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Exploring the Performance of a Novel Bio-Based Cutting Fluid

[1] G.V. S Dhanuss*, [2] S. Chakravarthi, [3] Y. Manikanta, [4] V. Amar Chowdary, [5] R. Manohar, [6] K. Arun Kumar

[1,2,3,4,5] U.G Students, Dept of Mechanical Engineering, Raghu Engineering College, Visakhapatnam, AP, India

[6] Associate Professor, Dept of Mechanical Engineering, Raghu Engineering College, Visakhapatnam, AP, India

ABSTRACT

Conventional metal cutting fluids, often mineral oil-based or petroleum-based, have found extensive use in the metalworking industry. These fluids act as coolants and lubricants, enhancing the efficacy and longevity of cutting tools and workpieces during machining.

Conventional cutting fluids offer advantages in terms of reducing friction and heat build-up but come with the disadvantage of posing significant health hazards and environmental pollution. Therefore, there is a transition to sustainable cutting fluids made from vegetable-based materials that provide a safer and more environmentally friendly alternative.

A comprehensive investigation was conducted to explore the properties of a new cutting fluid formulation. The study involved the development and evaluation of a novel cutting fluid, which was formulated using Waste cooking oil (WCO) which is easily available and cost-effective.

Waste cooking oil (WCO) physical and chemical properties, including viscosity index, density, , kinematic viscosity, flash point, and fire point, were systematically analysed.

1.Introduction

The manufacturing industry is highly competitive and to remain relevant and profitable, it needs to run its operations effectively and efficiently. One way to achieve this is by maintaining the quality of its products to meet the demands of consumers. However, the industry must also consider environmental issues, safety, and health as important factors that affect business activity. With increasing public awareness and government regulations, it has become necessary for the manufacturing industry to operate with due regard to these factors.

Machining is a process used in the manufacturing industry to cut materials into the desired final shape and size. This process involves the removal of excessive material in the form of chips or flakes. To increase production rates and minimize machining time, alloys are machined at high speeds. However, the heat generated during this process can affect the quality of the workpiece, tool life, time taken for machining, surface roughness, tool wear, chip thickness, chip formation, power consumption, and chip breaking behaviour.

To address these issues, many cooling and lubricating cutting fluids have been developed to reduce the heat generated during the machining operation. Cutting fluids can manage the temperature and friction during machining, but they also have negative impacts on the environment and human health. Due to financial and ecological concerns, industries are trying to minimize the use of cutting fluids in their processes. The use of an efficient coolant system can reduce coolant consumption and improve productivity.

However, the use of cutting fluids has many drawbacks, including environmental pollution, hazards to operators during the handling and disposal of the fluids, and wastage of the fluid. Thus, the industry is exploring alternatives such as biodegradable or eco-friendly cutting fluids, which can help improve performance, reduce wear and tear, have good lubricating properties, and reduce mechanical energy loss.

2.Literature Review

Waste cooking oil is a common feedstock for the production of bio-based fluids, including bio-lubricants and bio-cutting fluids. The following is a brief literature review on waste cooking oil:

A study by Ling et al. (2016) investigated the physical and chemical properties of waste cooking oil obtained from different sources. The study found that the waste cooking oil had high viscosity, high acidity, and high free fatty acid content, which can negatively affect the performance of bio-based fluids produced from it.

Several studies have investigated the production of bio-based fluids from waste cooking oil. For example, a study by Guo et al. (2019) investigated the use of waste cooking oil as a feedstock for the production of bio-lubricants. The study found that the waste cooking oil-based bio-lubricants had good thermal stability and anti-wear properties. Environmental impacts of waste cooking oil: A study by Bai et al. (2019) investigated the environmental impacts of using waste cooking oil as a feedstock for bio-diesel production. The study found that using waste cooking oil as a feedstock can reduce greenhouse gas emissions and have lower environmental impacts compared to using virgin vegetable oil as a feedstock. Machining is a manufacturing process that involves the use of various cutting tools and equipment to shape a workpiece to a desired shape and size. The process of machining can be classified into different types such as milling, drilling, turning, grinding, etc. Machining is widely used in various industries such as aerospace, automotive, medical, etc. The aim of this literature review is to provide an overview of the recent research works in the field of machining. There are various machining processes used in the industry [1]. The most common processes are milling, drilling, turning, and grinding. In recent years, research has focused on the development of new machining processes that are more efficient and cost-effective. The machining parameters such as cutting speed, feed rate, and depth of cut have a significant effect on the performance of the machining process. Recent research has focused on the optimization of these parameters to improve the machining efficiency [2].The cutting tools used in the machining process play a crucial role in determining the quality of the machined parts[3]. Recent research has focused on the development of new cutting tools with improved performance and longer tool life.

Some materials such as titanium, Inconel, and hardened steels are difficult to machine due to their high strength and hardness. Recent research has focused on the development of new machining techniques and cutting tools for these materials[4].

Machining simulations are used to predict the performance of the machining process before the actual machining is carried out[5]. Recent research has focused on the development of more accurate machining simulations that can predict the cutting forces, temperatures, and surface roughness of the machined parts.

The surface integrity of the machined parts is an important factor that determines the performance of the parts [6]. Recent research has focused on the development of new techniques for measuring the surface roughness, residual stresses, and microstructure of the machined parts.

Chemical and petroleum-based lubricants are widely used in various industrial applications due to their excellent lubricating properties. However, the use of these lubricants has several disadvantages such as environmental pollution, health hazards, and high cost. The aim of this literature review is to provide an overview of the disadvantages of chemical and petroleum-based lubricants. The use of chemical and petroleum-based lubricants can cause environmental pollution due to the release of toxic chemicals into the air and water. These lubricants contain harmful chemicals such as heavy metals, hydrocarbons, and additives that can contaminate the environment and harm human health. The use of chemical and petroleum-based lubricants can pose a significant health hazard to workers who come into contact with these lubricants. Exposure to these lubricants can cause skin irritation, respiratory problems, and other health issues. Moreover, the use of these lubricants can also lead to the development of cancer in some cases. The cost of chemical and petroleum-based lubricants is generally higher than that of other lubricants.

This is because these lubricants require complex manufacturing processes and are made from expensive raw materials. Additionally, the disposal of these lubricants also adds to the overall cost. Chemical and petroleum-based lubricants generally have a shorter lifespan than other types of lubricants. This is because these lubricants are prone to breaking down under high temperatures and pressure, which can lead to equipment failure.

3.Role of metal cutting fluids in machining

Lubricants and cutting fluids play a critical role in machining operations. Their primary purpose is to reduce friction between the cutting tool and the workpiece, which helps to extend the life of the cutting tool and improve the quality of the machined part. Here are some of the key roles that lubricants and cutting fluids play in machining operations.

Reducing Friction: Lubricants and cutting fluids reduce friction between the cutting tool and the workpiece, which reduces the amount of heat generated during the cutting process. This helps to extend the life of the cutting tool and prevent damage to the workpiece.

Cooling: Lubricants and cutting fluids also help to cool the cutting tool and the workpiece. This is particularly important in high-speed machining operations where the temperature can quickly rise, leading to tool wear and workpiece deformation. The cooling effect of lubricants and cutting fluids helps to maintain the temperature at a safe level.

Chip Removal: Lubricants and cutting fluids help to remove chips and debris from the cutting area. This prevents chips from clogging the cutting tool or getting stuck in the workpiece, which can lead to tool breakage and poor surface finish.

Corrosion Prevention: Some machining operations involve cutting materials that are prone to corrosion. Lubricants and cutting fluids can help to prevent corrosion by creating a protective barrier between the metal surface and the atmosphere.

Improved Surface Finish: Lubricants and cutting fluids can help to improve the surface finish of the machined part. By reducing friction and cooling the cutting area, lubricants and cutting fluids can prevent surface defects such as burrs, scratches, and cracks.

Lubricants and cutting fluids play a vital role in machining operations by improving tool life, workpiece quality, and process efficiency.

4.Health hazards caused due to cutting fluids

Exposure to cutting fluids has been linked to several respiratory diseases, including hypersensitivity pneumonitis, lipoid pneumonia, occupational asthma, chronic bronchitis, allergic contact dermatitis, and irritant contact dermatitis.

Hypersensitivity pneumonitis [7] is a type of lung inflammation that occurs in response to exposure to various substances, including cutting fluids. The condition is caused by an allergic reaction to inhaled particles, leading to shortness of breath, cough, and fever.

Lipoid pneumonia is a rare condition that occurs when cutting fluid droplets are inhaled into the lungs and cause an inflammatory response. The condition can be severe and can cause coughing, chest pain, and fever.

Occupational asthma is a type of asthma that is caused by exposure to cutting fluids or other irritants in the workplace. The condition is characterized by wheezing, coughing, and difficulty breathing, and can be chronic or acute.

Chronic bronchitis [8]is a condition that is characterized by long-term inflammation of the airways in the lungs. Exposure to cutting fluids can cause chronic bronchitis, which can lead to coughing, shortness of breath, and chest discomfort.

Allergic contact dermatitis is a skin condition that occurs when the skin comes into contact with cutting fluids or other irritants. The condition is characterized by redness, itching, and swelling of the skin.

Irritant contact dermatitis is another skin condition that can be caused by exposure to cutting fluids. The condition is characterized by dry, itchy, and inflamed skin, and can be chronic or acute.

Exposure to cutting fluids can cause a range of respiratory and skin conditions, and it is important to take measures to prevent exposure and reduce the risk of developing these health problems.

5.Benefits of Bio-Cutting fluids

Bio lubricants offer several benefits over traditional petroleum-based lubricants and coolants. Firstly, bio lubricants are biodegradable, meaning they can break down naturally in the environment and do not harm the ecosystem. This attribute makes them environmentally friendly and sustainable alternatives to petroleum-based lubricants and coolants. Secondly, bio lubricants and coolants are made from renewable resources such as vegetable oils or animal fats, reducing the reliance on non-renewable petroleum resources. As a result, they can help to reduce the environmental impact of machining operations and contribute to a more sustainable future.

Thirdly, bio lubricants often have superior lubricating and cooling properties, resulting in longer tool life, reduced wear and tear, and improved surface finish. The reduction in friction and heat generated during the machining process can also lead to less energy consumption, further contributing to the environmental benefits of using bio lubricants and coolants. Moreover, bio lubricants and bio coolants are less likely to cause skin irritation or respiratory problems in workers as they are free from harmful chemicals and additives that can cause health problems.

6.Waste Cooking Oil

Waste cooking oil (WCO) is a by-product generated from the use of vegetable oils for cooking and frying. Instead of discarding WCO, it can be collected and processed for reuse in various applications such as biofuels, soaps, and lubricants. Understanding the properties of WCO is essential for determining its suitability for different applications. Here are some key properties of WCO:

Fatty acid composition: WCO typically consists of a mix of fatty acids, such as oleic, linoleic, and palmitic acids. The fatty acid composition can affect the chemical and physical properties of WCO, such as its viscosity and oxidative stability.

Viscosity: The viscosity of WCO can vary depending on factors such as temperature and the presence of impurities. High viscosity can make it difficult to handle and process WCO, so it may need to be treated to reduce its viscosity before it can be used in some applications.

Density: The density of WCO is typically similar to that of vegetable oils, ranging from 0.91 to 0.93 g/cm3. However, the density may be affected by the presence of impurities and other factors.

Moisture content: The moisture content of WCO can affect its stability and suitability for various applications. High moisture content can lead to microbial growth, which can degrade the quality of the WCO and limit its use.

Acidity: The acidity of WCO is measured by its free fatty acid (FFA) content. High FFA content can indicate degradation of the oil and can affect its stability and suitability for various applications.

Oxidative stability: WCO is prone to oxidative degradation, which can result in the formation of harmful compounds and rancidity. The oxidative stability of WCO can be affected by factors such as its fatty acid composition and the presence of antioxidants.

Total sediment: Total sediment is a measure of the number of solid particles in WCO, such as food debris and impurities. High levels of total sediment can indicate poor quality WCO and can affect its suitability for various applications., the properties of WCO can vary depending on factors such as its fatty acid composition, viscosity, density, moisture content, acidity, oxidative stability, and total sediment. These properties are essential for determining the suitability of WCO for different applications and for processing and treating WCO to improve its quality and value.

7.Procedure

Mixing of Oils: To achieve superior cutting fluid performance, a blend of waste cooking oil has been explored as an alternative to traditional petroleum and chemical lubricants. This approach aims to enhance the physical and chemical properties of the cutting fluid, leading to better operational outcomes. The use of waste cooking oil as feedstocks is an eco-friendly and cost-effective option, as these resources are readily available and can be sustainably sourced. Additionally, the incorporation of these oils can help reduce the environmental impact associated with the disposal of waste cooking oil. The optimization of the composition and ratio of these oils may lead to further improvements in the performance of the cutting fluid, including increased lubrication, reduced friction and wear, and improved cooling and corrosion resistance. The use of sustainable and eco-friendly sources for cutting fluid formulation holds great potential in mitigating the adverse environmental impacts of industrial activities. The present study underscores the importance of exploring alternative sources of lubricants to optimize their efficiency and sustainability.

We will be comparing the waste cooking oil parameters with mineral oil parameters to check whether it meets to its requirements using as a cutting fluid.

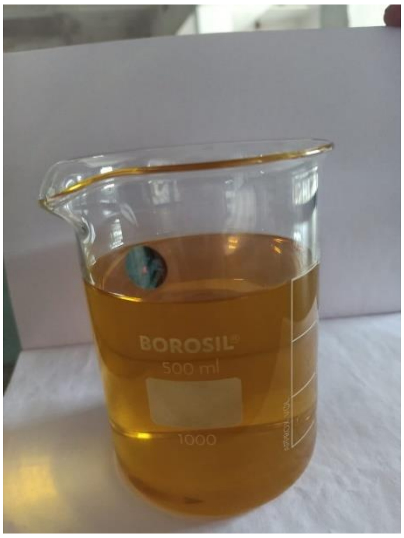

Fig .500ml of waste cooking oil.

The properties of oil as shown in tabular form:

Table. Properties of 500ml of waste cooking oil

Sl.No.	Parameter	Results	Units
01.	Density @ 15 ºC	0.913	g/cc
02.	Kinematic Viscosity @ 40ºC	42.85	cSt
03.	Kinematic Viscosity @ 100ºC	9.17	Cst
04.	Viscosity Index	204	-
05.	Flash Point	318	ºC
06.	Fire Point	352	ºC

Mineral Oil

We have taken on of the commonly used cutting fluid from the nearest machining shops, which has similar properties with 500ml of waste cooking oil.

The properties are shown in tabular form:

Table. Properties of mineral oils

Flash Point(°c)	150-300
Fire Point (° c)	>200
Viscosity Index	80-120

Density (kg/m)	800-1000
Kinematic Viscosity at 40°C (cSt)	10-100
Kinematic Viscosity at 100°C (cSt)	2-30

8.Conclusion/Future scope

In conclusion, the development of a new bio cutting fluid with promising characteristics and parameters compared to conventional chemical and petroleum-based cutting fluids is a significant step towards a sustainable and eco-friendly machining industry. The study's results demonstrate that the rheological parameters of the bio cutting fluid are suitable for machining applications. The successful implementation of this bio cutting fluid can reduce environmental impact, enhance worker safety, and improve productivity. Further research can explore the optimization of this bio cutting fluid's properties and compatibility with different machining processes and materials. This study paves the way for the adoption of the bio cutting fluid as an alternative to petroleum and chemical-based cutting fluids, ultimately leading to a more sustainable and environmentally responsible approach to machining. Finally it is concluding that, this cutting fluid will be used as an alternative cutting fluid instead of petroleum and chemical cutting fluids in machining.

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