PERFORMANCE VALIDATION OF NEWLY DEVELOPED MINIMUM QUANTITY LUBRICATION (MQL) SETUP ON CAPSTAN LATHE

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Abstract: **In all machining processes, tool wear is a natural phenomenon and it leads to tool failure. The growing demands for high productivity of machining need use of high cutting velocity and feed rate. Such machining inherently produces high cutting temperature, which not only reduces tool life but also impairs the product quality. Metal cutting fluids changes the performance of machining operations because of their lubrication, cooling, and chip flushing functions but the use of cutting fluid has become more problematic in terms of both employee health and environmental pollution. The use of cutting fluid generally causes economy of tools and it becomes easier to keep tight tolerances and to maintain work piece surface properties without damages. Due to these problems, 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 & optimum use of lubrication quantity. Hence we choose to go with optimization of lubrication quantity by using Minimum Quantity Lubrication (MQL) setup for optimization.**

Keywords: **Minimum Quantity Lubrication (MQL), Surface Roughness**

I. INTRODUCTION:

High production machining of metals inherently generates high cutting zone temperature. Such high temperature causes dimensional deviation and premature failure of cutting tools. It also impairs the surface integrity of the product by inducing tensile residual stresses and surface and subsurface micro cracks in addition to rapid oxidation and corrosion. In high speed machining, conventional cutting fluid application fails to penetrate the chip-tool interface and thus cannot remove heat effectively. 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 soluble Oil, when applied at the chip-tool interface, could reduce cutting temperature and improve tool life to some extent. However, the advantages caused by the cutting fluids have been questioned lately, due to the several negative effects they cause. When inappropriately handled, cutting fluids may damage soil and water resources, causing serious loss to the environment. Therefore, the handling and disposal of cutting fluids must obey rigid rules of environmental protection. On the shop floor, the machine operators may be affected by the adverse effects of cutting fluids, such as by skin and breathing problems.

For the companies, the costs related to cutting fluids represent a large amount of the total machining costs. Several research workers state that the costs related to cutting fluids are frequently higher than those related to 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, Machining with minimum quantity lubrication (MQL).

Dry machining is now of great interest and actually, some researcher's meet with success in the field of environmentally friendly manufacturing. In reality, however, they are sometimes less effective when higher machining efficiency, better surface finish quality and severer cutting conditions are required. For these situations, semi-dry operations utilizing very small amounts of cutting lubricants are expected to become a powerful tool and, in fact, they already play a significant role in a number of practical applications. Minimum quantity lubrication (MQL) refers to the use of cutting fluids of only a minute amount typically of a flow rate of 50 to 500 ml/hour which is about three to four orders of magnitude less than the amount commonly used in flood cooling condition. The concept of minimum quantity lubrication sometimes referred to as near dry lubrication or micro lubrication has been suggested since a decade ago as a means of addressing the issues of environmental intrusiveness and occupational hazards associated with the airborne cutting fluid particles on factory shop floors. The minimization of cutting fluid also leads to economical benefits by way of saving lubricant costs and work piece/tool/ machine cleaning cycle time.

Significant progress has been made in dry and semi dry machining recently, and minimum quantity lubrication machining in particular has been accepted as a successful semidry application because of its environmentally friendly characteristics. Some good results have been obtained with this technique used this technique in reaming process of gray cast iron and aluminum alloy with coated carbide tools and concluded that it caused a reduction of tool wear when compared with the completely dry process and, consequently, an improvement in the surface quality of the holes. Also used this technique in turning process of medium carbon steel and concluded that, in some cases, a mixture of air and soluble oil has been shown to be better than the overhead flooding

application of soluble oil. The drilling of aluminum-silicon alloys is one of those processes where dry cutting is impossible due to the high ductility of the work piece material. Without cooling and lubrication, the chip sticks to the tool and breaks it in a very short cutting time. Therefore, in this process a good alternative is the use of the MQL technique. The review of the literature suggests that minimum quantity lubrication provides several benefits in machining. The main parameters that we can investigate the role of Minimum Quantity Lubrication (MQL) on cutting temperature, tool wear, and surface roughness can also be changed or measured.

The review of the literature suggests that minimum quantity lubrication provides several benefits in machining. The main objective of the present work is to experimentally investigate the role of minimum quantity lubrication (MQL) on cutting temperature, tool wear, surface roughness and dimensional deviation in turning materials like steel, aluminum, brass and magnesium at industrial speed-feed condition on Capstan lathe by tungsten carbide insert (SNNM 1208) and compare the effectiveness of MQL with that of dry machining.

II. EXPERIMENTAL SETUP

In this experiment we have made the setup as per the block diagram that follows.

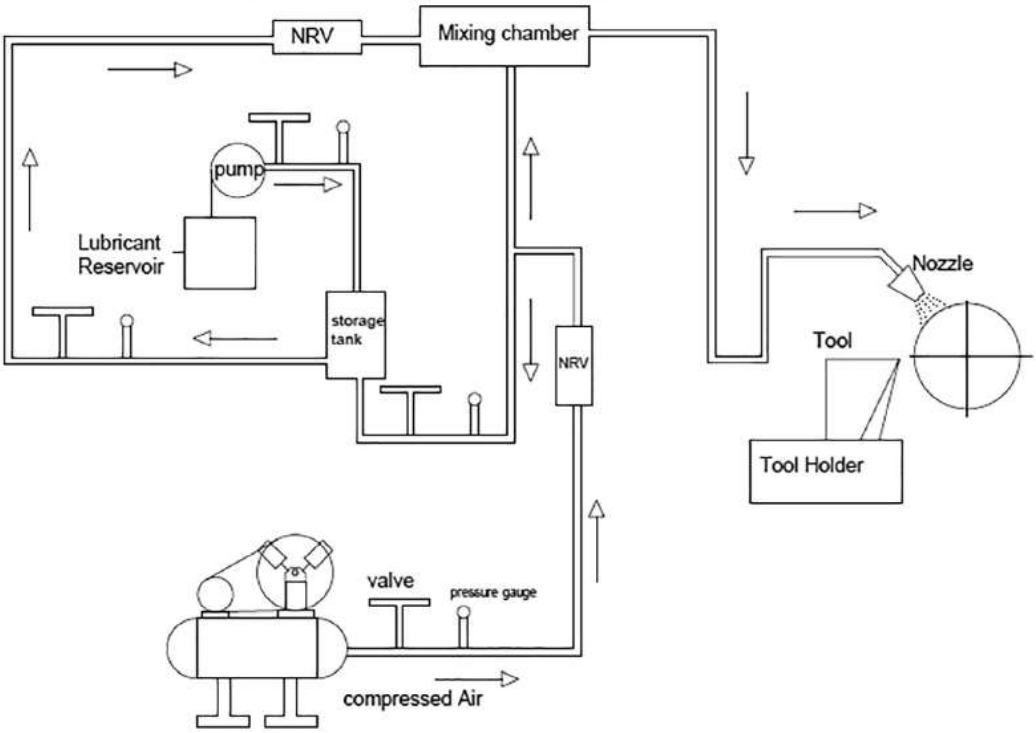

Figure 1: Block diagram of MQL setup

The components that used in the near dry lubrication are,

1) Compressor
2) Storage tank
3) Electric motor
4) Centrifugal pump
5) Mixing chamber
6) External nozzle

Compressor

The process of increasing the pressure of air, gas or vapor by reducing its volume is called compression and the device used to carry on this process is called compressor. A machine which takes air or gas during suction stroke at low pressure and then compresses it to high pressure in a piston – cylinder arrangement is known as reciprocating compressor. Compressor is a machine that used for increase the pressure of the air. The compressor may be low pressure generated up to 7 bar is enogh to run this project. The compressor used in here is reciprocating type, single cylinder & single acting air compressor with following specifications.

Power	: 1 HP
Revolution (RPM)	: 750 RPM
Capacity	: 3.4 cu / ft
Work pressure	: 7 kg / cm2
Design pressure	: 14 kg / cm2

Storage Tank

The storage tank used here is made up of steel. This tank is cylindrical in shape with four openings (ports).

Port 1 is at top of the tank used to supply the lubricant into the cylinder from the pump.

Port 2 is used to supply the air from the compressor and it is situated at side of the tank.

Port 3 is also at side of the tank which used for output from the cylinder has the mixture of compressed air and lubricating oil.

Port 4 is situated at bottom of the tank used for remove the lubricating oil from the tank when this setup is not in use. The specification of the storage tank used in this setup is follows,

Radius of the storage tank (R) = 0.125 m
Length of the storage tank (L) = 0.55 m
W.K.T volume of the cylinder (V) =ΠR2L / 2
V = Π x (0.125)2 x 0.55 / 2
V = 13.498 x 10-3 m3
V = 13.498 liters.

Electric Motor

The Main Application of electric motor is to run the centrifugal pump that used for supplying lubricant oil in to the storage tank. The specification of the electric motor is as follows,

Power	: 0.5 HP OR 0.37 kw
Revolution (RPM)	: 2800 RPM
Amps	: 2.5 A
Head	: 33 m
Quantity	: 30 LPM

Centrifugal Pump

The name centrifugal (C.F) pump to this pump is because of the use of principle of centrifugal force in this pump (v2 = 2gh). Centrifugal pump is a machine that imparts energy on the fluid to flow from higher level to low level or vice versa. C.F pump is extremely simple machine that consists of two basic parts namely impeller and casing. The C.F pump working is simple as its design. It is filled with fluid when impeller rotated and this rotation imparts on the fluid causes it to exits on the impeller vanes with higher velocity then it entered in the pump. This outward flow reduces pressure at the impeller eye, allowing more fluid to enter. The liquid that exits the impeller is collected in the casing where its velocity is converted into pressure before it leaves the pump's discharge. This pump is has a foot valve which connected to the sump of the lubricating oil tank. The output of the pump is connected to the port 1 of the storage tank. The pump here is used is centrifugal because it can be run on no load condition.

Mixing Chamber

We use the mixing chamber in order to mix the lubricant with the compressed air. This mixing chamber is made of a special type material and also it has three ports. One is the inlet from the storage tank that has the mixture of lubricating oil and compressed air. Another port is situated at extreme end that is connected to the inlet of the nozzle. The third port has the connection of another compressed air connection because of most efficient mixing of air and lubricating oil.

External Nozzle

Nozzle is a duct of varying cross – sectional area in which the velocity increases with the corresponding drop in the pressure. Its main function is to produce a jet of steam with high velocity. For example, nozzle is used in steam turbines, in jet engines, rocket motors, flow measurement and many other applications. The nozzle that we used here is convergent type. In convergent nozzle, the cross sectional area decreases from the inlet section to the outlet section.

For nozzle which used here,
Inlet diameter of nozzle d1 = 8.1 mm
= 8.1 x 10-3 m
Outlet diameter of nozzle d2 = 6.42 mm
= 6.42 x 10-3 m
W.K.T area A = Πd2 / 4 m2
Therefore inlet area of nozzle A1 = Π x (8.1 x 10-3)2 / 4
= 5.15299 x 10-5 m2
Outlet area of nozzle A2 = Π x (6.42 x 10-3)2 / 4
= 3.23712 x 10-5 m2

III. EXPERIMENTAL WORKING PROCESS

Working

The MQL needs to be supplied at high pressure and impinged at high speed through the nozzle at the cutting zone. Considering the conditions required for the present research work and uninterrupted supply of MQL at constant pressure over a reasonably long cut, a MQL delivery system has been designed, fabricated and used. The thin but high velocity stream of MQL was projected along the cutting edge of the tool. So that the coolant reaches as close to the chip-tool and the work-tool interfaces as possible. The MQL jet has been used mainly to target the rake and flank surface and to protect the auxiliary flank to enable better dimensional accuracy.

MQL is expected to provide some favorable effects mainly through reduction in cutting temperature. The effectiveness, efficiency and overall economy of machining any work material by the given tool depends largely only on the machinability characteristics of the tool-work material under the recommended condition. Machinability is usually judged by cutting temperature which affect product quality and cutting tool performance, pattern and mode of chip formation, magnitude of the cutting forces which affects power requirement, dimensional accuracy and vibration, surface finish and Tool wear and tool life. In this MQL method, first oil is pumped into the storage container using the motor with pump. At the same time the compressed air is made to pass into the storage tank with high pressure at 5 bar (500000 N / m2). Also the compressed air is taken from the inlet of storage

tank using three ways. A non return valve is fixed in the storage tank in order to avoid the back flow of air to compressor. By using the motor and pump, the lubricant is pumped into the storing tank from the sump. The lubricant used here may subject to vary with lubricant used. On storage tank the compressed air and lubricant made to mix.

This is because of high pressure at low volume equipment the lubricant is atomized and made to mix with the compressed air. From there the air lubricant mixture is made to pass to mixing chamber. In mixing chamber it is going to mix very agitatedly. Also the compressed air which from three ways is also made to pass into mixing chamber. So the mixture of compressed air with lubricant is very efficient. Then this mixture is made to pass through the nozzle. In between nozzle and mixing chamber a non return valve (NRV) is fixed. Its because to avoid this mixture backflow into the mixing chamber. In nozzle the mixture pressure energy is reduced and kinetic energy is developed from it. So a high velocity spray of air lubricant mixture is applied with decreased pressure at the range of 3 bar. If we want to supply air only to the machining as a lubricant, the lubricant supply is closed and only air is allowed. This type of machining is called dry machining which we discussed earlier. Then machining of the different work pieces is done at different federate and depth of cut on capstan lathe. The machined work piece is then made to analyzed for its surface temperature and surface roughness. These value been tabulated in tabular column. The chip formed during this process are taken and made to analyze.

Advantages

Minimum Quantity Lubrication (MQL) has many advantages compared with traditional wet machining and dry machining. Many researchers have suggested that MQL shows potential competitiveness in terms of tool life, surface finish and cutting forces in turning, milling, drilling, reaming and taping. The advantages of MQL application on machining operations are: Provides lubrication on machines set up for flood or high-pressure, high-volume coolant delivery and recovery, Reduces mist and spray, therefore, offering an attractive alternative on unenclosed machines like a typical tool room mill or lathe, Reduces or eliminates problems associated with thermal shocking of the cutting tool, MQL technique produces a significant role in terms of reducing cutting temperature between tool-work piece interfaces. MQL can reduce the corner and flank wear more effectively than a solution type of cutting fluid, Particularly well suited for tools and operations either generated heat or abrasion to the flank of the tool is the major players to tool failure, Reduces both cost of buying and disposing of conventional cutting fluid if all operations can be run with MQL.

Experimental Setup

Figure 2: Experimental setup

IV. MATERIALS & TESTING

Material

In this test we use four types of work pieces, they are

1. Steel
2. Aluminum
3. Brass
4. Magnesium

In all this material magnesium is very hard material and very hard to machining and also its main advantage is it is light in weight compared to other materials.

Figure 3: Different work pieces

Tool Dynamometer

Tool dynamometer is an instrument used for measuring the tool geometry and tool force at cutting insert and tool force analysis. Dynamometers are devices used to measure cutting forces in machining operation. The cutting force cannot be detected or quantified directly but their effect can be sensed using Transducer. For example, a force which can neither be seen nor be gripped but can be detected and also quantified respectively by its effect and the amount of those effects (on some material) like elastic deflection, deformation, pressure, strain etc. These effects, called signals, often need proper conditioning for easy, accurate and reliable detection and measurement.

Figure 4: Tool dynamometer

Surface Roughness Measuring Instrument

Surface roughness is defined as the irregularities which are inherent in the production process.(e.g. cutting tool or abrasive grit). Roughness It is quantified by the deviations in the direction of the normal vector of a real surface from its ideal form. If these deviations are large, the surface is rough; if they are small, the surface is smooth. Since the individual roughness irregularities are too small to see with the naked eye and a surface roughness measuring instrument is required. A small stylus is drawn across the surface at a constant speed for a set distance. An electrical signal is obtained and amplified to produce a much-enlarged vertical magnification. This signal may be displayed on both graph and screen outputs, together with numerical values that characterize the surface texture. The ISO standard for surface roughness measurements is a 60° or 90° conical stylus with a spherical tip of 2µm radius. However, this is quite a delicate stylus, and needs an instrument with excellent mechanical properties to fully exploit it.

Figure 5: surface roughness measuring instrument

Chip Tool Interface Temperature

This is measured by the infrared optical thermometer. It has laser point source detection and temperature is measured by passing infrared rays over the source destination and accurate temperature of that point is shown in the digital indicator. This infrared temperature indicator measures the temperature in the range of -50ºC to 550ºC.

Chip Morphology

These chips during every parameter change in turning are collected separately in a stick cover for taking chip morphology test.

Figure 6: magnesium chip formed

Figure 7: brass chip formed

Figure 8: mild steel chip formed

Figure 9: aluminum chip formed

V. EXPERIMENTAL RESULTS AND DISCUSSION

Table 1: Experimental conditions

S.NO	Equipment & specimen	Specification
1.	Machine tool	Capstan lathe
2.	work specimen I. Steel II. Aluminum III. Brass IV . Magnesium	 Φ25 x 300 mm Φ25 x 300 mm Φ25 x 300 mm Φ25 x 300 mm
3.	Cutting tool (insert) I. Cutting insert II. Tool holder III. Working tool geometry	Tungsten carbide
4.	Process parameters I. Feed rate II. Depth of cut	 0.25, 0.5, 0.75 mm / rev 0.5, 1, 1.5 mm
5.	MQL supply	100 ml / litre
6.	Environment	Dry and Minimum Quantity Lubrication(MQL)

Table 2: Experimental Results

INPUT PARAMETERS				OUTPUT PARAMETERS			
				DRY LUBRICATION		MQL	
Material	*Tool*	*Depth of cut (mm)*	*Feed (mm/rev)*	*Temperature (oc)*	*Surface roughness (µm)*	*Temperature (oc)*	*Surface roughness (µm)*
1	Tc	0.5	0.25 0.5 0.75	500 595 645	4.5 3.75 3.25	290 310 325	3.20 3.00 2.85
1	Tc	1.0	0.25 0.5 0.75	580 660 690	5.75 4.30 4.15	310 320 325	3.5 3.25 3.15
1	Tc	1.5	0.25 0.5 0.75	625 670 710	7.50 7.35 6.95	330 340 355	3.70 3.55 3.45
2	Tc	0.5	0.25 0.5 0.75	290 345 375	3.90 3.75 3.50	210 245 265	2.70 2.55 2.40
2	Tc	1.0	0.25 0.5 0.75	310 350 380	4.20 3.95 3.50	290 315 335	3.15 3.00 2.70
2	Tc	1.5	0.25 0.5 0.75	390 455 510	4.60 4.25 3.90	310 345 375	3.50 3.20 3.10
3	Tc	0.5	0.25 0.5 0.75	450 490 510	4.70 4.85 4.95	250 275 300	4.20 4.30 4.40
3	Tc	1.0	0.25 0.5 0.75	550 590 620	4.90 4.99 5.20	315 335 410	4.6 0 4.55 4.67
3	Tc	1.5	0.25 0.5 0.75	660 690 720	5.10 5.20 5.30	435 470 490	4.70 4.80 5.10

4	Tc	0.5	0.25 0.5 0.75	635 665 690	6.90 6.75 6.55	320 350 380	6.50 6.32 6.10
4	Tc	1.0	0.25 0.5 0.75	650 690 710	7.20 7.05 6.85	350 380 395	6.70 6.50 6.45
4	Tc	1.5	0.25 0.5 0.75	660 715 750	7.60 7.30 7.10	390 420 450	7.35 7.15 7.00

1 – material steel, 2 – material aluminium, 3 – material brass, 4 – material magnesium, Tc – Tungsten carbide

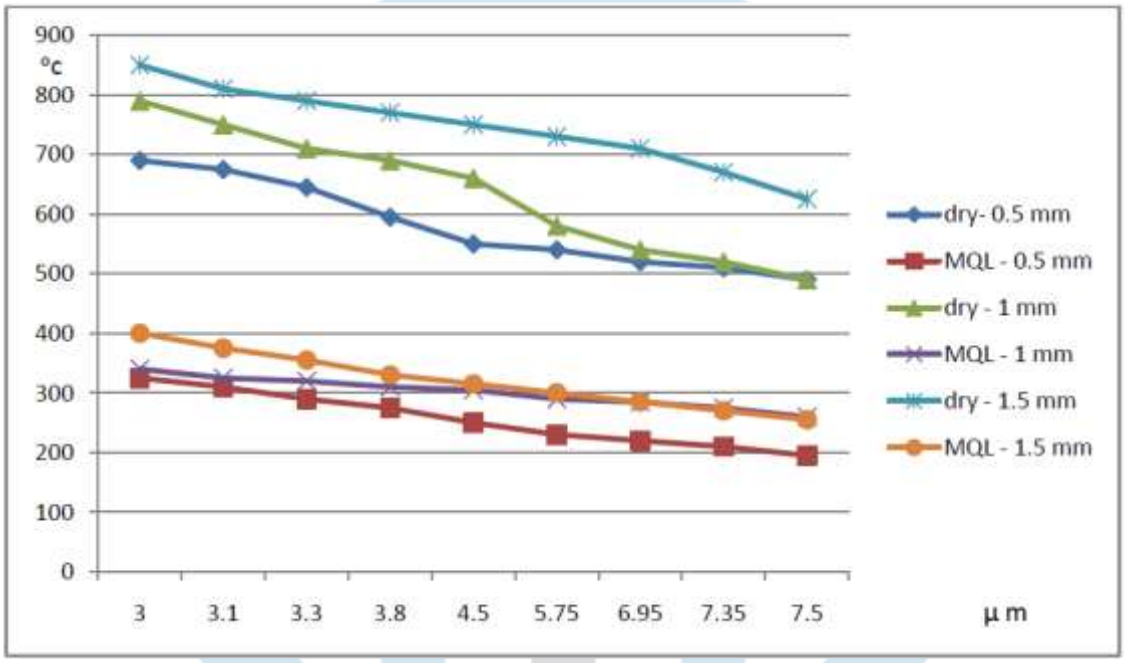

Figure 10: Temperature vs surface roughness for mild steel

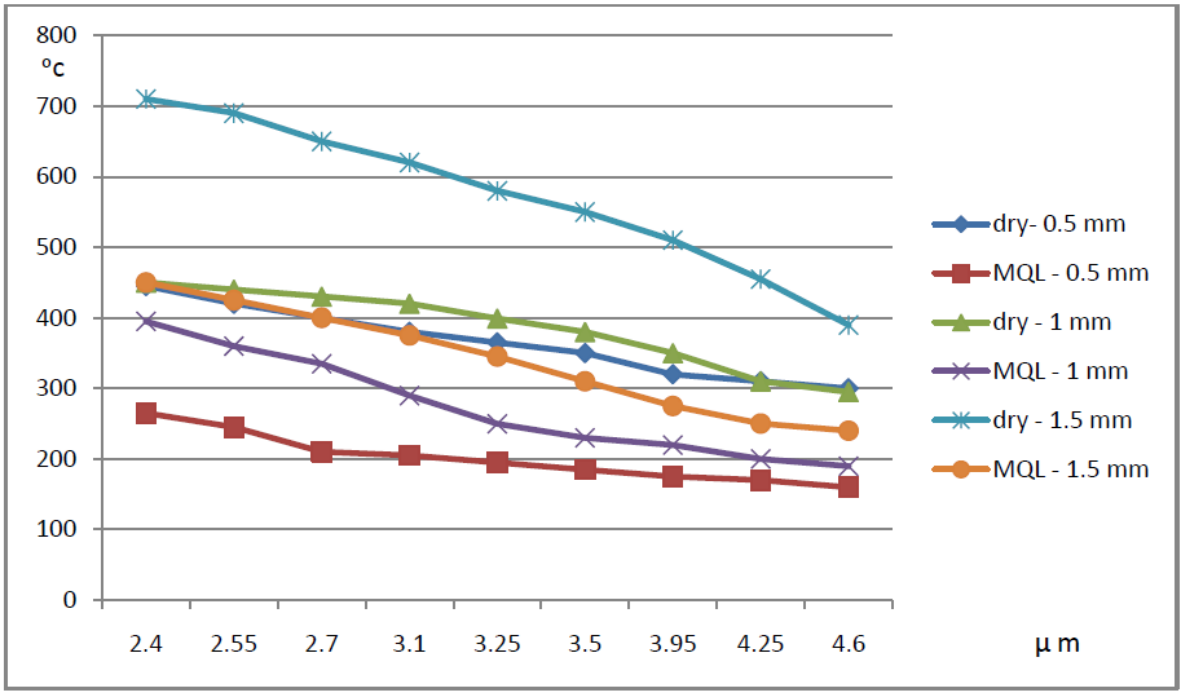

Figure 11: Temperature vs surface roughness for aluminium

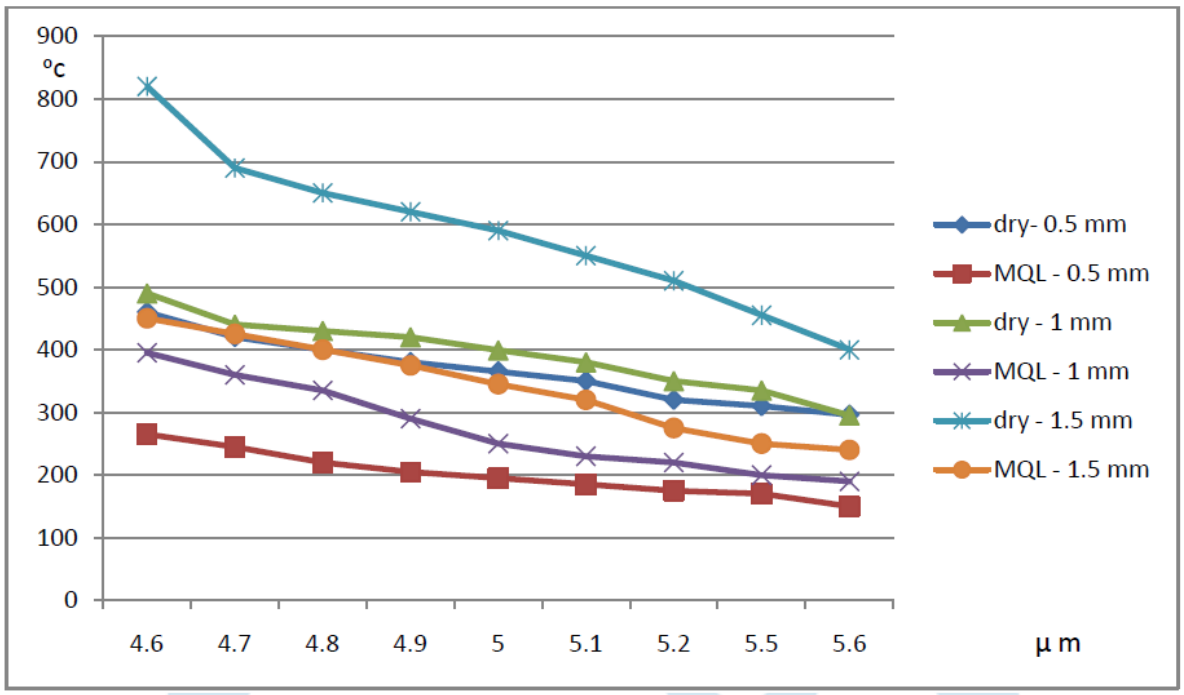

Figure 12: Temperature vs surface roughness for brass

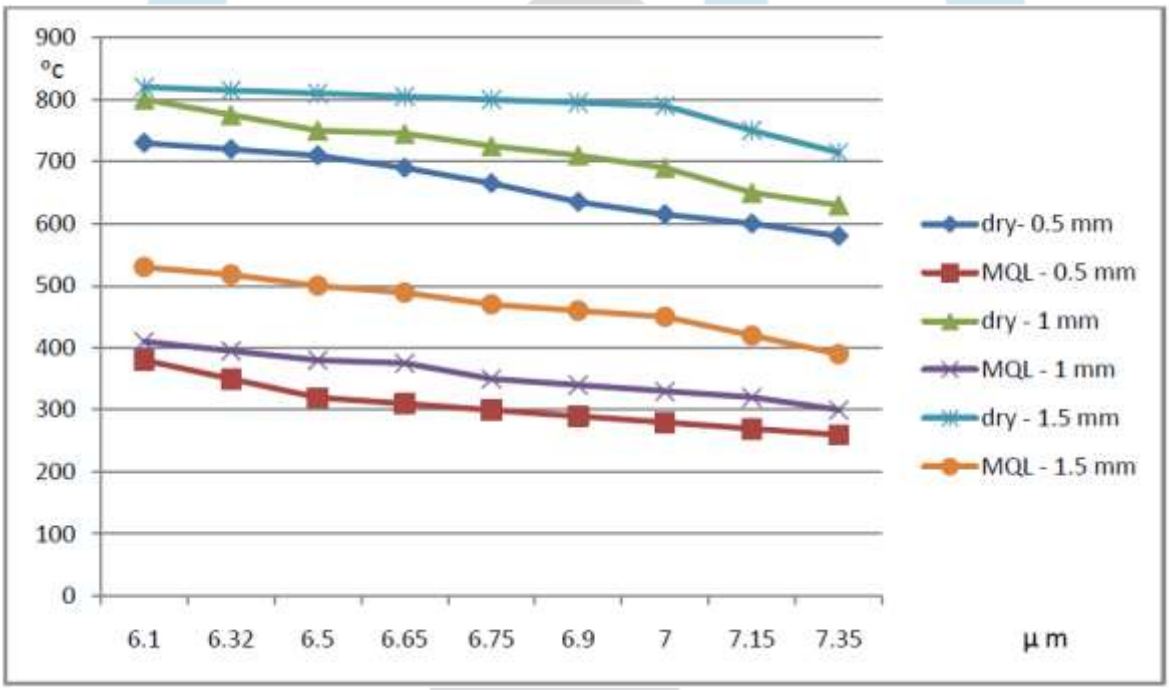

Figure 13: Temperature vs surface roughness for magnesium

Surface finish is an another important index of machinability as the performance and service life of the machined component are often affected by its surface finish, nature and extent of residual stresses and presence of surface or subsurface micro cracks, particularly when that component is to be used under dynamic loading or in conjugation with some other mating part(s). Generally, good surface finish is achieved by finishing processes like grinding but sometimes it is left to machining. Even if it is to be finally finished by grinding, machining prior to that needs to be done with surface roughness as low as possible to facilitate and economize the grinding operation and reduce initial surface defects as far as possible.

The variation in surface roughness observed during turning stainless steel 304 by tungsten coated carbide tip under dry and MQL conditions is shown in . MQL produces surface roughness grew very slowly under MQL conditions. From the graph we can able to note down that surface roughness grows quite fast under dry machining due to temperature, which is more intensive and stresses at the tooltips.MQL appeared to be effective in reducing surface roughness. Nevertheless, it is evident that MQL improves surface finish depending on the work tool materials and mainly through controlling the deterioration of the auxiliary cutting edge by abrasion, chipping and built up edge formation.

Figure 14: chip formed with MQL supply

Figure 15: Chip formed with dry machining.

CONCLUSION

Proposed minimum quantity lubricant technique can enable significant improvement in both productivity and product quality and hence overall machining economy longer tool life, better chip breaking and chip handling, higher productivity, lower productivity cost, better work surface finish, environmentally safer, healthier for the workers. The major conclusions from this investigation can be summarized as follows:-

- The surface roughness of the material i.e stainless steel is reduced by applying MQL technique.,
- The material removal rate is increased by using MQL technique,
- The heat produced in the work piece is reduced,
- Working area is free when compared with flood conditioning of the fluid.

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