A REVIEW OF MINIMUM QUANTITY LUBRICATION (MQL) ON MACHINING PROCESSES ON LATHE

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Abstract

The world is finding alternatives for flood lubrication machining processes, flood lubricants have ill effects on the operator moreover, the overall cost including recirculating cost and the cost of fluid are high. Techniques like near dry machining, air machining and minimum quantity lubrication are a possible solutions for replacing the same. Each of these techniques have their advantages but are not perfect and does not provide a complete solution. This article reviews various MQL methods used by various machining processes for different materials. MQL requires minimal quantity of lubricant and thus the overall cost decreases. It also highlights the future work directions for research in this area.

Keywords: Cutting fluids, Minimum Quantity Lubrication, Turning, near dry machining.

I. Introduction

People are working on ways to improve tool surface finish of work-piece along with an increase in tool life. Both of results are difficult to achieve simultaneously, thus improvement in the lubrication techniques were required which resulted into the emergence of MQL. The effectiveness of this technique depends on the lubricant used, the work piece material and also the machining conditions. There are major four categories of cutting fluid used namely, soluble oils, cutting oils, synthetic fluids and semi-synthetic fluids. Research is being carried out on use of vegetable oils as an effective lubricant. MQL provides means for using such oils as lubricant.

II. Minimum Quantity Lubrication

A. *Abbreviations and Acronyms*

- MQL: Minimum Quantity Lubrication.
- NDM: Near Dry Machining.
- BUE: Built up Edge.
- HSS: High Speed Steel.
- HPC: High Pressure Coolant.

B. *Review on MQL*

MQL is a considerable alternative for machining. It uses a small quantity of lubricant converted into an aerosol using high pressure air, thus also known as near dry machining. [1]The amount of lubricant required is 10000th part of the lubricant used during flood lubrication. [2]Similar to other lubricating techniques the performance of this method is also governed by process parameters, work material, tool material and the lubricant used. [3]It was observed that the total manufacturing costs would be lower as compared to the cost of traditional overhead flood cooling using large amount of water miscible. Despite all these benefits this technique is not known to many machinists, therefore they never enjoy the all these benefits.

In a nutshell, MQL makes use of a lubricant, not a coolant, and does so in 'minimum quantities' (like its name!). Where coolants flood the interface in an attempt to cool things down, MQL coats the interface with a thin lm of lubricant and prevents heat buildup through friction reduction. The excellent lubricity of a good MQL lubricant means that the majority of the heat from friction is transmitted to the chip and exits the interface as chips are expelled. This lubrication and transfer of heat keeps the cutting tool much cooler and reduces tool wear. The friction and heat in the interface vaporizes the small amount of lubricant and leaves cutting tools, parts, equipment, and floors dry and clean.

C. *Turning using MQL*

Out of all the available machining processes, turning remains to be the most widely used machining process because of wide variety of operations available. This varied operations can be used to increase productivity and reduce the manufacturing cost. [4][5] While turning at higher values of cutting parameters in order to increase productivity, the surface finish gets adversely affected and it also has a negative impact on tool life. Research has been focused on improving the conventional turning, to enhance tool life and reduce tool failure. Here tool failure is considered whenever the tool is incapable of doing any further machining. [6]Stress generated and the tool temperature are important parameters which affect the tool life. The tool damage is dependent of cutting parameters like cutting velocity, feed rate and depth of cut. The formation of a BUE is a result of machining at inappropriate parameters, BUE reduces the tool life considerably. Tool damage is classified as: adhesion, thermal damage (plastic deformation, thermal diffusion and chemical reaction), mechanical damage (abrasion, chipping, fracture and fatigue). Out of these damages, thermal damage increases drastically with increasing temperature. [7]Adhesion wear is also a temperature dependent phenomenon. The temperatures at which thermal damage and adhesion damage occur vary with tool and work material combination. Thus heat generation in turning leads to reduction in tool life and as a result reduced surface finish.

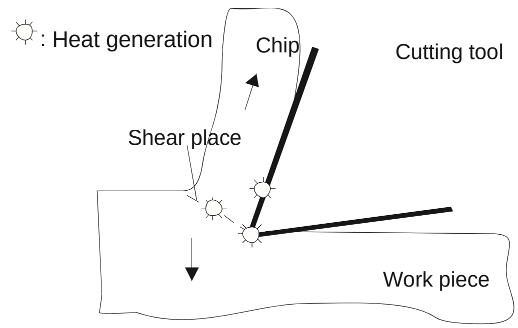

Figure1: Generation of heat during turning of metal [8]

The figure 1 shows the main centers of heat generation. [9]The maximum temperature in generated at the tool face at some distance from the tool tip. Thus tool is the main path for the heat to flow away from the interface, this is facilitated by the continuous temperature gradient between the two ends of tool. [10]The amount of heat conducted depends on the thermal conductivity of the tool and cross-section area of the tool. [11]The total amount of heat generated is summation of the heat generated because of the plastic deformation of the chips, friction between tool and chips and friction between tool and work-piece. Out of all these heat generated the chips carry the major amount of the heat generated (about 80%) and the remaining is shared between work-piece and tool. [12]An attempt to optimize the cutting parameters for Inconel alloy using MQL was carried out by Thakur et al. Experiments for different parameters like fluid pressure, Feed, Cutting speed. The optimum values found for various parameters were 13MPa, 0.05mm/min, and 40m/min. [13] It can be inferred from microstructure analysis that, plastic deformation occurred during high cutting speed, and the deformation direction was parallel to the cutting direction.

Turning experiments using MQL on high strength structural steel type St52-3 using uncoated cemented carbide K10 tool were carried out by S. Ekinovic et al., Experiments was carried out for different flow rate of oil and water and for different position of MQL nozzle on the tool. [14]Analysis showed that for MQL turning of steel St52-3, the optimum values of MQL parameters are: 10 ml/h of oil and 1.7 l/h of water, and Position of the nozzle does not significantly affect the cutting forces and Application of MQL machining is much more acceptable from an environmental viewpoint because the machining used vegetable oil that does not pollute the environment.

Experiment of MQL turning was done by Mohammad jafar Hadad et. al. on AISI 4140 steel alloy using HSS tool. In that experiment, MQL fluid was applied with two external nozzles, positioned to the rake and flank faces of the tool. [15] Experiment results showed that, cutting performance of MQL machining is better than that of dry and conventional machining with flood cutting fluid supply, because MQL provides the benefits mainly by reducing the cutting forces which improves the chip-tool interaction and maintains sharpness of the cutting edges and lower machining temperatures. Surface finishes improved mainly due to reduction of wear and damage at the tool tip by the application of MQL. V.N. Gaitonde et. al. attempted experiment of MQL turning on brass using K10 carbide tool and found optimal parameters. [16]Analysis showed that, Taguchi method has been employed to determine the optimal process parameters for simultaneously minimizing the surface roughness and specific cutting force during turning of brass with K10 carbide tool.

Experiment of MQL turning of AISI 4340 was done by N. R. Dhar et. al. using carbide tool.[17]analysis showed that The cutting performance of MQL machining is better than that of dry and conventional machining with flood cutting fluid supply because MQL provides the benefits mainly by reducing the cutting temperature, which improves the chip–tool interaction and maintains sharpness of the cutting edges. C. Bruni et. al. done experiment of MQL turning on AISI 420B using carbide tool.[18] Experiments showed the effect of lubrication-cooling technique, insert technology and machine bed material on surface finish and tool wear in cutting operations has been studied. The wiper inserts, notwithstanding a slightly higher tool wear, lead to a surface fin. Finish turning performed on the machine tool equipped with the polymer concrete bed allows the obtaining of values of VB and Ra lower than the ones provided by the same operations carried out on the turning centre equipped with the cast iron bed. V.S.Sharma et al. presented an overview this paper presents an overview of major advances in techniques as MQL, NDM, HPC, cryogenic cooling, compressed air cooling and use of solid lubricants/coolants. These techniques have resulted in reduction in friction and heat at the cutting zone, hence improved productivity of the process. [19] Tool life improves dramatically in cryogenic cooling due to the fact that cryogenic fluid is able to penetrate the chip–tool interface and perform both lubrication and cooling functions satisfactorily.
With the MQL/NDM technique, there can be a remarkable reduction in machining cost, quantity of lubricant used and surface roughness by properly orienting the nozzle on flank face of the tool.

In another study A. Attanasio et al. performed experiments 100Cr6 hardened steel to obtain results from turning tests, at two feed rates and two cutting lengths, using MQL on the rake and flank of the tool. [20] The results obtained show that when MQL is applied to the tool rake, tool life is generally no different from dry conditions, but MQL applied to the tool flank can increase tool life. J. Paulo Davim et al. performed an experiment in which Machining of brass workpieces were carried out under different conditions of lubricant environments using K10 inserts. Influence of parameters like feed rate and cutting speed on cutting power, specific cutting force, surface roughness and chip form were studied. [21] The specific cutting force at 200m/min was seen to be the lowest. Hence 200m/min can be considered to be the critical velocity for machining brass at MQL. The surface roughness of the machined surfaces increased with increase in feed rate and decrease with the lubricated conditions. The chip form obtained in MQL of lubrication or flood lubrication conditions is similar.

III. Conclusion

To sum up, MQL has provided better results than dry machining and also flood cooling techniques. It has been found that notable increase in surface finish is obtained, along with reduction in cutting forces. All this occurs because the chips now carry a larger amount of heat energy along with them keeping the tool and work-piece cool enough. This temperature reduction helps tool to maintain its hardness and thereby reduces the cutting forces. However the performance of MQL depends on number of factors like lubricant, air pressure, and proper atomization of the spray. The use of vegetable oils instead of chemicals reduces its harmfulness to the operator. Taking into consideration all its economic and environmental friendliness, MQL is a suitable alternative for conventional lubrication techniques and has a bright future scope.

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