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Review on Turning Process of Different Materials with Minimal Cutting Fluid Application

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Abstract-

Numerous of our theoretical works and understanding of conventional machining is inapplicable to the advancement of machining technology for hard metals. To address the problems with pollution and manufacturing expense, it is fundamental to look at the machining properties of materials, generally no coolant is used when doing the hard turning operations. These two problems are the major concerns of the industries over the past several decades. The use of machining centres for turning process, which use less electricity than other machining techniques, also lowers manufacturing costs. To speed up production process and reduce the processing time, hard machining is chosen. Hard turning requiresboth tough machine tools and extremely hard cutting tools since it entails turning materials that have already been hardened to the desired near ~~the~~ net size. During machining, cutting fluids are utilized to lower the cutting temperatures and forces. In the progress of the last three decades reduce the use of cutting fluids during machining. Methods like mist cooling, cryogenic lubrication, minimal cutting fluid application and minimal quantity lubrication systems came into existence. Since a few years ago, cutting fluid reduction has been the subject of extensive research. This review article analyzes the technique known as minimal cutting fluid application (MCFA), which entails applying a high-velocity cutting fluid in the form of a pulsed jet at the critical cutting zone during machining. The high velocity cutting fluid dissipates the heat produced in the crucial zone and also offers enough lubrication to lessen the cutting force. Previous studies have demonstrated how much more effective this procedure is than dry and wet machining. This review is based on the study that several researchers have done in the area of applying cutting fluids.

Keywords :*Turning; Minimal cutting fluid application; Cutting fluid; Tool life; Cutting force; Surface finish.*

INTRODUCTION

Due to market customization, the majority of manufacturing facilities are now concentrating on production cost and process optimization. This entails looking for and determining the ideal process parameters that will have an impact on response values such as the maximum tool life, the least amount of cutting force, the best surface finish, etc. High hardness materials are typically machined to their appropriate net shape under soft circumstances, and then following heat treatment, they are ground to their final size to achieve the desired hardness. These processes take a lot of time and raise the price of the final product. In typical machining procedures, cutting fluid consumption is relatively considerable. Cutting fluid storage, upkeep, and disposal put a financial strain on the makers. Research by Attanasio et al (2006) found that cutting fluids account for 7% to 17% of the entire production cost. This necessitates a decrease in cutting fluid usage. When cutting fluids are used in high volumes, there is also a health risk. According to the Occupational Safety and Health Administration (OSHA) and the American National Institute for Occupational Safety and Health (NIOSH), the permissible exposure level (PEL) for cutting fluid aerosol concentration in a manufacturing industry is 5 mg/m3 and 0.5 mg/m3 by Aronsin (1995). Employees may experience major health problems as a result of the increased exposure to oil mist on the work floor. Large-scale exposure to cutting fluids can cause dermatitis, respiratory conditions like asthma, and even cancer in workers. Cutting fluid contamination, pH, concentration, smoke, odor, and fungal development all need to be watched over and managed. Machado et al. argue that an active cutting fluid processing system is required for the upkeep of cutting fluids (1997). Studies in dry machining were carried out to lessen the negative impacts of cutting fluids and their expensive burden on the industry.

As implied by the name, dry machining involves no use of a cutting fluid throughout the machining process. However, inflexible machine tools and extremely hard cutting tools are needed to dry-machine hard materials. Dry machining increases tool wear rate, cutting force, and temperatures, which would reduce surface smoothness and surface accuracy, according to several studies carried out by various researchers Varadarajan et al., (2002) and Dhar et al, (2007). During machining tool holder produces enormous vibrations and it will have an impact on tool life and product quality in the absence of a suitable damper. Vibration during hard turning may cause premature tool failure Sampaul et al., (2013). Therefore, it is not always possible to machine hard materials using hard dry machining. When used for machining, the cutting fluid has a cooling and lubricating action that facilitates the easy flow of chips. Numerous studies investigated minimal cutting fluid application (MCFA) and minimum quantity lubrication (MQL). Cutting fluids are employed in these procedures in extremely modest doses, ranging from 5 to 50 ml/min. In MQL, the cutting fluid is combined with a high-pressure air stream to atomize it into smaller molecules that are then sent at a high velocity through a nozzle to the cutting zone by Itoigawa et al., (2006) and Vasu et al., (2011). The primary cutting fluid in the MQL system is made up of water and oil emulsions. The system uses high-pressure air that is channelled into a chamber with a small supply of cutting fluid. Pumping air and cutting fluid together causes a spray or mist to form at the exit of the nozzle. Thus, mist cooling is another name for it. The cooling of these areas will decrease tool wear, cutting force, and cutting temperature. The cutting fluid mist is directed to the cutting zones (tool-work interface, tool-chip interface, or rear side of the chip). The cutting fluid provides sufficient lubrication while simultaneously dissipating heat through vaporization by Dhar et al., (2007). Cutting fluid is poured into the chip's back side to provide a recall effect that aids in chip breakup and, as a result, lessens flank wear. The direction of application, mist velocity and pressure, and amount of cutting fluid employed is the distinguishing aspects of this system that were taken into consideration. The majority of researchers have carried out tests to increase these parameters to enhance the cooling and lubrication system in machining. To protect the machine operator, the MQL system must minimize mist generation. A recent area of study that controls the development of mist during cutting fluid application is called minimal cutting fluid application (MCFA). In this technique, the air is not combined with the cutting fluids, which are essentially emulsions. A minimum cutting fluid applicator is used to directly pump the emulsions at the correct pressure and volume. MCFA uses a positive displacement pump to provide the cutting fluid in pulsesas shown in Fig 1. Varadarajan et al. designed this system (2002). Six outlets can be provided simultaneously using this method.

Cutting fluid emulsion is delivered by the MCFA system at a pressure of 50 to 200 bar and a pulse rate of 500 to 1000 per minute. Cutting fluid can be applied at rates ranging from less than 1 ml/minute to more than 30 ml/minute. When cutting fluid emulsion is fed directly at high speeds to the cutting zone, the technology has proven to be effective. Due to the cutting fluid's rapid arrival at the cutting zone and immediate vaporization, the heat generated there will be reduced. In various trials to demonstrate the effectiveness of the system, specially formulated cutting fluids and cutting fluids made of vegetable oil were also employed by Leo et al., (2010) and Robinson et al., (2012). A detailed literature survey was conducted to assess the performance of MCFA where different materials, machining processes, and cutting fluids were used.

MACHINING WITH MINIMAL CUTTING FLUID APPLICATION

Varadarajan et al. (2002) experimented with the hard turning of hardened steel with low application of cutting fluid (HTMF). In this project, the tool-work and tool-chip interfaces were treated with a specifically prepared cutting fluid. The cutting tool was a multicoated hard metal insert with a sculptured rake face (SNMG 120408 MT TT 5100) from SANDVIK, and the workpiece was AISI 4340 of 46 HRC. Cutting fluid was delivered in the form of a pulsed jet by the developed cutting fluid application system at high pressure and velocity.

Cutting fluid supplied enough cooling and lubrication when it was applied into the cutting zone at high pressure and velocity. The cutting fluid was delivered at a pressure of 20 MPa and a maximum speed of 100 m/s. The amount of cutting fluid used in this experiment was reduced to 2 ml/min, and it was discovered that this method was more effective than turning with flood cooling and dry turning. Hard turning was shown to create substantially less cutting power and cutting temperature. The author described the "rebinder effect," a mechanical phenomenon that aided in inducing chip curl and shortening tool-chip contact length.

Vikram Kumar et al. (2007) conducted a study to determine how coated tools performed when used in hard turning with MCFA. Taguchi's 8-run orthogonal array, which had 7 operating parameters and was variably set at two levels, was created for the investigation. The factors taken into consideration were the type of tool coating, cutting fluid pressure, quantity used, frequency of pulsing, cutting speed, feed rate, and depth of cut. The cutting force, cutting temperature, and surface smoothness of the machined components were all improved by using the MCFA process. Due to both convective and evaporative heat transmission, the pulsing jet of cutting fluid transported heat more effectively than traditional wet turning. This study used an ANOVA analysis to determine how operating conditions affected results. Through severe turning with MCFA, Vikram Kumar et al. (2008) conducted a varied speed, feed, and flank wear test. In this study, the performance of

TiCN and TiAlN coated inserts were examined. They employed a cutting fluid pumping arrangement that can supply cutting fluids up to 30 MPa pressure with varied frequencies of a maximum of 1000 pulses/min on an AISI 4340 steel workpiece with a 44 HRC. The Taguchi's L18 orthogonal array was employed in the investigation, and 7 operating parameters were changed at three different levels. In this investigation, the MCFA approach outperformed both dry and wet turning. The TiAlN coated tool's performance was observed to be better compared to TiCN coated tool.

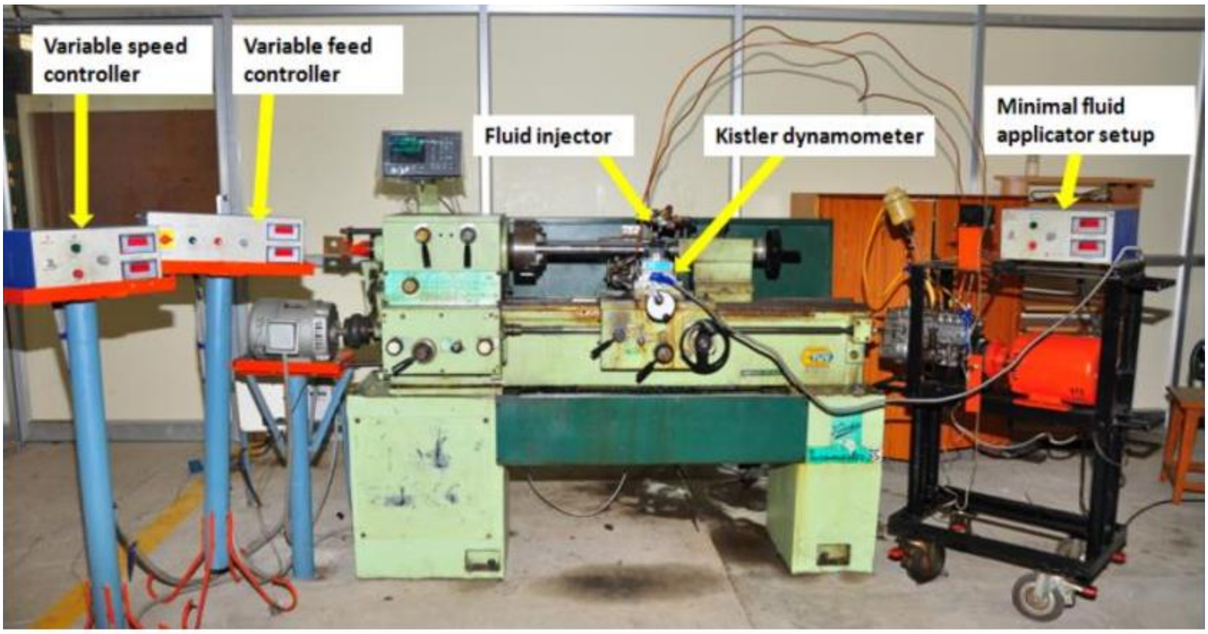

Fig.1 Experimental set up of MCFA

Ramkumar et al. tested the strategy of applying little cutting fluid (2008). They looked at how hard turning with MCFA might be affected by repeated jets of cutting fluid application. This study looked into the impact of a second, pulsing jet of cutting fluid on the chip's reverse. The goal of the study was to determine how the rebinder effect promoted chip curl by shortening the length of tool-chip contact, which in turn decreased cutting force and tool wear. They created an orthogonal Taguchi's L8 array with four operating parameters that could be changed on two levels. Mineral oil emulsion was used in the study as the cutting fluid. The quantity of cutting fluid, the frequency of pulsing, the composition of the emulsion, and the direction of application were the parameters chosen for the investigation. The research found that a cutting fluid flow rate of 5 ml/min, a pulse rate of 300 ps/min, and cutting fluid composition of 10% emulsion with 90% water produced satisfactory results. The inclusion of a second jet on the chip's reverse side improved the surface polish. Low tool chip contact lengths were found to result in lower tool wear, cutting temperature, and cutting force.

Robinson Ganadurai et al. (2012) reported on the minimum impact of auxiliary cutting fluid application after conducting a thorough investigation to demonstrate its effectiveness. The investigation in this paper supported the findings from Ramkumar et al. (2008), but it also demonstrated the effectiveness of a 20 percent concentration emulsion. To demonstrate the viability of MCFA, the author ran tests on changing feed, speed, and tool life. On the back of the chip, the X-Ray Diffraction test (XRD) and Electron spectroscopy for chemical analysis (ESCA) were carried out to determine the impact of the cutting fluid. Both experiments showed that the chip's embrittlement boosted the rebinder effect. Scanning Electron Microscope was used to analyze the tool wear that happened during dry, wet, MCFA, and MCFA with an auxiliary jet. The results displayed that tool wear was comparatively less during hard turning with MCFA with auxiliary jet.

A cutting fluid made from environmentally friendly coconut oil was utilized in a study by Varadarajan et al. (2012). The manufacturing sector is paying a lot of attention to green machining. Multiple additives that enhance the capabilities of coconut oil were utilized in the formulation of the cutting fluid, and this oil was then used for testing in the form of an emulsion. In this study, cutting fluids based on mineral oil and coconut oil were tested with MCFA. According to the study, coconut oil-based cutting fluid can perform as well as mineral oil-based cutting fluid. Sampaul et al. (2013) investigated the effects of using a semi-solid lubricant while hard turning AISI 4340 steel with a 46 HRC. This study's MCFA concentration, semi-solid lubricant (grease), and addition of 10% graphite were all present during the experiment. The tool-chip interface, the chip's reverse side, and the tool-work interface all received the semi-solid lubricant. When a semi-solid lubricant was used, heat transfer occurred by evaporation, which was more efficient than traditional heat transfer during wet turning. A pneumatically operated device that can supply the desired quantity in the needed direction was used to apply the semi-solid lubricant. Cutting force, surface roughness, tool vibration, tool wear, and cutting temperature were used to determine the results. The comparison of MCFA with dry and traditional wet turning demonstrated the efficacy of semi-solid lubricant. According to the results of the comparison, turning with semi-solid and MCFA lubricants showed less tool vibration, less cutting force, better surface smoothness, lower cutting temperature, and less tool wear.

One of the crucial turning-related variables that influences tool wear and surface roughness is tool vibration. There have been several research efforts made to reduce tool vibrations during MCFA. In one of the related studies were done by Sampaul et al. (2015), a magnetorheological fluid damper was employed to lessen the vibration of the instrument. They created a magnetorheological fluid damper with electrical power as a means of activation. Magnetic fluid particles in the MR damper become magnetized, giving the plunger damping capabilities. In this project, the plunger was attached to the cutting tool's base. The vibration that was created at the tool was transferred to the plunger's end. The minimal cutting fluid parameters used in this experiment were held constant. The provided current to the damper, the shape of the plunger, the viscosity of the oil utilized, and the size of the ferromagnetic particles in the damper were the variable parameters used in this experiment. It was discovered that the damper was able to absorb every vibration. This contributed to improving the work part's surface finish and decreasing tool wear.

Anil Raj et al (2015) investigates that there was a 23.52% reduction in cutting temperature during MCFA assisted hard turning when compared to MQL assisted hard turning. The overall performance during Minimal Cutting Fluid Application was found to be superior to that during dry turning, conventional wet turning and hard turning with MQL on the basis of tool wear. This technique can form a viable alternative to conventional wet turning and MQL assisted hard turning as it is more environments friendly and technologically superior to the MQL assisted hard turning and can be implemented on the shop floor without drastic alterations in the existing setups.

An experimental investigation to quantify the benefits that can be achieved by installing a heat pipe as a performance enhancer during hard turning with minimal fluid application was made by R. Robinson Gnanadurai et al (2016). A comparative study is also made to compare the performance during dry turning, wet turning, conventional hard turning with minimal fluid application, heat pipe assisted minimal fluid application. Heat pipe assisted cooling of the cutting tool can bring forth better cutting performance during hard turning with minimal fluid application. Extraction of more heat from the cutting zone by the presence of heat pipe leads to the overall reduction of average cutting temperature, and this can also reduce the thermal degradation of the cutting fluid which helps in preserving its lubricating ability. When heat pipe was introduced during minimal fluid application, there was a reduction of cutting temperature by 22%, the tool wear by 15%, the surface roughness by 0.83% and the main cutting force by 2.9% when compared to conventional minimal fluid application without the aid of heat pipe for extracting heat from the tool for the same cutting conditions.

Researchers have investigated hard turning with MCFA, and they have found the process to be highly effective, environmentally benign, shop floor-friendly, and economically advantageous to the sector. The researchers used a variety of techniques to plan their experiments, and the majority of them used Taguchi's method before moving on to ANOVA analysis, artificial neural networks, and regression techniques to back up their findings. To demonstrate the efficacy of their research, the tools and chips generated were examined using a scanning electron microscope, an X-ray diffraction test, and electron spectroscopy for chemical analysis (ESCA).

CONCLUSION

The study on machining of materials with minimal cutting fluid application revealed the following.

- The process of MCFA can generate a green environment on the shop floor and also reduces cutting fluid costs.
- The process proved itself to be efficient and useful in improving the health condition of workers in the industries.
- The study helped in understanding the effectiveness of the MCFA process.

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