MQL: An Emerging Cooling Technique for Cutting Operation

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Abstract— Micro lubrication or also known as minimum quantity lubrication (MQL) serves as an alternative to flood cooling by reducing the volume of cutting fluid used in the machining process. Minimum quantity lubrication (MQL) has increasingly found its way into the area of metal cutting machining and in many areas, has already been established. The adverse health effects caused by the use of coolants and on another side the potential economic advantages of greener machining methods like MQL are drawing manufacturer's attention to adapt and develop new methods of using lubricants. The aim of this research is to determine if the minimal quantity lubrication (MQL) technique in turning gives some advantages in terms of work piece surface roughness using work piece material as EN-31 steel and carbide cutting tool material. Fluid selection is important for MQL because it must be a superior fluid such as vegetable oil or synthetic oil. The costs of these superior fluids are higher but eliminate the need for costly fluid recycling and disposal services. We used Taguchi method to plan and conduct experiments to obtain enough optimized and relevant data. It was found that, MQL produced better surface finish as compared to wet machining. The result can significantly reduce cost and environmental pollution.

Key words: MQL, EN-31, cutting fluid, metal cutting, machining, carbide cutting tool, wet machining, surface roughness

I. INTRODUCTION

To Manufactured any product there must removal of material from it by applying processes like Drilling, Turning, Boring, and Milling etc. on it. And this is known as Machining process. so machining is an important part of any production Industry. During Machining operation large amount of heat is generated between contact of tool and work piece and that is not desirable case because it increases power consumption, affects product quality and also result in early failure of cutting tool. Machining is manufacturing process that

Involves removing materials using cutting tools for getting rid of the unwanted materials from some work piece and converting it into the shape you desire. A large piece of stock is used for cutting the workpiece. The large stock might be in any shape such as solid bar, flat sheet, beam or even hollow tubes. The process can also be performed on some existing part like forging or casting.

Lubrication during machining offers great potentials in solving this problem. Lubrication not only reduces frictional force and enhance tool-life, it equally help cool the tool and work piece sufficiently and maintain them at ambient condition. This ensures that error of size resulting from thermal expansion is eliminated, metallurgical transformation is prevented and thus, dimensional accuracy and good surface finish is guaranteed. Several options of cutting fluid have been explored for lubrication. Some of these are universal solvent; petroleum based metal cutting fluid and vegetable oil based metal cutting fluid. Conventional cutting fluids are essentially petroleum based which creates some techno-environmental problems such as environmental pollution and biological problems to the operators while used thoroughly. There are many variations in the process of applying cutting fluid during cutting operation. Such as Flood application, Mist application, Pulse jet application etc.

One such alternative is the use of minimum quantity lubrication also known as MQL. The concept of minimum quantity lubrication (MQL) is delivering a very small amount of coolant to the chip tool interface in the form of an oil mist or aerosol, as opposed to traditional techniques of flooding the work piece and tool with a substantial volume of liquid coolant.

Minimum Quantity lubrication is also known as semi dry lubrication or micro lubrication. The concept of MQL suggests usage of a very insignificant amount of cutting fluid in the range of 50-500 ml per hour as compared to flood cooling which consumes liters of cutting fluid per hour. Minimum quantity lubrication represents an interesting alternative which combines the functionality of cooling lubrication with an extremely low consumption of cutting fluids. MQL has been suggested since a decade ago as a mean of addressing the issues of environmental and occupational hazards associated with the airborne cutting fluid particles on factory shop floors leading to degradation in health of the worker. Then minimization of cutting fluid also leads to economic benefits by way of saving lubricant costs and work piece/tool/machine cleaning cycle time.

However, the use of cutting fluids has been questioned in the recent times in concern with environmental hazards, health of the worker, expenditure for lubricant rectification, maintenance and disposal. In spite of many attempts to discourage the use of cutting fluids completely, it is still essential to obtain an economical tool life and required surface integrities. It is applicable in particular if narrow tolerances, high dimensional accuracies are required or if hard to cut metals are machined. It is estimated that the cost of cutting fluids is in the range of 7%-17% of the total costs in the industry.

II. MINIMAL QUANTITY LUBRICATION

The concept of MQL was suggested a decade ago as a mean for addressing the issues of environmental intrusiveness and occupational hazard associated with airborne cutting fluid particles. The MQL needs to be supplied at high pressure and impinged at high speed through the spray painting gun on the cutting zone. Considering the conditions required for the present work and uninterrupted supply of MQL at a constant pressure of around 6 bar over a reasonably long cut, a MQL delivery system was designed, fabricated and used. The schematic view of the MQL set-up is shown in Fig 1.

Cutting tools. Consequently, elimination on the use of cutting fluids, if possible, can be a significant economic incentive. Considering the high cost associated with the use of cutting fluids and projected escalating costs when the stricter environmental laws are enforced, the choice seems obvious. Because of them some alternatives has been sought to minimize or even avoid the use of cutting fluid in machining operations. Some of these alternatives are dry machining and machining with minimum quantity lubrication (MQL).

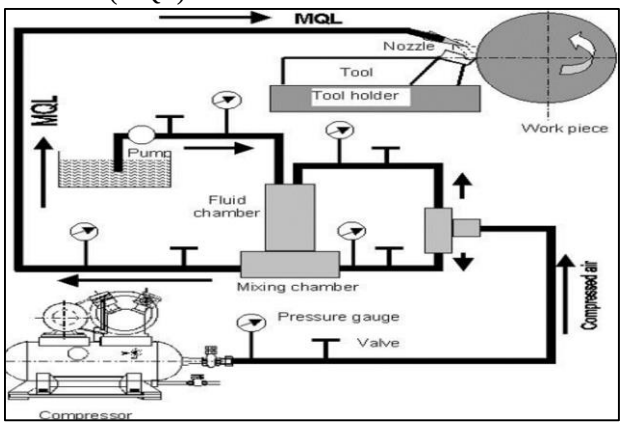

Fig. 1:

A. *Working Of (MQL)*

High cutting zone temperature is generally tried to be controlled by employing flood cooling by soluble oil. In high speed–feed machining, conventional cutting fluid application fails to penetrate the chip-tool interface and thus cannot remove heat effectively and the use of cutting fluid has become more problematic in terms of both employee health and environmental pollution. Addition of extreme pressure additives in the cutting fluids does not ensure penetration of coolant at the chip–tool interface to provide lubrication and cooling. Minimum quantity lubrication (MQL) is based on the principle that a drop of liquid is split by an air flow, distributed in streaks and transported in the direction of flow of air. The consumptions of oil in industrial applications are in the range of the length of machining was increased wear by the tool increased. MQL consists of a mixture of pressurized air and oil micro-droplets applied directly into the interface between the tool and chips. However, the question of how the lubricants can decrease the friction under very high temperature and loads is still not answered especially for long engagements times. MQL decreased the contact length compared to dry cutting for both short and long engagement time. Addition of extreme pressure additives in the cutting fluids does not ensure penetration of coolant at the chip–tool interface to provide lubrication and cooling. However, high-pressure jet of vegetable oil, when applied at the chip–tool interface, could reduce cutting temperature and improve tool life to some extent.

B. *Mql on Straight Turning Operation*

Turning is a form of machining, a material removal process, which is used to create rotational parts by cutting away unwanted material. The turning process requires a turning machine or lathe, workpiece, fixture, and cutting tool. The workpiece is a piece of pre-shaped material that is secured to the fixture, which itself is attached to the turning machine, and allowed to rotate at high speeds. The cutter is typically a single-point cutting tool that is also secured in the machine, although some operations make use of multi-point tools. The cutting tool feeds into the rotating workpiece and cuts away material in the form of small chips to create the desired shape.

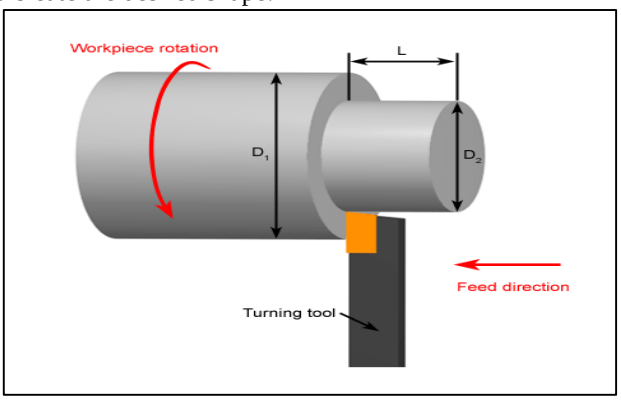

Fig. 2:

Turning is used to produce rotational, typically axis-symmetric, parts that have many features, such as holes, grooves, threads, tapers, various diameter steps, and even contoured surfaces. Parts that are fabricated completely through turning often include components that are used in limited quantities, perhaps for prototypes, such as custom designed shafts and fasteners. Turning is also commonly used as a secondary process to add or refine features on parts that were manufactured using a different process. Due to the high tolerances and surface finishes that turning can offer, it is ideal for adding precision rotational features to a part whose basic shape has already been formed.

III. LUBRICATION

The main task of the MQL systems is the targeted supply of an appropriate lubricant to the contact point of the tool. For fault-free, low-emission metal machining when using minimum quantity lubrication, lubricants with very good lubricity and a high thermal rating are best. Lubricants perform the following key functions

- Keep moving parts apart.
- Reduce friction.
- Transfer heat.
- Carry away contaminants and debris.
- Transmit power.
- Protect against wear.
- Prevent against wear.
- Seal for gases.
- Stop the risk of smoke and fire of objects.

The cutting fluid can interchangeably be a coolant and a lubricant and this depends upon the temperature, the cutting speed and type of machining operation .Generally at high cutting speed it acts as a coolant thus cools the cutting zone and at low cutting speed operation such as broaching and tapping, it acts as a lubricant thus reduces the formation of Built-up-edge (BUE) and increases the surface finish.
Lubricants generally used are classified in four categories:

- Straight oils (mineral or petroleum oil)
- Synthetic fluids (alkaline inorganic compounds)
- Soluble oils (mineral + water)

Semi synthetic fluids (synthetic +soluble oil)

A. *Lubricant (Vegetable Oil)*

It is used as a coolant during the machining. From the view point of environmental safety, health, performance and cost, high biodegradability, high viscosity index and good thermal stability. The vegetable based oil could produce better result than the mineral reference oil in view of increased machining performance as well as renewable source. The highly lubricating properties of vegetable oil are made possible by the fundamental composition of the vegetable oil molecules, as well as the chemical structure of the oil itself. For coolants based on vegetable oils, lubricity arises from the intrinsic "oiliness" of its vegetable oil constituents; and its properties are the direct result of the vegetable oil's "smart molecules." These molecules are long, heavy, and dipolar in nature; that is, the ends of the molecules have opposing electrical charges.

The "polar heads" of the molecules have a great chemical affinity for metal surfaces and attach themselves to the metal like little magnets. The result is a dense, homogeneous alignment of vegetable oil molecules, perpendicular along the metal surface that creates a thick, strong, and durable film layer of lubricant. This strong lubricating film gives the vegetable oil a greater capacity to absorb pressure.

The selection of vegetable oil as a cutting fluid is done dependent on its inherent properties such as:

- Cultivation & refining of constituents for specific performance properties & technical requirements.
- Highly lubricating properties.
- Higher viscosity index.
- Non-toxicity, higher polar lubrication bonding and greater molecular weight

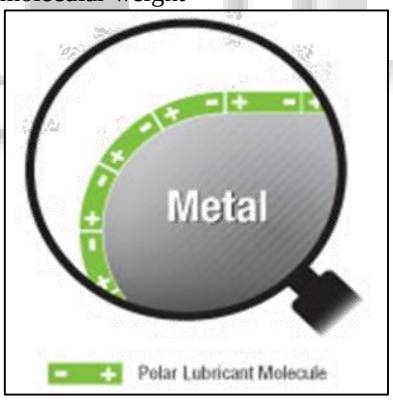

Fig. 3:

IV. WORKPIECE

A workpiece is an object being worked on with a tool or machine. The **EN-31** high carbon alloy steel by its character has high resisting nature against wear and can be used for components which are subjected to severe abrasion, wear and high surface loading and thus are used as workpiece material. The EN-31 series alloy steel is generally used in ball and roller bearing, spinning tools, beading rolls, punches and dies.

V. CUTTING TOOL

In the context of machining, a cutting tool or cutter is any tool that is used to remove material from the workpiece by means of shear deformation. Cutting may be accomplished by single-point or multipoint tools. The cemented carbide material is used as a cutting tool material. The cemented carbide tool is moderately expensive than the other cutting tools and is common tool material used in industry today. It is offered in several grades containing different proportion of tungsten carbide and binder (usually cobalt). This material has high resistance to abrasion. For high solubility in iron, it requires the additions of tantalum carbide and niobium carbide for steel usage. Its main usage is in turning tool bits although it is very common in milling cutters and saw blades. The hardness of the material is about HRA 93 which would be suitable for using it as a cutting tool material.

VI. AIMS OF MQL

The aim of MQL machining is

- Reduction of thermal stresses at the tool point
- Less tool wear
- Effective chip evacuation from deep holes
- Reduction of cooling lubricant requirement
- High cooling and lubrication effect especially in deep holes
- Reduction in component cleaning costs
- Reduction in cooling lubricant disposal costs
- Reduction in cost of disposal of scrap contaminated with cooling lubricant
- Protection of environment and health through lower Emissions

VII. ADVANTAGES OF MQL

- Due to the omission of supply and disposal of coolant, high savings are possible.
- After optimization of processes, a higher tool life can be expected.
- There will be no expenditures for control and care of coolant.
- No used emulsions will accumulate.
- Accidents due to large quantities of leaking coolant are avoided.
- Due to a dry machine, the risk of accidents at work are reduced.
- Airway or skin diseases caused by coolants can be avoided.

VIII. CONCLUSION

The results obtained in several researches prove that MQL does generate a significant amount of mist compared to flood cooling. With these technologies in place however, machining is safe for both operators and the environment, particularly when vegetable based lubricants are used. On the other hand, the processes of lubrication and cooling in MQL are yet to be well understood. The use of MQL also decreases the production cost by reducing the coolant costs. It can be concluded that adaption of MQL coolant system over conventional coolant system yields significant advantages like reduction in costs, providing good environmental working conditions etc.

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