.	M. Anthony Xavior et.al	Assessing the impact of cutting fluids on surface roughness and tool wear when turning AISI 304 austenitic stainless steel	Turning	Coconut oil Soluble oil Straight oilt	AISI 304 with carbide tool	Cutting depth, feed, and speed	Temperatue, cutting force, surface roughness, and flank wear
4.	Rasaq.A.Kazeem et.al	Improvements in the use of cutting fluids based on vegetable oil for environmentally friendly machining processes	Turning drilling milling grinding	Non edible vegetable oils		feed, depth of cut, cutting speed.	Temperature Surface roughness Cutting force
5.	G. Singh M.kumar et.al	An experimental study examining the performance of	Turning	Vegetable oil Mineral oil		MQL	Surface roughness

		mineral and vegetable oils when machining En-31 steel while using the least amount of lubricant					
6.	Gajrani ,K.K.	Using flood cooling and lowest quantity cutting fluid procedures, biodegradation and hard machining performance of mineral oil and eco-friendly cutting fluid are compared.	Hard machining		Hardened AISI H - 13steel	Cutting force, feed force	Surface roughness, Coefficient of friction.
7.	Suhaili,S.N.	Investigation of surface roughness and chip development in mild steel milling with vegetable-based oil as lubricant	Milling	Sunflower oil	Mild steel	Feed rate , Depth of cut. Cutting speed.	Surface roughness Chip formation
8.	Y.M. Shashidhara	Using vegetable oils as a cutting fluid, experimental measurements of cutting power for turning and material remove rate for drilling of AA6061-T6 were made.	Drilling	Jatropha, Pogammia pinnata,	AA 6061-T6 sheets HSS drill tool	Cutting force , Cutting speed Feed Depth of cut	Material removal rate
9.	Emelkuram, M.Huseyin	Performance evaluation of cutting fluids made from developed vegetables using D-optimal experimental design in the turning process	Turning	Sunflower oil Canola oil	AISI 304L material carbide tool7	Feed Depth of cut , Cutting speed	cutting and feed force , Surface roughness
10.	N.Talib ,E.A.Rahim	Assessment of chemically altered crude jatropha oil's performance as a bio-based metal working fluid for machining	Orthogonal cutting process	Crude jatropha oil	AISI 1045 mild steel	Rake angle MQL pressure supplied , Cutting speed Feed rate	Cutting force cutting temperature

3. CONCLUSIONS

Numerous investigations have shown that vegetable oils can serve as mineral working fluids in place of conventional mineral oil. The possible disadvantages of utilising conventional mineral oils as cutting fluids were noted in this study, along with the advantages of switching to vegetable oil. It seems that vegetable oils have potential. How far they have progressed into metal working fluids in terms of temperature reduction, tool wear, force, and surface roughness during a variety of machining procedures.

Key findings from the literature review:

1. Better surface smoothness and higher cutting speeds while machining compared to traditional solvents.

2. Using environmentally friendly cutting fluids results in longer tool life, less surface irregularity, and more precision because there is less heat generated.

3. The use of cutting fluids based on vegetable oil during machining results in low cutting force.

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