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SUSTAINABLE MACHINING USING MINIMUM QUANTITY LUBRICATION A COMPREHENSIVE REVIEW

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Abstract: In the machining process, conventional cutting fluid injected at the tool-workpiece interface as a coolant. Conventional coolant creates harmful health effects. Minimum quantity lubrication plays a crucial role in the machining process, it works as a substitute to conventional lubrication system by reducing the quantity of lubricant used. It reduces environmental impact also protected possible health hazard an operator. Also, machining, costs can reduce significantly. It is a method between dry and flood lubrication to ensure lubrication effects. This review article provides recent advancements in MQL with a special emphasis on turning, milling machining operations. In the end, it is concluded that there is an improvement in surface roughness, chip removal, tool life and tool wear with use of MQL when compared with dry machining and conventional cooling.

Keywords: Cutting fluid, Dry machining, Surface Roughness, Tool Wear

1. Introduction

Machining is the most significant processes in the industry. Cutting tools are employed in various machining process like turning, milling, drilling, grinding for the removal of material from the work as a chip. In chip formation heat generated at a chip-tool interface within cutting zone. Use of cutting fluid in the machining processes diminishes temperature at the tool and chip interface as well as friction at tool-work interface, by providing lubrication to workpiece and tool, consequently improved in surface finish and tool life. Also, it removes chips from the cutting zone (1-2). However, conventional cutting fluid creates health and environmental related issues (3). MQL (Minimum quantity lubrication) incorporates usages of minimum quantity and high-quality lubricants. It is also called as a “near-dry” cutting method (4). MQL reduces health concerns, also the overall cost of machining due to a less amount of fluid utilized (flow rate 50 ml/hr. to 500 ml/hr.) in the machining. In MQL atmosphere a synthetic ester, vegetable oil (VO), nanofluid is utilized as a coolant. Vegetable oils are utmost usual cutting fluids due to their superior as well as high-pressure performance. Nanofluid is a combination of base oil and nano-metre size particles. Cutting fluid selection depending upon various factors like material of the workpiece and tool, machining process and cutting parameters. MQL technique is composed of atomizing a few amounts of fluid in an airflow sprayed in the cutting zone. For a supply of the high-pressure air, a compressor is used. Then, high-pressure air passed through nozzles and sprayed at the tip of the tool. In an MQL technique, carbide tools are used for machining hard materials (steels, Inconel and aluminum alloys). The objective of the review is to provide with clear understanding usefulness of MQL as a substitute for conventional cooling.

2. Machining with MQL

Machining (turning, drilling, milling, grinding) of various materials using MQL with different lubricants has been studied by various researchers. MQL has contemplated impact on machining cost, surface finish, tool life, cutting force, chip thickness, cutting temperature.

2.1. Machining Using MQL in Turning

Turning is one of the machining processes in which a cutting tool, normally a non-revolving tool, depicts a helical tool path by moving almost straight while the workpiece revolve.

MQL based turning of Alloy 718, lubricants were chosen in experiments as rapeseed oil and nano-sized powder (~30 nm) of nano-additives (GnP) 0.2% (vol.), Gutnichenko et al.**,** (1) revealed that a decrease in cutting force values as a consequence of a decrease in friction at a cutting zone along with improvement in life of tool and surface finish of work.

MQL and dry system is employed in turning on AISI 420 hardened stainless steel (46-48 HRC) on CNC (lathe machine), machining was completed with WC-6%wCo tool, coated with PVD TiAlN and cutting fluid used castor oil, Elmunafi et al. (2**)** noticed that up to 170 m/min cutting speed, 0.24 mm/rev. feed and a small quantity of fluid of 50 ml/h. results in larger tool life and slightly enhanced cutting forces values and surface roughness due to less heat produced in cutting zone as compared with a dry system.

In an orthogonal cutting of AISI 1045 on NC lathe machine with cutting inserts used uncoated carbide, synthetic ester as cutting fluid, Rahim et al. (3) observed that there is a decrease in cutting zone temperature by 10% to 30% approximately, cutting force was decreased by 5% to 28% approximately and tool-chip contact length decreased by 12% due to lubricant effect of synthetic ester, lubricant reduces the friction at a tool and chip interface due to lowered cutting temperature, also chip thickness was 3% to 9% thinner than dry condition.

The impact of MQL, on tool wear and cutting force, with nanoparticles of Al_2O_3 in soluble cutting oil (SCO), while a turning of NiTi on the CNC turning machine using insert of coated carbide, Ahmad et al. (4) reported that as compared with dry machining, 4.2% to 34.5% depletion in tool wear and 6% to 10% in cutting force achieved due to the effect of lubrication. Besides using nanoparticles was evidenced improvement in lubrication properties of SCO.

Rabin Kumar Das et al. (5) expressed that minor wear of a tool at flank surface and superior surface finish of work accomplished, when compared with dry condition due to decrease in friction and temperature, during a turning of heat treated hardened steel AISI 4340 on CNC lathe, lubricant was used in this experiment was LRT 30 iron aluminum oil blended with air having 50 ml/hr. flow rate.

Mixture of cottonseed oil and aloe vera gel as fluid (MQL) in a turning of M2 steel (molybdenum high speed steel) with coated carbide inserts on CNC lathe, Agrawal and Patil (6) reported that lowered the values of surface roughness by 6.7% and tool wear by 0.14% in MQL than conventional fluid used (Servo cut S).

MQL and conventional cooling conditions used in turning of Incoloy 800 with tungsten carbide uncoated tool and sunflower seed oil used as lubricant, Joshi et al. (7) noticed that advancement in tool life, surface finish with use of MQL (230 ml/hr.) in accordance with conventional cooling conditions and MQL (150 ml/hr.)

Gunjal and Patil (8) examined the impact of vegetable fluid (soybean oil, canola oil and coconut oil) under MQL condition on turning of AISI 4340 (52-54 HRC) hardened steel on CNC lathe and machining was done by inserts of PVD AlTiN coated carbide, utilization of synthetic oil shows the best outcomes at the highest cutting speed. Canola oil fluid shows good performance on tool wear and tool life due to the maximum cooling effect of canola oil. Use of canola oil shows better surface roughness values as compared to soybean oil and coconut oil.

Ali et al. (9) investigated dry, chilled air and minimum quantity aluminium oxide nano lubricant, an effect in Inconel 718 turning on CNC Chevalier FCL-608 turning machine with the help of coated carbide (TiAlN PVD) inserts, investigation results demonstrates a minor difference in specific cutting energy generated with a dry, chilled air and minimum quantity aluminum oxide nano lubricant. However, MQL nano lubricants show better performance.

Paturia et al. (10) studied MQL based turning process on Inconel 718 with carbide inserts. WS2 (Tungsten disulfide) solid lubricant micron-sized powder particles (0.5% wt.) were scattered in emulsifier oil (20:1) based cutting fluid. WS2 solid lubricant used MQL machining indicated improvement in the surface finishes values of work by 35% on average when compared with MQL machining. Feed rate is a more noticeable parameter during the process.

3.2. Machining Using MQL in Milling

Milling is a metal cutting process in which multipoint rotating cutter is fitted on arbor of the milling machine.

Milling process was performed on AISI 420 with tungsten carbide uncoated (WC) cutting tool on CNC milling machine. Vegetable fluid used in experiments with 1% wt. of MoS_2 (Molybdenum Disulphide) nanoparticles, Uysal et al., (11) investigated that wear reduction observed during experiments as 16.8% and 19.9%, and decrease in surface roughness value by 36.3% at flow rate of 20 ml/h also 39.2% at 40 ml/h flow rate, as compared to dry milling.

Aslantas and Cicek (12) conducted micro-milling of super-alloy Inconel 718 with micro-end mills TiCN coated, experiment was conducted at different conditions MQL (vegetable-based fluid), ethanol, and conventional fluid (water-soluble), less tool wear found in MQL and the largest tool wear found in ethanol due to its less cooling effect, and better surface finish work of during MOL and dry machining.

Experiment on AISI 4140 hardened steel (40 HRC), at dry machining and MQL conditions. Bashir et al. (13) suggested that MQL gives the best performance than dry machining. MQL, in high-speed milling results, shows an increase in tool life, reduction in cutting force and tool wear but improvement in surface roughness values.

Thamizhmanii et al. (14) conducted the milling experiment on Inconel 718 with the tool of super hard cobalt material, MQL vegetable based and dry conditions.

Experimental results proved that the tool travelled longer under the MQL condition with a flow rate 37.5 ml/hr. provides the optimum surface roughness (Ra) and flank wear of the work material. Moreover, flank wear reduction led to a tool life increases with 43.75% compared to dry milling.

Kedare et al. (15) investigated the effect MQL and conventional fluid on M.S. (15 HRC) with HSS (uncoated), reported that MQL techniques show a better result in surface roughness as compared to conventional fluid.

Conclusion

Minimum quantity lubrication gives a few advantages in the machining methods. From the result obtained from various researchers, it is noticed that minimum quantity lubrication offers better result on surface finish, tool wear, tool life as compared to dry and flood cooling during various machining process like turning and milling process. Also, the MQL system reduces the cost of lubrication. Now day's minimum quantity lubrication is one of the paramount techniques to accomplish sustainable machining efforts.

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