STUDY OF ADVERSE EFFECTS OF CUTTING FLUIDS IN METAL CUTTING AND ANALYSIS

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Abstract : In the 21st century, there has been a lot of emphasis on sustainable development and eco-friendly societies. In this constantly evolving world, big steps are taken towards enabling this idea. For this to be a reality, this concept has to be implemented in the basic levels of any industry. One of the prime factors in any industry is manufacturing. Machining operations and their post-processing involve a lot of processes that are hazardous to human life and environment. The cutting fluids that are currently deployed are mostly mineral oils or synthetic oils. Mineral oils are limited and not sustainable whereas synthetic oils are non-degradable and cause a lot of pollution. Also, most of the cutting fluids used presently are not eco-friendly to work with and are hazardous to machine operators. The eco-friendly cutting fluid has material properties equivalent to the commercial formulation without any environmental hazards. Green cutting fluid is compared to commercial metal working in corrosion prevention, inhibition of microbial growth and other machining processes. The research in the area of green cutting fluids is left behind, so our research is to analyze different compositions of organic cutting fluids based on their performance characteristics. Our research involves compiling various grades of oils which can reduce the ecological effects of metal cutting without sacrificing quality, cost, reliability, performance and efficiency.

Index Terms **- Sustainable development, green manufacturing, cutting fluids.**

I. 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. One of the prime factors in any industry is manufacturing. Machining operations and their post-processing involve a lot of processes that are hazardous to human life and environment. Mineral oils are limited and not sustainable whereas synthetic oils are non-degradable and cause a lot of pollution, not eco-friendly to work with and are hazardous to machine operators. Green cutting fluids are compared to commercial metal working in corrosion prevention, inhibition of microbial growth and other machining processes.

Mineral oils, chemically synthesized emulsifiers, and additives are the basic ingredients of commercially available metal cutting fluids. However, their harmful effects on the environment and life-threatening health hazards to workers are of great concern and calls for a better alternative. The research in the area of green cutting fluids is left behind, so our project's main focus is to analyze different compositions of organic cutting fluids based on their performance characteristics. Our research involves compiling various grades of oils which can reduce the ecological effects of metal cutting without sacrificing quality, cost, reliability, performance and efficiency.

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: straight oils, soluble oils, semi synthetic fluids and synthetic fluids. Straight oils are non-emulsifiable. These oils in undiluted form are used in machining operations. They are composed of a base mineral or petroleum oil and often contain polar lubricants such as fats, vegetable oils and esters as well as extreme pressure additives such as chlorine, sulphur and phosphorous. Straight oils provide the best lubrications and poor cooling characteristics among cutting fluids. Synthetic fluids are formulated from alkaline inorganic and organic compounds along with additives for corrosion inhibition. They are generally used in a diluted form. Synthetic fluids provide the best cooling performance among all cutting fluids. Soluble oil fluids when mixed with water form an emulsion. The concentrate consists of emulsifiers and base mineral oil to help produce a stable emulsion. They provide good lubrication and heat transfer performance. They are the least expensive among all cutting fluids. Semi synthetic fluids are combination of soluble oil fluids and synthetic fluids. They have characteristics common to both types. Table 1.1 shows the pros and cons of different types of cutting fluids

The basic functions of cutting fluids include the following four considerations: cooling, lubrication, corrosion protection and chip removal. In cooling, the energy generated in metal cutting operation both through deformation and the sliding friction appears to be thermal energy or heat. This high temperature can usually shorten the fool life, cause an undesirable surface finish and bring down the cycle time due to the reduction of cutting speed. This cutting fluid acts as coolant and reduces the heat generated. It is believed that due to high pressure and relatively high temperature in most cutting operations, liquid film cannot be sustained along tool/work piece interface for all the time. Thus, the conditions in a typical cutting process are believed to approach boundary lubrication. This can be achieved by cutting fluids. A good cutting fluid protects the work piece from corrosion damage. The fourth major function of cutting fluid in machining process is to remove chips from the cutting zone. And the fluid will also prevent the machined surface from being scratched by chips.

Table 1.1: Pros and Cons of different types of cutting fluids

	Cooling	Lubrication	Corrosion protection	Chip Removal
Straight oils	Poor	Good	Good	Moderate
Soluble oils,	Moderate	Good	Moderate	Moderate
semi synthetic fluids	Good	Moderate	Good	Moderate
Synthetic fluids	Good	Good	Good	Moderate

The Desirable properties of cutting fluids in general are- high thermal conductivity for cooling, good lubricating qualities, high flash point should not entail a fire hazard, must not procedure a gummy or solid precipitate at ordinary working temperatures, must not promote corrosion or dislocation of the work material, must afford some corrosion protection to nearly formed surfaces, the components of the lubricant must not become rancid easily, no unpleasant odder must develop from continued used, not cause skin irritation or contamination and viscosity that will permit free flow from the work and dripping from the chips.

Characteristics of cutting fluids are- good lubricating qualities to reduce friction and heat generation, good cooling action to dissipate the heat effectively that is generated during machining, effective anti-adhesion qualities to prevent metal seizure between the chip and the rake face, good wetting characteristics which allow the fluid to penetrate better into the contact areas as well as in the cracks, should not cause rust and corrosion of the machine components, relatively low viscosity fluids to allow metal chips and dirt to settle out, resistance to rancidity and to formation of a sticky or gummy residue on parts or machines and should be economical in use, filter and dispose.

II. FACTORS TO BE CONSIDERED WHILE SELECTING CUTTING FLUIDS

2.1 Types of workpiece materials

Cutting fluids used, should provide easy machining operation in all materials. Ferrous metal are brittle in nature and hence during machining they break into small size chips. The friction between cutting tool and chip is less due to small size chip formation. It was proposed that using emulsion cutting fluids increases surface finish quality and prevents dust formation during machining. During machining operation of, generally the high pressure containing and additive cutting fluids are used. In stainless steel machining, high pressure cutting oils should be selected. Work-hardening properties in some steels would cause some problems during machining operation. For machining of heat resistant and difficult-to-cut steel alloys, water based cutting fluids are preferred, because temperature becomes higher in cutting area. During machining of aluminium and aluminium alloys, high temperatures do not occur Waterless cutting fluids prevent the formation of ―built up edge‖, however this type of cutting fluids must be non-active. Machining of copper alloys poses similar problems. The application of emulsion cutting fluids or thin mineral oils should be selected for copper and copper based alloys machining. High pressure additive cutting oils are preferred for brass machining. In the machining of nickel and nickel alloys, the machining operation should be carried out as dry or using cutting fluids. Higher cutting speeds and feed rates should be selected when cutting fluids are used in the machining of these materials. Generally sulphured mineral oil as cutting fluid is preferred.

2.2 Types of cutting tool material

The other influential parameter for selection of cutting fluid in machining processes is the cutting tool material. Different cutting tool materials are commercially available for carrying out different machining operation. High speed steel cutting tools can be used with all type of cutting fluids. However waterless cutting fluids are preferred when difficult-to-cut materials are machined. In case of the tungsten carbide (WC) cutting tools application, more cooling characteristics from cutting fluids are required. This is because of high generated heat in the interface of cutting tool and workpiece material. The negative effect of generated heat during machining with WC cutting tools causes rapid tool wear. Hence toll life will be shorter and surface finish quality falls.

III. REDUCING ADVERSE EFFECTS OF CUTTING FLUIDS ON ENVIRONMENTAL

3.1 Dry machining

Dry machining means that no cutting fluid is used during process. For economic as well as environmental reasons machining process is carried out without any cutting fluid. Some workpiece materials present many problems during dry machining like aluminium, which is a soft material. Dry machining of aluminium induces influences on the surface quality of the work piece. Higher friction between tool and work piece in dry machining can increase the temperature in cutting region. In milling cutting, tool does not cut continuously and the using of cutting fluids increase thermal shock effect. Hence, dry machining is better suited for milling operations. In drilling, especially gun drilling the most important function of cutting fluid is the chip removal and dry cutting may induce drill breakage.

3.2 Minimum quantity of lubrication (MQL):

Due to economic, ecological and technical reasons, at present it is attempting to reduce the use of oils and cutting fluids in metal cutting. The first option is dry machining, but in many cases this is impossible due to the nature of the workpiece materials. During machining, many nonferrous alloys, and especially aluminium, tend to be adhered to tool edges, giving rise to complex problems like the wrong cutting of the workpiece material and leading to a high tool wear. In this case, an interesting option is the use a lubrication/coolant system based on the injection of pressurized air with small quantities of oil. This technique is designated MQL (Minimum Quantity of lubrication). In MQL the chip, workpiece and tool holder have a low residue of lubricant thus their cleaning is easier and cheaper as compared to flooding of cutting fluid. The cutting region is not flooded in MQL during machining so the operation can be seen by the operator. MQL is used as a lubricating method rather than cooling. This poor cooling capacity limits the effectiveness of MQL in machining of difficult-to-machine materials such as titanium and nickel-based alloys due to the excessive heat generation. Several experimental studies have investigated for the performance of MQL in the drilling, turning, milling and grinding processes. The most literature studies compared the performance of MQL with dry cutting and flood

application. The overall performance (cutting force, tool life, surface finish, cutting ratio, cutting temperature and tool-chip contact length) during MQL was found to be superior to dry and conventional wet turning of hardened steel.

3.2 Drawbacks of petroleum based cutting 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.

3.3 Vegetable based cutting fluid:

Vegetable oil‖ is a triglyceride extracted from a plant. Vegetable oils that are solid at room temperature are sometimes called vegetable fats. 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. Vegetable oils are extracted from plants by placing the relevant part of the plant under pressure, to squeeze the oil out. Oils (edible or nonedible) may also be extracted from plants by dissolving parts of plants in water or another solvent, and distilling the oil, or by infusing parts of plants in base oil. 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 Pongamia Pinnata (karanja), Jatrophacurcas (Ratanjyot) etc., prominently for biofuel applications and needs focused attention for fulfilling the environmentally 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.

3.4 Applications of vegetable oils:

Vegetable oils are used as an ingredient (or) component in many manufacture products. These oils are particularly suitable as drying oils, and are used in making paints and other wood treatment products. Vegetable oils are increasingly being used in the electrical industry as insulators. As vegetable oils are not toxic to the environment, biodegradable if spilled and have high flash and fire points. However, vegetable oils are less stable chemically, so they are generally used in systems where they are not exposed to oxygen. Vegetable oil is being used to produce biodegradable hydraulic fluid and lubricant.

3.5 Edible oils:

A liquid fat that is capable of being eaten as a food or food access, like Coconut, Olive, Soya bean, Sunflower, Palm, Peanut, Rapeseed, and Corn etc. Various countries import edible for their food requirements. India is the biggest importer of edible oils in the world. Approximately, 16.6 million tons of edible oils consumed each year in India. Therefore, edible oil seeds usage for lubricant needs may not be able to meet domestic requirements for ever increasing population.

3.6 Non edible oils:

As an alternative non-edible vegetable oil and tree borne seeds can prove to be worthwhile. These products from non-edible vegetable oils like Neem, castor, Mahua, rice bran, karanja, Jatropha, and linseed oils which offer better or at least same performance as petroleum oil based products besides being less expensive [8, 9]. Non edible vegetable oils are technically and environmentally acceptable and easily available resource for bio lubricants.

IV. LITERATURE REVIEW

In this paper, attention is focused on recent research work on the application of vegetable oil-based cutting fluids in machining non-ferrous metals. The efficiency of various vegetable oil-based cutting fluids based on some process parameters such as thrust force, temperature developed at the tool chip interface and flank wear during machining of some non-ferrous metals using different tool materials were highlighted. The utilization of metalworking fluids in the metal machining technological process provides, apart from benefits, certain negatives that are mainly associated with air contamination of the working environment. Cutting fluids are used in machining industries for improving tool life, reducing work piece and thermal deformation, improving surface finish and flushing away chips from the cutting zone. The application of cutting fluids increases the tool life and Machining efficiency, but it has many major problems related to environmental impacts and health hazards along with recycling & disposal. In the present work, Non-edible vegetable oil like Neem and Honge are been used as cutting fluid for drilling of Mild steel and its effect on cutting temperature, hardness and surface roughness are been investigated. Results obtained are compared with SAE 20W40 (petroleum based cutting fluid) and dry cutting condition. Metal working fluids are widely employed but their usage poses a great threat to ecology and health of workers in the industry, cutting fluid exposed the workers, and the environment in a wider context, to toxic mists, oil fags and fumes causing health problems of the nature of skin and respiratory ailments and through waste disposal polluting the soil and water resources. Vegetable oils have become identified world over as a potential source of environmentally favourable metal working fluids due to a combination of biodegradability, renewability and excellent lubrication performance. But Low oxidation and thermal stability, poor low temperature behaviour limit their potential application as metal working lubricants. Vegetable oils that have shown promising scope of their emergence as metal working fluids are castor oil, coconut oil, rapeseed oil and canola oil.

A review of general information regarding machining using vegetable oil-based cutting fluids through various coolant conditions during turning, drilling, and milling process, on various work materials like steel, Aluminium and so on is provided. An

overview of the previous work done by other researchers includes the studies conducted to investigate the influence of various vegetable oils as cutting fluid on different work material is presented.

Yasuo Fukutani et al. (2001) studied about water-soluble cutting fluid which is characterized by excellent cooling and lubricating properties and does not exert a harmful influence on the environment. A solution containing hydrogen carbonate ion, bromide ion, carbonic acid ion, and, if necessary, fluoride ion, and being adjusted to a pH of 7.0 to 11.5 can be used as a substitute for cutting oil. A water-soluble cutting fluid further including additives such as rust preventive agents and the like can be also used as a substitute for conventional cutting oil.

Vaibhav Koushik et al. (2012) reported that, metal working fluids are widely employed but their usage poses a great threat to ecology and health of workers in the industry, cutting fluid exposed the workers, and the environment in a wider context, to toxic mists, oil fags and fumes causing health problems of the nature of skin and respiratory ailments and through waste disposal polluting the soil and water resources. Vegetable oils have become identified world over as a potential source of environmentally favourable metal working fluids due to a combination of biodegradability, renewability and excellent lubrication performance. But Low oxidation and thermal stability, poor low temperature behaviour limit their potential application as metal working lubricants. Few green cutting fluids are taken and their characteristics have been studied and compared with inorganic cutting fluids on the basis of temperature, cutting speed, surface roughness and tool life. Vegetable oils that have shown promising scope of their emergence as metal working fluids are castor oil, coconut oil, rapeseed oil and canola oil.

Albert Lawal (2013) reported that, attention is focused on recent research work on the application of vegetable oil-based cutting fluids in machining non-ferrous metals. The efficiency of various vegetable oil-based cutting fluids based on some process parameters such as thrust force, temperature developed at the tool chip interface and flank wear during machining of some non-ferrous metals using different tool materials were highlighted. Nonferrous metals like titanium alloys, Aluminium, copper and brass are tested with green metal working fluids like palm oil coconut oil groundnut oil shear butter oil and kernel oil with parameters like speed of cutting, temperature, feed rate and surface roughness. The results obtained established vegetable oil-based cutting fluids as a good metalworking fluid.

Marián Schwarz et al. (2014) reported that, the utilization of metalworking fluids in the metal machining technological process provides, apart from benefits, certain negatives that are mainly associated with air contamination of the working environment. Typical health problems that result from inhalant exposure of metalworking machine operators to the metalworking fluid mist include respiratory diseases (asthma, chronic bronchitis, and hypersensitivity pneumonitis), cancer, and skin diseases. Possible health risks posed by the utilization of metalworking fluids, various methods for measuring their concentration in the working environment, and treatment of MWFs are discussed.

Mohamed Handawi et al. (2015) reported that, the performance of castor oil as cutting fluid using MQL technique was evaluated compared to dry cutting. Work piece used is hardened stainless steel 48 HRC and machining is conducted on Alpha 1350S CNC lathe. It was found that increasing cutting speed and feed reduces tool life. There is slight increase in surface roughness with increasing cutting speed and feed. Tangential force was the biggest of all forces directions and forces increases with increasing cutting speed and feed. When MQL was applied, tool life reduces with increase in cutting speed and feed. However, tool life using MQIL increases twofold then tool life under dry machining. Surface roughness is also slightly enhanced while using MQL technique as compared to dry.

Rakesh Somashekaraiah et al. (2016) reported that, mineral oils, chemically synthesized emulsifiers, and additives are the basic ingredients of commercially available metal working fluids. Its application in metal cutting have earned widespread acceptance all over the world. However, their harmful effects on the environment and life-threatening health hazards to workers are of great concern and calls for a better alternative. In this present study a green metalworking fluid / green cutting fluid (GCF) was formulated and the performance was evaluated comparing with the commercial metal working fluid (COM) used in industries for machining processes. The obtained eco-friendly formulation has material properties equivalent to the commercial formulation without any environmental hazard. GCF is comparable to COM in corrosion prevention, inhibition of microbial growth and other machining processes. It was reported that vegetable oil-based green cutting fluids have more of Gram-negative bacterial growth whereas mineral oil-based ones have more of Gram-positive bacteria. These bacteria cause environmental hazards and antimicrobials can be included for better antimicrobial properties. GCF supersedes COM by being non-toxic at LC50 >1000 mg/L and COM being toxic at LC50 < 100 mg/L according to OECD 203 tests methods. GCF, produced only from renewable sources is non-toxic and biodegradable and helps contribute towards green and sustainable manufacturing processes without any environmental pollution or hazards.

Jyothi et al. (2017) reported that, cutting fluids are used in machining industries for improving tool life, reducing work piece and thermal deformation, improving surface finish and flushing away chips from the cutting zone. The application of cutting fluids increases the tool life and Machining efficiency, but it has many major problems related to environmental impacts and health hazards along with recycling & disposal. In the present work, Non-edible vegetable oil like Neem and Honge are been used as cutting fluid for drilling of Mild steel and its effect on cutting temperature, hardness and surface roughness are been investigated. Results obtained are compared with SAE 20W40 (petroleum based cutting fluid) and dry cutting condition.

Shrikant U Gunjal et al. (2018) reported that, machining is the key process in every manufacturing and production industry. Heat generated during machining cause several negative impacts on tool and overall machining environment. Minimum Quantity Lubrication (MQL) is the key process, which signifies the exact amount of cutting fluid that is needed during machining. Current industrial practices are moreover inclined towards environment friendly processes. In view of the same, we have chosen vegetable based cutting fluids namely; canola oil, coconut oil and soybean oil for investigation of surface roughness and tool life of the hardened AISI 4340 steel during turning operation at higher cutting speed range, keeping feed rate and depth of cut at constant level. This experimental investigation is the successful move towards evaluation of machining characteristics at aggressive cutting speed.

Mohammad Nizammuddin et al. (2018) reported that, orthogonal cutting of AISI 1045 steel is carried out on CNC lathe using Karanja oil in water based cutting fluid and conventional fluid in water and their respective performance are compared. Chip thickness was found to be less using Karanja based soluble cutting fluid than the conventional cutting fluid. Long, heavy and dipolar nature of Karanja cutting fluid attributed to the good performance of the Karanja Oil. It is capable of providing a dense, homogeneous and strong lubricious film which provides better support for varying cutting speed, feed and depth of cut. Also, considerably less loss from vaporization and misting is achieved due to higher flash point and greater molecular weight.

V. SUMMARY

In this paper, different characteristics of cutting fluids required are presented. A brief review about recent work carried out using various vegetable-based oils on various materials for different machining operations. Many papers discussed the effect of these cutting fluids on machining efficiency like surface finish, cutting force and so on.

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