Performance of Vegetable Oil Based Cutting Fluid in Machining of Steel by using MQL – A Review

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Abstract- *Plants oil will play very important role for lubricant and cutting fluid industries because plant oils are renewable, natural, non-toxic, non-polluting and cheaper than artificial synthetic oils. Plant oils, in comparison to mineral oils have different properties due to their unique chemical structures. Plant oils have better lubrication ability, viscosity indices, and superior anticorrosion properties, which are due to the higher affinity of plant oils to metal surfaces. For the purpose of this work, jatropha curcas seed was extracted to obtain crude oil. Recent research has found that jatropha curcas has good potential as both, biodiesel and bio lubricant. Jatropha oil isnon edible due to the toxic content of its oil and therefore its usage as a biofuel will not be in any competition with other plant-based oils which are edible and are needed in the various food industries.*

Keywords- Jatropha, Vegetable oil, Minimum Quantity Lubrication (MQL), Surface Roughness, Tool wear, Cutting force

I. INTRODUCTION

The machining processes have an important place in the traditional production industry. Cost effectiveness of all machining processes has been eagerly investigated. This is mainly affected selection of suitable machining parameters like cutting speed, feed rate and depth of cut according to cutting tool and work piece material. The selection of optimum machining parameters will result in longer tool life, better surface finish and higher material removal rate. During machining process, friction between work piece-cutting tool and cutting tool- chip interfaces cause high temperature on cutting tool. The effect of this generated heat decreases tool life, increases surface roughness and decreases the dimensional sensitiveness of work material. This case is more important when machining of difficult-to- cut materials, when more heat would be observed. Various methods have been reported to protect cutting tool from the generated heat. Choosing coated cutting tools are an expensive alternative and generally it is a suitable approach for machining some materials such as titanium alloys, heat resistance alloys etc.

The function of the cutting fluid in the machining process is to provide lubrication and cooling and to minimize the heat produced between the surface of the part and tool. Cooling is required for the economically feasible service life of tools and the required service qualities. It cannot be eliminated completely particularly when tight tolerances are required or when the machining of difficult to cut materials is involved. This makes the Minimum Quantity of Lubrication (MQL) is an alternative, to reduce the tools friction and to prevent the adherence of material. In MQL small amount of lubricant is pulverized in a compressed air stream. The fluid used nearly less than 300ml/hr. The advantages of MQL are less polluted, Labor costs are reduced while disposal, cycle time of cleaning of machine tool/ work piece/ tool is less and during machining the working area is not flooded so if necessary the cutting operation can be observed easily. Lot of research work has been done on MQL to find the effect of feed, speed and depth of cut on surface.

Roughness, cutting forces, tool life and chip formation. The application of solid lubricant in dry machining has proved to be a feasible alternative to cutting fluid, if it can be applied properly. There is a considerable improvement in surface roughness and quality of product produced. But this is cost consuming lubricant as compared to MQL. The surface roughness quality is better than solid lubricant.

The effect of different cutting parameters on the properties of material. There are several important factors in the product quality which are surface finish, cutting temperature, tool life and coolant quality. The use of coolant generally causes life of tools and it also maintains work piece surface properties without damages. There are some negative effects and cutting fluid wastes in industries. In this paper, attention is focused on minimum quantity lubrication and recent work and some outcomes of machining factors from minimum quantity lubrication are presented. The review of the literature suggests that minimal fluid application provides several benefits in machining. It has been found that hardened alloy steel like AISI 4340 is known to be difficult to cut and a little knowledge is available in use of MQL for cooling. The main objective of the study of MQL is to reduce the surface roughness during machining and machining cost of cutting fluid. The minimum quantity lubrication also affects the surface finishing, reduce tool wear and reduce the cutting force.

II. LITERATURE REVIEW

Pollution caused by mineral based oil is severe and causes long term damage to both soil and waterways. The non-degradable and toxic properties of mineral based oil have been identified as a key factor of the problem. Research throughout the world has found a potential substitute for mineral oil, namely biodegradable lubricants derived from oil bearing plants. Lubricants are oils that are widely used for reducing friction in machinery. Mineral based lubricants have long served in applications such as automobile engines and hydraulic machinery. However there are few applications that use plant based biodegrade-able lubricants since the requirements for such lubricants are less stringent (Erhan and Asadauskas, 2000).[2]

The use of natural fats and oils by man dates back to antiquity. The chemical composition of fats and oils and their specific properties have allowed them to be used as foods, fuels and lubricants. The sources of natural fats and oils are numerous and encompass vegetable, animal and marine sources. The usefulness of fats and oils are determined by their chemical nature, and these compounds have common characteristics. Fats and oils are naturally occurring substances that consist – predominantly – of mixtures of fatty acid esters derived glycerol. [1]

The lack of extensive use of plant based oil is largely due to the poor performance characteristics of the oil. Research has found that most of these plant based oils are unstable at higher temperatures. The main factor that causes instability at high temperatures has been found to be caused by the glycerol part of the triglycerides molecule. Triglycerides are the main component of most plant bearing oils. The arrangement of the hydrogen atom in the hydroxyl group of glycerol molecules has been found to be the key feature of the instability. In order to overcome the limitations of plant oil, chemical modifications namely hydrogenation, epoxidation and transesterification can be applied to further enhance its thermal stability (Omeis et al., 1998; Konishi et al., 1998; Oosukainen et al., 1998). Chemical modifications will produce a synthetic ester with better properties. In this work, transesterification has been chosen as the reaction path whereby the glycerol part is removed and substituted by polyol (Yunus et al., 2004). Trimethylolpropane (TMP), a type of polyol, was chosen as reactant in this research work as it is cheaper and it react at lower temperature as compared to other polyol such as neopentylglycol (NPG) and pentaerythritol; thus reducing the cost (Oosukainen et al., 1998). [3]

The transesterification of jatropha bio lubricant was done via the reaction of trim ethyl-ol-propane (TMP) with Jatrophy methyl ester (JME) in a batch stirred reactor. Sodium meth oxide (NaOCH3) was used as the catalyst. JME was first synthesized from low free fatty acid content crude atrophy oil (CJO) via a transesterification process. The JME produced was then washed and purified before synthesizing the atrophybio lubricant. The two-step transesterification was deemed necessary since the process route used to produce jatropha bio lubricant was through methyl ester and not fatty acids. The single branch ester (methyl ester) was found less viscous than the original oil, CJO, and thus a second reaction with TMP produced oil with almost similar viscosities as the CJO but with better thermal-stability and pour point (Mohd. Ghazi et al.,2009). The optimum temperature for this reaction was studied by varying the temperature from 120 ◦ C to 200 ◦ C. The jatropha bio lubricant produced after the reaction was filtered and fractionated to obtain a high purity of up to 95% bio lubricant.[3]

Jatropha curcas seeds were selected as the primary source of crude plant oil and were obtained from ACGT Malaysia. Trim ethyl-ol-propane (TMP), sodium meth oxide (NaOCH3) in 30% methanol and sodium hydroxide (NaOH) pellets, used for the synthe-sis of jatropha bio lubricant were purchased from Fluka. Other analytical grade solvents, ethyl acetate and N,O-Bis (trimethylsilyl)-trifluoroacetamide (BSTFA) were also purchased from Fluka. Methanol (99%), sulphuric acid (H2SO4) and ortho-phosphoric acid (H3PO4) and an industrial grade n-hexane (C6H14) were purchased from Sigma–Aldrich. A three neck flask was used as a batch stirred reactor and fitted with a reflux condenser. A partially immersed mercury thermometer was used to determine the temperature. A magnetic hot plate was used to provide sufficient heat and a stirring facility. Whitman No. 5 filter paper was used to filter impurities from the extracted oil. The vacuum condition inside the reactor was achieved by using a BOC Edward RV8 vacuum pump and gauge.[2]

Chemically modified JCO via transesterification produces the jatropha bio lubricant with a better pour point and a comparable Viscosity Index to other plant based bio lubricants. The effects of temperature on the synthesis of jatropha bio lubricant indicate that the optimum temperature is at 150 ◦ C. The reaction follows an overall second order kinetics with a rate constant of 1.80E−01 (%wt/wt min ◦ C)−1. The estimated activation energy is 1.65 kJ/mol. The pour point for jatropha bio lubricant is −6 ◦ C for all the tested temperatures with the Viscosity Index (VI) ranging from 178 to 183. The viscosities, wear scar, oxidative stability and pour point of jatropha bio lubricant are comparable to other plant based bio lubricants. The present emphasis on conservation has brought about renewed interest in the use of these ‘‘natural oils’’ for non-edible purposes. The sources of natural oils and fats come from various plants and animals-based raw materials (e.g., soy bean, palm, tallow, lard). Plant oils are superior in terms of biodegradability, especially when compared to mineral oils. Attention has been focused on technologies that incorporate plant oils as bio fuels and industrial lubricants, due to the fact that they are renewable and non-toxic.[5]

The application of plant oils and animal fats for industrial purposes, specifically as lubricats, has been in practice for many years. Environmental and economic reasons lead to the utilization of plant oils and animal fats, or used oils and fats after their appropriate chemical modification. Plant oil-based lubricants and derivatives have excellent lubricity and bio-degradability, for which they are being investigated as a base stock for lubricants and functional fluids [4].

Cutting fluids are used in metal machining for a variety of reasons such as improving tool life, reducing workpiece thermal deformation, improving surface finish and flushing away chips from the cutting zone.In addition, flash points greater than 3008C classify plant oils as non-flammable liquids. To improvement characteristics such as sensitivity to hydrolysis and oxidative attacks, poor low temperature behavior, and low viscosity index coefficients, plant oils may be chemically modified. Plant oils may be used in almost all automotive and industrial applications. It will become more difficult to find a balance between the economic possibilities of bio lubricants and their ecological requirements. Products with toxicological and ecological issues must be excluded from further use in lubricants, if they pose a significant health risk. However, it must be taken into account that the technological level of lubricants will decrease if unnecessary restrictions are put into place. In conclusion, plant bio-based oils are an important part of new strategies, policies, and subsidies, which aid in the reduction of the dependence on mineral oil and other non-renewable sources.[7]

MQL machining was performed much superior compared to the This paper presents the effects of minimum quantity lubrication (MQL) by vegetable oil-based cutting fluid on the turning performance of low alloy steel AISI 9310 as compared to completely dry and wet machining in terms of chip–tool interface temperature, chip formation mode, tool wear and surface roughness. The minimum quantity lubrication was provided with a spray of air and vegetable dry and wet machining due to substantial reduction in cutting zone temperature enabling favorable chip formation and chip–tool interaction. It was also seen from the results that the substantial reduction in tool wears resulted in enhanced the tool life and surface finish. Furthermore, MQL provides environment friendliness (maintaining neat, clean and dry working area, avoiding inconvenience and health hazards due to heat, smoke, fumes, gases, etc. and preventing pollution of the surroundings) and improves the machinability characteristics.[6]

The total manufacturing cost would be lower as compared to the cost of traditional overhead flood cooling using large amounts of water-miscible MWFsfor the same cutting conditions, with dry cutting and wet cutting, the minimum quantity of cutting fluid method led to lower cutting forces, temperatures, better surface finish, longer tool life. In addition, it was observed that tightly coiled chips were formed during wet turning and during minimal application, while long snarled chips were prevalent during dry turning. It must be noted that during minimal application, the rate of fluid was only 0.05% of that used during wet turning. The major part of the fluid used during minimal quantity application was evaporated; the remnant was carried out by work and chips and was too low in volume to cause contamination of the environment.[9]

Based on the results of the present experimental investigation, the following conclusions can be drawn:MQL provided significant improvements expectedly, though in varying degree, in respect of chip formation modes, tool wear and surface finish throughout the range of Vc and S0 undertaken mainly due to reduction in the average chip–tool interface temperature. Wet cooling by soluble oil could not control the cutting temperature appreciably and its effectiveness decreased further with the increase in cutting velocity and feed rate. The present MQL systems enabled reduction in average chip–tool interface temperature up to 10% as compared to wet machining depending upon the cutting conditions and even such apparently small reduction, unlike common belief, enabled significant improvement in the major machinability indices. The chips produced under both dry and wet condition are of ribbon type continuous chips at lower feed rates and more or less tubular type continuous chips at higher feed rates. When machined with MQL the form of these ductile chips did not change appreciably but their back surface appeared much brighter and smoother. This indicates that the amount of reduction of temperature and presence of MQL application enabled favorable chip–tool interaction and elimination of even trace of built-up edge formation. The significant contribution of MQL jet in machining the low alloy steel by the carbide insert undertaken has been the reduction in flank wear, which would enable either remarkable improvement in tool life or enhancement of productivity (MRR) allowing higher cutting velocity and feed. Such reduction in tool wear might have been possible for retardation of abrasion, decrease or prevention of adhesion and diffusion type thermal sensitivity wear at the flanks and reduction of built-up edge formation that accelerates wear at the cutting edges by chipping and flaking. Minimum quantity lubrication reduces deep grooving, which is very detri-mental and may cause premature and catastrophic failure of the cutting tools. [6]

Surface finishes also improved mainly due to reduction of wear and damage at the tool-tip by the application of MQL.

Cutting fluids of various types are usually employed to control the heat generated in machining. The continued application of conventional cutting fluids is being challenged by the need to reduce overall volume of fluids, minimize health risks and bio-confirmation. Functions such as improving tool life and machining process efficiency, enhancing surface integrity and part accuracy, reducing cutting forces and vibrations are obtained by using cutting fluids. Mineral, synthetic and semi-synthetic cutting fluids involve in the ecological cycle with air, soil and water and their toxicity effect damages the ecosystem. In the reviewed papers researchers suggested that to overcome problems in machining, vegetable based cutting fluids can be used to optimize machining conditions.[3]

III. CONCLUSION

The effects of minimum quantity lubrication (MQL) by vegetable oil based cutting fluid on the turning performance of low alloy steel AISI 9310 as compared to completely dry and wet machining in terms of chip–tool interface temperature, chip formation mode, tool wear and surface roughness. The minimum quantity lubrication was provided with a spray of air and vegetable oil. MQL machining was performed much superior compared to the dry and wet machining due to substantial reduction in cutting zone temperature enabling favorable chip formation and chip–tool interaction. Jatropha bio lubricant is also the better lubricant for cutting fluid along with MQL. Jatropha oils have better lubrication ability, viscosity indices, and superior anticorrosion properties, which are due to the higher affinity of plant oils to metal surfaces. It was also seen from the results that the substantial reduction in tool wears resulted in enhanced the tool life and surface finish. Furthermore, Jatropha bio lubricant along with MQL provides environment friendliness maintaining neat, clean and dry working area, avoiding inconvenience and health hazards due to heat, smoke, fumes, gases, etc. and preventing pollution of the surroundings and improves the machinability characteristics.

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