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RESEARCH ARTICLE

Experimental Investigation on Cutting Speed and Temperature Variations during Orthogonal Machining of AISI 4340 Steel using Mak Sherol B as Coolant under Mist Conditions

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Abstract

High production machining particularly of high strength and heat resistant materials is associated with generation of large amount of heat. Such high temperatures profoundly tend to cause dimensional deviation in the work piece and premature failing of the cutting tool. The cutting fluids remove the heat from the work-tool interface. One of the methods of supplying cutting fluid to the work piece (at the work-tool interface to be precise) is by using a mist generator that carries the soluble cutting fluid and mixes it with compressed air, making the cutting fluid to spray on the working area in the form of mist (suspension of liquid particles in air).This is a technique of Minimum Quantity Lubrication (MQL) where the wastage of cutting fluid as admissible in conventional flood type cooling is prevented. Also, the oil mist particles coming out at high velocities, in the form of fluid jets, when incident on the work-tool interface, reduce the working temperatures of the high temperature zones and consequently improve the tool life. The mist machining is also considered an environmental friendly approach over conventional machining. By comparing the machining parameters such as cutting temperatures, tool wear, chip shapes and surface roughness(of work) obtained by admitting the cutting fluid in the form of mist (MQL) and by conventional flood type machining (Wet Machining) and without admitting coolant(Dry Machining), on high strength alloy steels such as AISI 4340 grade Steel using carbide inserts , it is possible to experimentally investigate the most suitable and efficient type of machining in terms of optimization in machining variables, especially cutting temperatures, chip morphology and tool wear rate and other important factors like machining economy and environmental considerations.

INTRODUCTION

Md. Abdul Hasib et al [1], 2008, developed mist application device to apply cutting fluid for turning operation of medium carbon steels. The experimental investigation of mist cooling carried out under different cutting speeds, depth of cut as well as spindle speeds The above operation have been done by the authors for dry condition and compared the results obtained with wet machining and mist cooling. The authors concluded that mist application leads to reduction in the cutting temperature by 40% lower than conventional fluid cooling systems.

Evald Wahlmuller et al [2], 1999, conducted studies to identify major factors for lubricant mist exposure covered 15 metal machining sites. The study confirmed that appropriate service measures lower both aerosol emissions and lubricant vapor concentrations due to the reduction of exposed oil-wetted surfaces. The performed measurements showed no significant relationship between loads of airborne lubricants and the type of machining process. The authors concluded that the individual assessment of any workplace due to the complex situation remains essential.
Jonarthan et al [3], 2000, investigated the use of metalworking fluids during machining results in a mist that is associated with adverse health effects. The authors conducted experiments on a small lathe and quantified the amount of mist generated by evaporation/condensation, centrifugal force, and impaction. The authors determined that evaporation/condensation was the most important mechanism, followed by centrifugal force, and then impaction. Hong et al [4], 1999 studied the effect of cryogenic chip cooling on the machining of AISI 1008 low carbon steel. It was found that chip breaking was improved in cryogenic machining over dry machining.
Hong et al [5], 2001, carried out experimental investigation into the role of cryogenic cooling by liquid nitrogen on friction and cutting force in machining of Ti-6Al-4V. The experimental results indicated that cutting force was increased in cryogenic machining. It was also found that the friction coefficient on the tool-chip interface was considerably reduced in cryogenic machining. Venugopal et al [6], 2007, investigated the tool wear and tool life of carbide inserts in turning Ti-6Al-4V alloy under dry, wet and cryogenic environment. It was found that tool wear parameters are less in cryogenic environment. Afzao et al[7] (2010) investigated end milling of AISI 4340 steel using the finite element method and successfully predicted the cutting forces using the numerical model. An orthogonal FE model was developed by varying the cutting velocities, depth of cut and feed rates and compared with experimentally obtained results. The predicted and the measured forces were in very good agreement. The micro milling of cutting forces was determined by using the predicted forces from the orthogonal cutting FE model and the calculated uncut chip thickness. Wang et al [8], 1996, have carried out turning of ceramics [Si3N4] with Polycrystalline Cubic Boron Nitride [PCBN] under cryogenic cutting condition and reported that liquid nitrogen cooling system reduced the cutting tool temperature and tool wear over dry machining. Khan et al [9], 2008, studied the effect of cryogenic cooling with the modified tool and reported that the tool life increases about more than four times by applying liquid nitrogen using modified tool. Wisley et al [10], 1996 investigated during metal machining where aerosols were generated from severely refined, non-aqueous cutting oils used during the lathe working of metal rod stock. The authors determined that the ratio in which exposure to inhalable aerosol was greater than to “total” aerosol which is consistent with previous observations in other industries.

Objectives

To experimentally investigate the various machining parameters namely the cutting temperature, tool wear and chip morphology during the orthogonal machining of high strength and heat resistance alloy steels such as AISI 4340 grade Steel with Coated and Uncoated Carbide inserts by supplying oil mist particles (Cutting fluid mixed with compressed air and supplied at high velocities on the work-tool interface and comparing it with the conventional flood type machining as well as dry machining. And to optimize the most efficient method of feeding cutting fluid onto the work-tool interface among the three above mentioned methods of supplying coolant. These parameters are to be investigated for machining high grade AISI 4340 (EN-24) Steels during the orthogonal machining of a hollow cylindrical work piece using coated and uncoated carbide inserts in a capstan lathe by using at least three different combinations of speed and three different combinations of feed rate under dry, wet and oil mist (MQL) conditions. And subsequently to optimize the best method to machine the work under several specified and unspecified conditions.

Minimum Quantity Lubrication

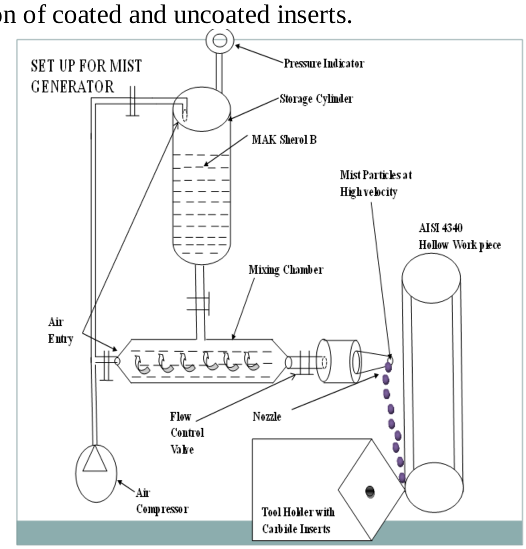
Concerns about coolant costs and environmental problems from large quantity cutting fluid application has led to recent developments in the use of dry or near dry cutting conditions. The near dry condition is otherwise called as Minimum Quantity Lubrication. For dry cutting to be acceptable, steps must be taken to compensate for the primary functions of the cutting fluids. More friction and adhesion between the work piece and tool will occur. The thermal loads on the tool and work piece are greater, which may result in increased levels of tool wear. In addition chip formation may change and chip control will become tedious. As a result, careful choice of tool becomes necessary.
Thus, for MQL application, the fluids are mixed with air to form an aerosol (mist) and delivered close to the cutting edge. Thus, mist machining is a form of Minimum Quantity Lubrication. Fig. 1 shows conventional MQL type oil-mist application of cutting fluids where in the cutting oil particles suspended in air, is directed at high velocity with

the help of compressed air at the high temperature zones to ensure minimum wastage of the oil, least environmental effects and more temperature reduction due to high temperature reduction properties and atomization of the oil particles under suitable conditions.

MAK SHEROL B is established to perform orthogonal machining of AISI 4340 steel under the three conditions of coolant applications using both coated and uncoated inserts and compare the experimental results of various parameters under consideration. As a result, it becomes mandatory to select the appropriate cutting fluid for application which could not only serve the purpose for machining grade steels but also to machine non-ferrous components which are considered to have typical industrial applications. In simple words, the cutting fluid must suit both ferrous and non-ferrous alloys and at the same time must be eligible to be used in the mist generator to generate mist which can be applied on the minute areas of the work-tool interface to achieve cooling action with the use of minimum cutting oil. After careful studies and enquiries from various industrial personnel's, it was decided that, widely used cutting oil named "MAK SHEROL B" serves our purpose.

Experimental Procedure

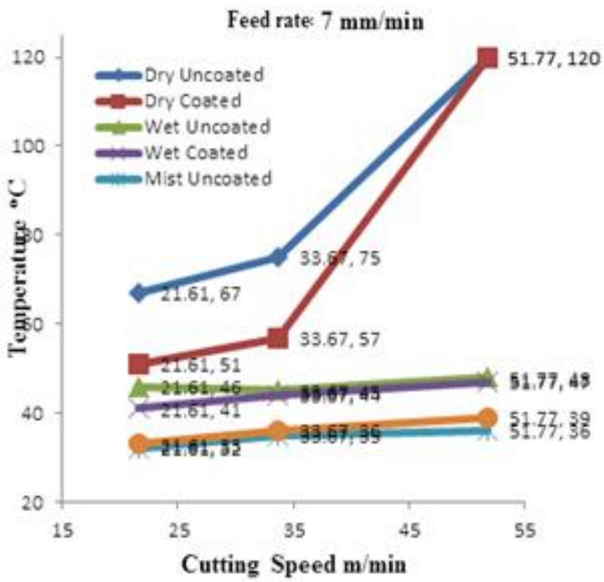
Once the experimental set up is installed, the following procedure has to be followed to conduct experiments for evaluation. The work piece (AISI 4340 hollow rod) was clamped on the collet chuck of the Capstan lathe, the tool holder was fixed on the clamp and the uncoated inserts was fixed tightly. Standard precautions such as use of gloves, masks and goggles were ensured. Thick paper was placed for collecting chips. The required cutting speed-feed combination was selected. The motor was started and the hollow work piece was machined for a standard length. The laser of the thermometer gun was beamed on the work tool interface and the temperature was recorded at the end of the machining. The chips were collected with the help of gloves and placed in a zip-lock cover and the appropriate speed feed combination was noted down for identification. The machine was cleaned of residual chips with brush. The next cutting speed-feed combination was chosen and the above procedure was repeated. Likewise the above procedure was repeated for coated inserts and the readings were tabulated. Now the outlet valve of the Set up used for Applying flood type coolant was opened. The above steps for both coated and uncoated inserts were repeated for wet (flood type) machining. Now the compressor was connected to the set up and the venturi was placed incident on the work-tool interface. Now, the compressor was opened and the air was circulated into the mixing chamber and storage cylinder by opening corresponding valves. The above steps for both coated and uncoated inserts were repeated for mist conditions. The chips were taken to the Metrology laboratory and the chip thickness was determined after machining with the help of tool makers microscope and the values were tabulated. The observation table was prepared for comparison of dry, wet and mist conditions. Similarly another observation table was prepared for comparison of coated and uncoated inserts.

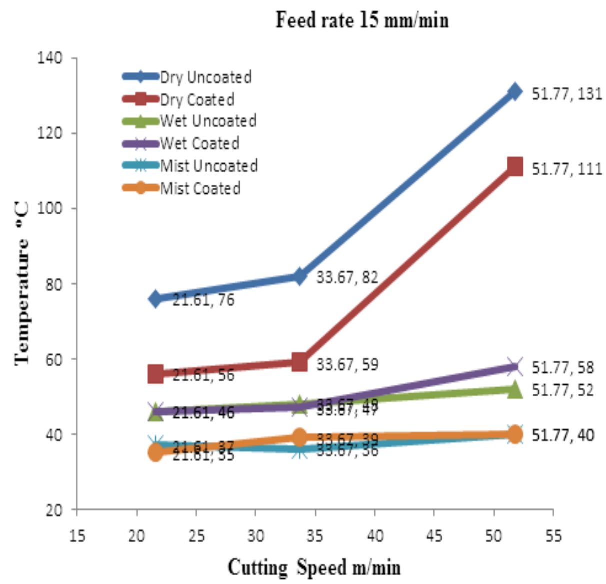


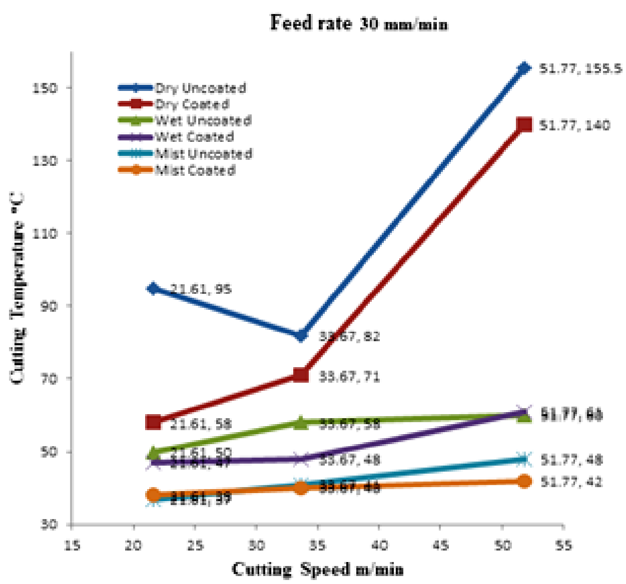
Result and Discussion

In this section, we shall tabulate the quantitative comparisons of Cutting temperature for AISI 4340 steel among various Cutting speed-feed rate combinations for both coated and uncoated inserts for dry, wet and mist conditions

and find the percentage reduction in cutting temperatures in the primary shear zone of mist over wet and dry conditions. Further, Graphs are drawn to make distinctive comparisons among dry, wet and mist conditions by keeping Cutting Temperature as dependent variables and Cutting Velocity and Feed rate as independent variables.
It is largely observed that the cutting temperature in case of mist application of cutting fluids is much less when compared to other types of cutting fluid applications. It may be observed the temperature tends to increase as the cutting speed and feed rate increases.







However, it may be observed that in a certain cases, the temperature suddenly reduces to a low value at medium feeds/speeds and then suddenly increase. This change in trend is owed to the fact that the material may get softer in certain areas due to procurement conditions or repeated machining, which justifies the reduction and sudden rise of temperatures in certain areas. Irrespective of the type of machining, the temperature-cutting speed/feed plot finds a steep increase and it is always observed that the cutting temperatures during mist machining is always less than other types of machining for all cutting speed/cutting feed rate conditions. Reduced temperature is a prospectus of mist machining as mist flows at high velocity with oil particles in the form of broken globules which tend to remove the heat at a higher rate than flood type or dry type machining. It is also found that the cutting temperatures obtained

using coated carbide inserts is lower when compared to using uncoated inserts. However, the percentage reduction (Coated Vs Uncoated) in mist and wet conditions is lower when compared to that in dry conditions.
A similar trend is obtained for shear angle plots but here the shear angle obtained in coated conditions is higher than that of uncoated conditions theoretically indicating that lesser cutting force is generated using coated inserts than when uncoated inserts are used.

Conclusions

It can be concluded that nearly 25% reduction in cutting temperatures is possible by using mist application when compared to the wet type coolant application using uncoated inserts and about 22% reduction is possible when coated inserts are used.
Similarly, an average of 60 % reduction in cutting temperature is possible by using mist application when compared to dry type machining using uncoated inserts and an average of 50% similar reduction under the influence of coated inserts.
The cutting temperature, in general, increases with the increase in cutting speed as well as cutting feed rate.
Similarly, the cutting temperature followed the same pattern as mentioned above for different conditions, but remained higher for uncoated inserts when compared to coated inserts. However, the variations among coated and uncoated inserts were not uniform for all cases, the effect of temperature on the work material being one of the key factors for the same.
The chip was found to be regular and continuous when machining under mist conditions than under wet and dry conditions of machining. Chips remained continuous only at high cutting speeds for dry conditions, but majority of continuous and near continuous chips were obtained in the case of mist machining.
As far as the effectiveness of the mist cooling on the tool wear is concerned, it is evident that the tool wear was rapid for dry machining for both uncoated inserts (six cutting operations on an average) and for coated inserts (eighteen to twenty two operations) on an average. When wet application was used, it was found to be more efficient than dry machining in terms of the wear parameter. But the interesting result is of the mist application when no wearing of the tool was noticed for any operation for both coated and uncoated inserts, clearly proving the exceptional efficiency of the mist machining in terms of tool wear rate.

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