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A Review Study on Minimum Quantity Lubrication in Machining

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***Abstract*- Machining is the wide spread metal shaping process, it exhibits rapid wear rate of cutting tools due to high cutting temperature generated during the process. Thus effective control of the heat generated during machining is essential to ensure good workpiece quality. Cutting fluids are applied to avoid the problem; however cutting fluids are restricted due to their harmful health and environmental impacts. Newly developed economical and environmental friendly alternative to completely dry or flood lubrication is minimum quantity of lubrication (MQL). Minimum Quantity of Lubrication machining refers to the use of a small amount of cutting fluid, typically in order of 500 ml/hr or less, which are about three to four orders of magnitudes lower than that used in flooded lubricating conditions, MQL technique consists in atomizing a very small quantity of lubricant in an airflow directed towards the cutting zone. This papers deals with the study of minimum quantity of lubrication (MQL) and its advantages over dry or flooded condition.**

***Keywords*-- Minimum quantity of lubrication (MQL), tool wear and surface roughness.**

I. INTRODUCTION

Metal cutting also known as machining is one of the most used techniques for producing different components. In the machining processes a cutting tool removes material from a workpiece of a less resistant material. The removed material called chip slides on the tool face and leaves the work piece material (Shokrani et al., 2012). Machining process induces surface residual stresses of a high order of magnitude, which are often tensile. These are detrimental to the service life and the stress-corrosion resistance of the component. Other effects such as surface cracking, and difficulty in maintaining close tolerances on account of warping, are encountered during machining (Mishra and Prasad, 1985). The residual stress state in a piece depends on the material of the component and on the cutting parameters employed: cutting speed, cutting feed, depth of cut, kind of cutting tool (geometry, coating of the tool, etc), wear of the tool, lubrication, etc. (Navas et al., 2012).

Surface roughness is mainly a result of process parameters such as tool geometry and cutting conditions. In machining operation, lot of heat is generated due to plastic deformation of the work material, friction at the tool-chip interface and friction between tool and the work-piece. The heat produced adversely affects the quality of the products produced (Singh and Rao, 2008). To enhance productivity different methods have been reported to protect cutting tool and work piece during machining operations. The selection of 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. Another alternative is to apply cutting fluids in machining operation. They are used to provide lubrication and cooling effects between cutting tool and work piece and cutting tool and chip during machining operation (Cakir et al., 2007). In recent years, high-speed machining (HSM) technology is becoming matured, HSM exhibits a higher metal removal rate, better surface finish, no critical heat of the work piece, etc. But the rapid wear rate of the cutting tool due to high cutting temperature generated during the process still remains unsolved. Generally the cutting fluid applied in the machining process is considered to act as cooling and lubricating agent, hence the cutting temperature can be reduced and the tool life and machined surface finish can be improved (Liao and Lin, 2007). The cutting fluids have many detrimental effects as it contain environmentally harmful or potentially damaging chemical constituents. These fluids are difficult to dispose and expensive to recycle and can cause skin and lung disease to the operators and air pollution. The costs associated with the use of cutting fluids is estimated to be several billion $/year. Consequently, elimination on the use of cutting fluids, if possible, can be a significant economic incentive (Thakur et al., 2009). Minimizing the use of cutting fluid also leads to economic benefits, as cutting fluids can account for a significant portion (up to 20%) of machining costs (Braga et al., 2002).

One possible solution lies in minimum quantity of lubrication (MQL), MQL refers to the use of cutting fluids of only a minute amount-typically of a flow rate of 50–500 ml/h which is about three to four orders of magnitude lower than the amount commonly used in flood cooling condition (Dhar et al., 2006). MQL technique consists in atomizing a very small quantity of lubricant in an airflow directed towards the cutting zone. The aerosol can be sprayed by means of an external supply system, via one or more nozzles (Bruni et al., 2006). Among various techniques to reduce full usage of metal working fluids (MWF), nanofluid minimum quantity lubrication (MQL) was such an environment-friendly one, which has been recently introduced. Nanofluid is a fluid containing nano-particles such as carbon nano-tube (CNT), C_{60}, TiO_2, Al_2O_3, MoS_2, SiO_2, diamond and so forth. In a nanofluid MQL, the nanofluid is supplied to the machining area as a form of mist mixed with highly pressurized compressed air through a nozzle. Nano-particles are an excellent media to increase the thermal conductivity of the base fluid. Besides, nano-particles enhance tribological and wear characteristics significantly (Nam et al., 2011).

II. Studies On Minimum Quantity Of Lubrication (MQL)

Dhar et al., 2006 studied the role of MQL in turning AISI-4340 steel by uncoated carbide insert and observed that the cutting performance of MQL machining was 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. In another study Abhang & Hameedullah, 2010 studied use of minimum quantity lubricants in alloy steel turning. In this work 10% boric acid by weight mixed with base oil SAE 40 was used as MQL in turning process and observed that minimum quantity lubricant can reduce the chip-tool interface temperature, cutting forces and reduces chip thickness over dry turning. Surface finish was significantly improved mainly due to significant reduction wear and damage at the tool tip by the application of minimum quantity lubricant. In another study Krishna et al., 2010 studied the performance of nanoboric acid suspensions in SAE-40 and coconut oil during turning of AISI 1040 steel and 50 µm particle size boric acid solid lubricants suspensions were used and studied that thermal conductivity increased and specific heat decreased with percentage increase in nano boric acid in base oil.

The cutting temperatures, tool flank wear and surface roughness were decreased significantly with nano-lubricants compared to base oil due to lubrication action of boric acid and coconut oil based nano-particle suspension showed better performance compared to SAE-40 based lubricant. In another study Braga et al., 2002 studied the performance of the uncoated and diamond coated carbide drills, using minimal lubrication in the drilling of aluminum–silicon alloys (A356) and concluded that the holes obtained with the MQL system presented either similar or better quality than those obtained with flood of abundant soluble oil. The values of flank wear were similar for the two cooling/lubrication systems used. In another study Meena and Mansori, 2007 studied the role of minimum quantity lubrication (MQL) drilling on cutting forces, tool wear and surface roughness of austempered ductile iron (ADI) by using TiAlN-coated tungsten carbide tools and observed that the cutting performance, surface finish and tool life of MQL drilling is better than dry drilling and comparable to flooded drilling up to 40 holed drilled. Tool life in dry drilling of ADI was 80 holes while in MQL drilling was110 holes using the TiAlN-coated tungsten carbide tool. MQL drilling reduces the tool wear and improves the tool life as compared to dry drilling.

Nam et al., 2011 studied the micro-drilling process with the nanofluid minimum quantity lubrication (MQL). In the nanofluid MQL, nano-diamond particles having the diameter of 30 nm were used with the base fluids of paraffin and vegetable oils and observed that the number of drilled holes was significantly increased when the pure MQL and nanofluid MQL being applied, nanofluid MQL significantly reduce the magnitudes of drilling torques and thrust forces, the quality of drilled holes could be significantly improved when applying nanofluid MQL. By applying nanofluid MQL the remaining chips inside the holes and burrs around the holes were mostly eliminated. In another study Li and Chou, 2010 studied the performance of minimum quantity lubrication (MQL) technique in near micro milling with respect to dry cutting and observed that the reductions of tool flank wear lengths in MQL cutting compared to dry cutting are about 60% under all cutting conditions and the values of surface roughness (Ra) under MQL are smaller. In another study Liao et al., 2007 studied feasibility of minimum quantity lubrication (MQL) in high-speed end milling of NAK80 hardened steel by coated carbide tool and observed that MQL proved beneficial at high speed milling when superior coated tools were used. In comparison with dry cutting, MQL delay the formation of welding chips and hence improve tool life and also improves the surface finish at high cutting speeds.

In another study Zhang et al., 2012 studied dry and minimum quantity cooling lubrication (MQCL) cutting with biodegradable vegetable oil during end milling Inconel 718 with coated cutting tools and observed that the tool wear under dry cutting were similar to MQCL but the tool life under MQCL was more which implies that vegetable oil can significantly reduce tool wear rate and extend tool life. The lower cutting forces under MQCL May attribute to low friction force at tool/chip and tool/workpiece interfaces. In another study Silva et al., 2007 studied the performance of MQL technique in grinding of tempered 4340 steel and concluded that MQL technique provide environmentally correct and technologically gains. With the use of MQL surface roughness values were substantially reduced, no significant clogging of the grinding wheel pores, no significant subsurface alterations in the microstructure were detected under MQL. In another study Tawakoli et al., 2010 studied the influence of the abrasive and coolant-lubricant types on the minimum quantity lubrication (MQL) grinding performance and concluded that the grind ability of 100Cr6 hardened steel was found to increase substantially by using the MQL. In another study P.Kalita et al., 2012 studied that surface-grinding test were performed on ductile iron work pieces using an aluminium oxide wheel and impingement of advanced nano lubricants, consisting of organic molecules with phosphide intercalated-MoS_2 nano particles (<100 nm), was observed and concluded that the effectiveness of the nano lubricants, measuring a decline of 45–50% in force-ratio and specific energy, and a 48–55% decrease in abrasive wheel wear, with conventional flood cooling and MQL with paraffin (base) lubricant.

III. Conclusions

- The tool performance can be enhanced by using MQL under all cutting speeds.
- It is found that MQL can provide extra oxygen to promote the formation of a protective oxide layer in between the chip–tool interface.
- MQL gave the best performance in terms of the surface roughness, feed forces, tool wears and surface quality.
- Minimum quantity of lubrication enabled sizeable reduction in the cutting zone temperature and favorable change in the chip–tool and work–tool interactions, which helped in reducing friction, built-up edge formation, and thermal distortion of the work and wear of the cutting tool.
- MQL is less polluted, environmental friendly and labour costs are reduced while disposal.

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