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MQL Application in Reaming - A Review

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Abstract: The purpose of this article is to review the relevant literature in reaming using minimum quantity lubrication. Modern machining requirements often demand mass production of holes with good surface finish and geometrical accuracy which are needed for precision assembly. Near about 100 million gallons of metal working fluid is used for machining operation of various parts. Maximum machining operation parts are created under flood lubrication but flood lubrication contributes to adverse health effect and safety issues, including toxicity, lung diseases to operator and air pollution etc. In order to minimize the use of cutting fluid the Minimal Quantity Lubrication (MQL) technology was introduced. MQL is the process to apply minute amount of lubrication to the tool tip. The lubricant is mixed with compressed air and forms aerosol mixture called as MQL. According to the various literatures, the use of MQL technology resulted in decrease of overall cost by about 13 percent and it is possible to achieve effective lubrication of cutting process with extremely small quantity of oil. The result is not only high productivity but also longer tool life and cost saving.

Keywords: Cost, Health, MQL, Reaming, Tool life

I. INTRODUCTION

In mass production scenario higher productivity along with better quality is the foremost requirement and hence in most of the machining operations the use of flood lubrication is common in the industries resulting in high cost and some environmental issues. Hence, concerns about environmental issues have emphasized the importance of reduction or total elimination of the use of flood lubrication in the manufacturing industry. Government regulations for example in North America, the National Institute for Occupational Safety and Health (NIOSH) recommends that occupational exposes to cutting fluid aerosols be limited to 0.5 mg/m3 from its current standard value of 5 mg/m3 [1].

Cutting fluids used in machining operations have to carry out number of functions like lubrication, easy metal removal, cooling and hence acts as a heat carrier in the machining operations taking away the heat generated during machining between the surface of the work piece and the tool and the contact area between tool and chip, thus avoiding deformation of work pieces and producing close dimensional tolerances. However, during the last decade, a significant research has been undertaken with the aim of reducing the quantity of cutting fluids applied in production, due to the fact that the use of large amounts of cutting fluids brings several drawbacks. Cutting fluids can be difficult and expensive to recycle; they can cause skin and lung diseases to the operator and cause air pollution. Other reasons for decreasing the quantity of cutting fluids are the costs related to the fluids, which have been evaluated to be in the range 7–17% of the overall manufacturing costs [4].

Currently, industries use very huge amount of metal working fluids (MWFs) in machining and hence are looking for ways to reduce the amount of lubricants in metal removing operations due to the ecological, economical and most importantly occupational pressure. From a study, Kalhofer (1997) revealed that respiration and skin problems were the main side effects of MWF. However, Greaves et al. (1997) studied the types of occupational risks associated with MWFs,

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which became airborne and formed aerosol during machining and showed that these risks were numerous and widespread. It is, therefore, important to find a way to manufacture products using the sustainable methods and processes that minimize the use of MWFs in machining operations [2].

In automotive industries, close tolerance holes are the basic requirement for the assembly of different components. The quality of the hole plays an important role in the assembly. The reaming process is taking a large application in automobile industry which has recently withstand a significant development in vehicle technology [3].

II. REAMING OPERATION

Reaming is a common machining process with the characteristic property of enlarging, smoothing and accurately sizing existing holes to tight tolerances. The quality of the hole depends on reamer geometry, cutting conditions, application, stock removal, lubrication and the quality of the holes to be reamed. Reaming is a finishing operation which is normally carried out after drilling. Since stock removal is small and must be uniform in reaming, the starting holes (drilled or otherwise produced) must have relatively good roundness, straightness, and surface finish. Reamers tend to follow the existing Centerline of the hole being reamed. If insufficient stock removal is left in the hole before reaming, the reamer can wear faster than normally and result in loss of diameter accuracy. In general applications, average surface roughness for reaming is expected to be in range between 0.8 μm and 3.2 μm but high-accuracy reaming can produce average surface roughness as low as 0.4 μm. The quality of the reaming process when using MQL has been investigated by number of authors. Literature shows that a number of different performance criteria for the manufacturing quality assessment were selected, concerning both the product and the process. In particular, the quality of the reamed holes was evaluated in terms of geometrical characteristics (diameter, roundness, cylindricity, and surface roughness) while the process was evaluated by measuring cutting torque and thrust. All characteristics were considered both in terms of absolute measured values and repeatability (i.e. standard deviation) [4].

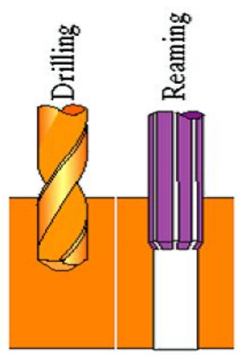

FIGURE NO:-1 DRILLING AND REAMING

III. MINIMUM QUANTITY LUBRICATION (MQL)

Minimum Quantity Lubrication (MQL) is a machining method that delivers a precise amount of lubrication to the tool tip. The lubricant is mixed with compressed air and forms the desired air/oil aerosol mixture. MQL, also known as "Micro lubrication", (MaClure, Adams, Gugger and Gressel, 2007) and "Near-Dry Machining" (KlockeandEisenblatter, 1997) is the latest technique of delivering metal cutting fluid to the tool/work interface. Using this technology, a little fluid, when properly selected and applied, can make a substantial difference in how effectively a tool performs. In conventional

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operations utilizing flood coolant, cutting fluids are selected mainly on the basis of their contributions to cutting performance. In MQL however, secondary characteristics are important. These include their safety properties, (environment pollution and human contact), biodegradability, oxidation and storage stability. This is important because the lubricant must be compatible with the environment and resistant to long term usage caused by low consumption (Wakabayashi, InasakiandSuda, 2006). In MQL, lubrication is obtained via the lubricant, while a minimum cooling action is achieved by the pressurized air that reaches the tool/work interface. Further, MQReduces induced thermal shock and helps to increase the workpiece surface integrity in situations of high tool pressure (Attanasio, Gelfi, GiardiniandRemino, 2006) [1].

TABLE NO.1
LUBRICATION USAGE PER HOUR

Sr.No	ml/hour	Condition of lubricant
1	0 ml/hour	Dry
2	< 80 ml/hour	Minimum Quantity Lubrication (MQL)
3	80 ml/hour → 2000 ml/hour	Minimum flow lubrication
4	> 2000 ml/hour	Flood lubrication

III.A.TYPES OF MQL SYSTEMS

There are two basic types of MQL delivery systems: external spray and through-tool. The external spray system consists of a coolant tank or reservoir which is connected with tubes fitted with one or more nozzles. The system can be assembled near or on the machine and has independently adjustable air and coolant flow for balancing coolant delivery. It is inexpensive, portable, and suited for almost all machining operations. Through-tool MQL systems are available in two configurations; based on the method of creating the air-oil mist. The first is the external mixing or one-channel system. Here, the oil and air are mixed externally, and piped through the spindle and tool to the cutting zone. [1]

III.B.WORKING PRINCIPLE OF MQL

The MQL needs to be supplied at high pressure and impinged at high speed either through the nozzle externally or through the tool spindle internally on the cutting zone. In generalized MQL system, a compressor is used to supply air at a high pressure. This high pressure air from the compressor enters into two chambers like fluid chamber and mixing chamber at two different but preselected pressures. The fluid chamber is connected at the bottom with the mixing chamber by very small diameter flexible tube. This tube is passed through a roller type flow controller to permit a little amount of fluid to flow under high pressure. The compressed air entering into the inlet port creates pressure to cause the fluid to flow continuously to the mixing chamber through controller at a constant rate. The air and the oil are mixed in the mixing chamber so that the mixture of oil and air impinged at a high velocity through the nozzle on the chip–tool interface. The

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stream of MQL can be projected at the tip of the cutting tool. Consequently, the coolant reaches as close to the chip–tool and the work tool interfaces as possible [2].

The figure below shows a two-channel MQL system for through spindle (Internal) lubrication. In a two-channel system, the precise amount of oil is transported through a lance to a pipe nozzle located at the tool holder's base. As lubricant moves through the lance and into the pipe nozzle, air supplied through the rotary transmission travels down the spindle coolant tube that encapsulates the lance to the mixing chamber of the pipe nozzle, where it combines with fluid to form an aerosol [9].

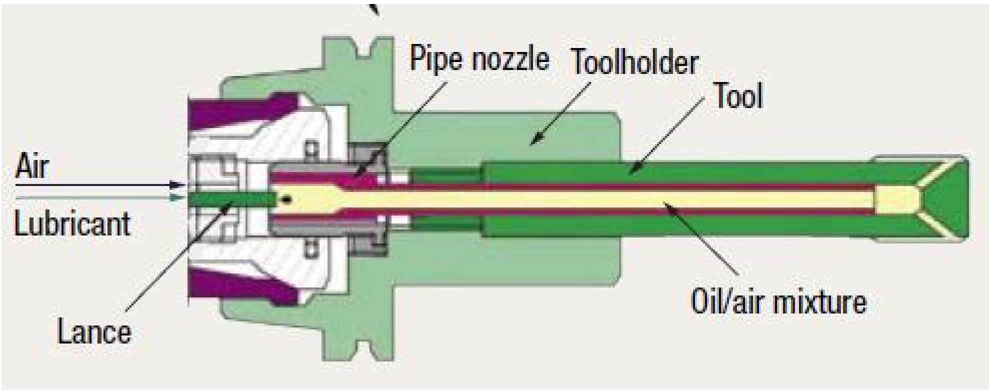

FIGURE NO: - 2 THROUGH SPINDLE (INTERNAL) LUBRICATION [9]

IV. LITERATURE REVIEW

Nourredine Boubekri et al. [1] focused on the environmental, health issues and future potential research in this field and they conclude that MQL does generate a significant amount of mist compared to flood cooling. Mist collection or filtering equipment is required to manage the resulting fine mist. With these technologies in place however, machining is safe for both operators and the environment, particularly if using vegetable based lubricants. On the other hand, the processes of lubrication and cooling in MQL are yet to be well understood. Similarly the process of mist particles generation and their physical characteristics are yet to be determined for a whole class of machining processes and machining conditions.

M.M.A. Khan et al. [2] performed experiment on alloy steel with vegetable oil based cutting fluid and found that, The present MQL system enabled reduction in the 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. Surface finish also improved mainly due to reduction of wear and damage at the tool-tip by the application of MQL.

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A.A.Bezerra *et al.* [3] have investigated the effect of machining parameters like depth of cut, cutting speed, feed rate, helix angle, number of blades and margin for the reaming of the aluminium-silicon alloy with the carbide reamers at lower depth of cut 0.2 and 0.3 mm gave the best results in overall terms of accuracy, surface finish, roundness, and cylindricity of the hole produced. The best dimensional stability, surface finish as well as the lower power consumption can be achieved when reaming the aluminium-silicon alloy at lower cutting speed of 25 m/min. The reamer with more blades produced better hole diameter accuracy, surface finish and roundness at the expense of the holes with poorer cylindricity and higher power consumption when machining Aluminium-Silicon Alloy

Leonardo De Chiffre *et al.*[4] studied the capability of reaming when using minimal quantity lubrication (MQL) was investigated under different conditions. Austenitic stainless steel was selected as work piece material for this research. Process performance in terms of hole characteristics as well as torque and thrust were analyzed using a metrological approach. It was observed that different cutting conditions determine different process performances. In particular, it was observed that a higher feed rate leads to lower and more repeatable roughness, but at the same time to higher and less repeatable reaming thrust and torque. MQL in reaming leads to high quality results in terms of hole dimensions and surface finish.

N.B.BORKAR et al. [5] have found that the MQL systems enabled reduction in average tool wear for reduction and significant improvement in the major machinability. MQL provided better surface finish ultimately increases dimensional accuracy, substantially improved mainly due to significant reduction of wear and damage at the tool tip by the application of MQL. The cutting performance of MQL machining is better than that of conventional machining with flood cutting fluid supply. The most significant contribution of application of MQL in machining the steel by H.S.S tool undertaken has been the high reduction in flank wears, which would enable remarkable improvement in tool life. Such reduction in tool wear might have been possible for retardation of abrasion and notching, decrease or prevention of adhesion and diffusion type thermal sensitive wear at the flanks and reduction of built-up edge (BUE) formation which accelerates wear at the cutting edges by chipping and flaking. Deep notching and grooving, which are very detrimental and may cause premature and catastrophic failure of the cutting tools, are remarkably reduced by MQL.

The work of W. Belluco et al. [6] presents an investigation on the effect of new formulations of vegetable oils on surface integrity and part accuracy in reaming operations with AISI 316L stainless steel. An investigation was carried out to compare cutting fluid efficiency with respect to part accuracy, surface roughness and microhardness in reaming. The vegetable oils used in this investigation resulted in comparable or better performance than mineral oils in reaming and Increases in microhardness at a distance of 15 μm from the surface were as high as 100% in reaming.

Shilpa Sahare et al.[7] focused on relevant literature in machining using minimum quantity lubrication and comparative study was made for tool wear and surface roughness by varying cutting parameters under dry and Minimum Quantity Lubrication (MQL). They concluded that the cutting fluid contributes significantly toward machining cost and also possesses environmental threats. However, they also require some modification of machine tools for obtaining the best performance out of them. When the flood coolant system is not present, the machine tools should be equipped with a chip removal system.

G. Globočki Lakić et al.[8] performed experimental research on turning of carbon steel and using the novel model, machinability of different cooling lubrication techniques can be concluded. Cutting forces, intensity of tool wear and surface roughness were used as the machinability criteria. Analysis shows that turning with MQL is a good alternative for conventional lubrication. It is important for cost of machining and for ecology as well. Future research will be performed in area of low cost technologies, high productive and hybrid machining processes.

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V. CONCLUSION

Conventional methods of lubrication are largely expensive and environmentally hazardous. Although the technique of MQL resulted in significant advantages related to cost and environment friendly nature of machining operations, the processes of lubrication and cooling in MQL are yet to be well understood. The effect of MQL parameters on the surface quality and power consumption needs to be explored in a wide manner. The literature shows that the use of MQL resulted in cost savings on cooling lubricants are higher along with the longer tool life and high productivity.

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