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INFLUENCE OF MINIMUM QUANTITY LUBRICATION (MQL) ON CHIP AND SURFACE FINISH IN TURNING MEDIUM CARBON STEEL BY COATED CARBIDE

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Abstract*-This paper deals with high cutting velocity and feed during machining that usually generates large amount of heat as well as high cutting temperature which increases tool wear, shortens the tool life and deteriorates surface quality. The use of coolant generally increases life of tool is a common belief. There are also some negative effects of cutting fluid wastes in industries. This paper suggests that minimal fluid application provides several benefits in machining. It has been found that minimum quantity lubrication (MQL) do better in respect of cutting temperature, chip form (chip shape, chip Color and chip thickness ratio), surface finish and dimensional accuracy while turning medium carbon steel by coated insert. The use of cutting oil and vegetable oil as MQL leads to reduce surface roughness, increases surface finish and dimensional accuracy by lowering cutting temperature, while also having favorable chip tool interaction.*

Key words: Minimum Quantity Lubrication, chip, Surface Finish

1. INTRODUCTION

Machining removes material from the surface of a less resistant body through relative movement of the tool and application of force. Due to removal of material in the form of chips, mechanical energy transforms into heat, leading to conditions of high pressure, high temperature and severe thermal conditions at the tool-chip interface. The higher the tool temperature, the faster the flank wears. The use of cutting fluids in machining processes reduces cutting zone temperature by cooling and lubrication.

The performance and service life of engineering component depends on their material, dimensional or form accuracy and surface quality. But high production machining with high cutting velocity, feed, and depth of cut is inherently associated with generation of large amount of heat and high cutting temperature. Such high cutting temperature not only reduces dimensional accuracy but also impairs the surface integrity of the product by inducing tensile residual stresses and surface and subsurface micro cracks in addition to rapid oxidation and corrosion. In high speed machining, conventional cutting fluid application fails to penetrate into the chip-tool interface and thus cannot remove heat effectively **[1].**

Use of cutting fluid provides numerous advantages in machining but suffers from serious drawbacks of operator health hazard as well as environmental and economic problems. Improper disposal of cutting fluids pollutes land, water, and air and thus disturbs the whole environment **[2].** Contact of cutting fluid with skin and inhalation of its vapor causes skin and respiratory problems due to presence of various additives such as emulsifiers, biocides, rust inhibitors, stabilizers, etc. In addition, cutting fluid particles remain suspended in the environment for a long period **[3]** and thus affect other employees, which are not in direct contact with cutting fluids **[4].**

The use of coolant fluid costs from 7 to 17% of the total manufacturing cost of work-piece **[5]** and requires additional time for work-piece/tool/machine cleaning **[6].** Moreover, a study conducted by Sutherland et al. [**3**] reveals that 12-80 times more cutting fluid mist was generated with wet turning, than cast iron dust in dry turning. Most investigations of using MQL have been focused mainly on turning and drilling operations. Most research has concluded positive effects to its lubrication ability. Thus, this work is undertaken with the aim to evaluate the use of vegetable oil and cutting oil through the application of MQL technique when turning medium carbon steel using solid coated SNMG tool.

2. EXPERIMENTAL DETAILS

2.1 Experimental Conditions

In this experiment MQL conditions are used during machining to compare the results with the same by dry condition. For MQL supply the positioning of nozzle tip is very important and that has been settled after a number of trials. During machining the MQL jet is directed along the main cutting edge to reach at the principal flank and partially under the flowing chips to the cutting edges.

Table 1: Experimental conditions

• Machine tool	:	Lathe, 7.5 kW
• Work material	:	AISI 1060 steel Chemical Composition by weight percent (Fe =98.67, C = 0.58, Si = 0.07, Mn = 0.6, P = 0.03 and S = 0.05)
Physical Properties	:	Density 7.85 g/cm^3, Melting point 1510ºC.
Mechanical Properties	:	Ultimate tensile strength 620 MPa, Yield strength 485 MPa.
Hardness, Brinell:	:	183
• Cutting insert	:	Coated carbide, SNMG 120408, WIDIA
Process parameters	:	
• Cutting speed, V	:	67, 84, 105, 134, 167 and 211 m/min
• Feed, f	:	0.10, 0.125, 0.15 and 0.175 mm/rev
• Depth of cut, d	:	1mm
• Tool geometry	:	-6°,-6°,6°,5°,15°,75°,0.8 (mm)
• Coolant type	:	soluble fluid, Cutting oil (VG 68) and Vegetable oil
• Coolant delivery methods	:	Minimum quantity lubrication with a spray of air and cutting fluids at a pressure of 8 bars and flow rate of 100 ml/hour.

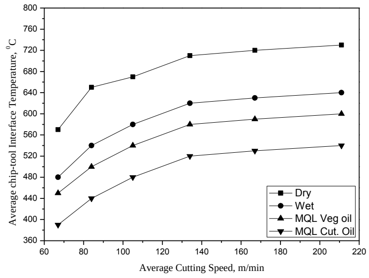
2.2 Test apparatus

The Photographic view of the MQL applicator is shown in Fig. 1. Minimum quantity lubrication jet was injected through the tool rake face, the set up consists of a compressor, MQL applicator, center lathe machine, tool-wear thermocouple and experimental steel. In this study, the minimum quantity lubrication (MQL) was provided with a spray of air and cutting fluids at a pressure 8 bars and coolant flow rate of 100 ml/hr.

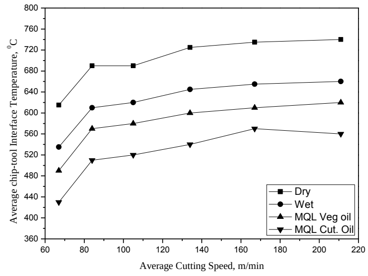
Fig. 1: Photographic view of the MQL applicator

3.EXPERIMENTAL RESULTS

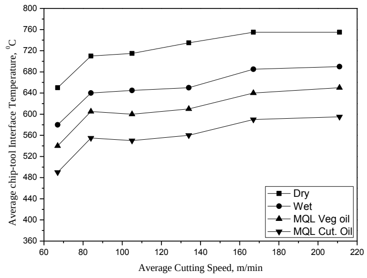
3.1 Effect of Cutting temperature



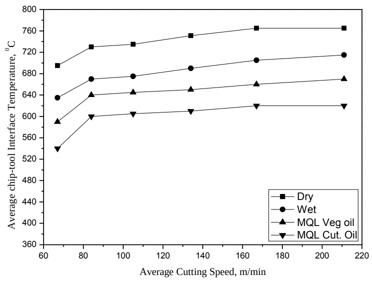
Feed 0.10 mm/rev



Feed 0.125 mm/rev



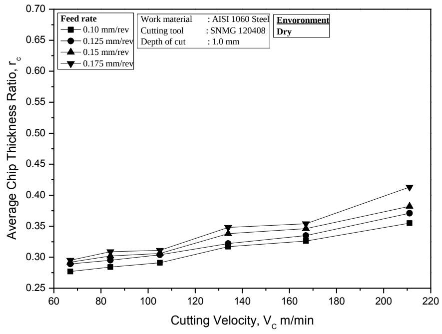
Feed 0.15 mm/rev



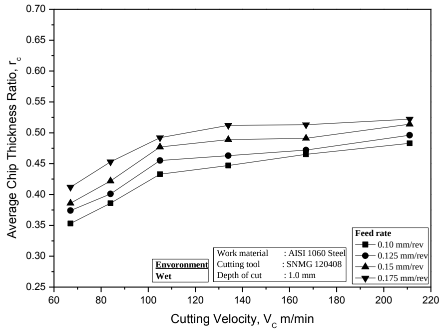
Feed 0.175 mm/rev

Fig. 2: Variation of average chip-tool interface temperature with different speed under dry, wet, MQL with Vegetable oil and MQL with Cutting Oil, VG 68 condition during machining AISI 1060 steel

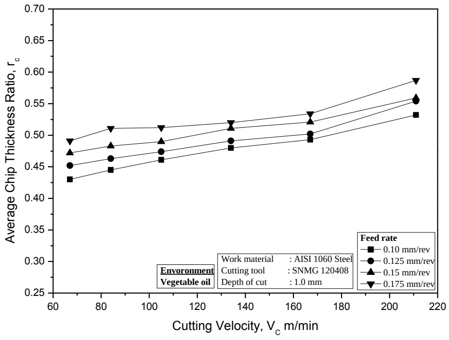
3.2 Effect of chip thickness



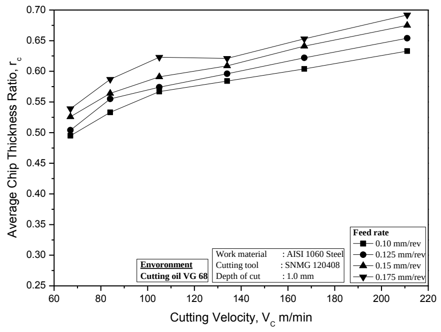
Dry Condition



Wet Condition



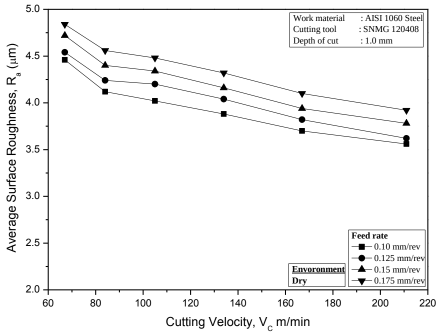
MQL (Vegetable oil) condition



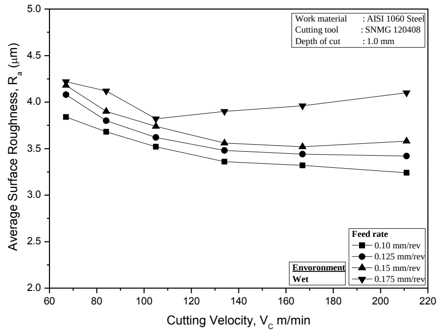
MQL (Cutting Oil VG 68) condition

Fig. 3: Variation of average chip thickness ratio (r_c) with different speed and feed under different conditions during machining AISI 1060 steel

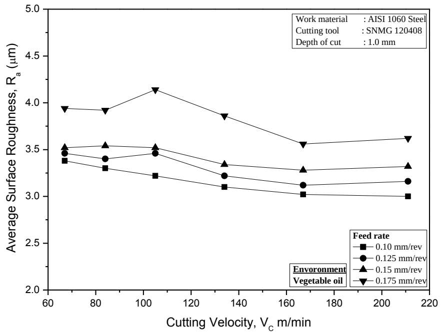
3.3 Effect of Surface roughness



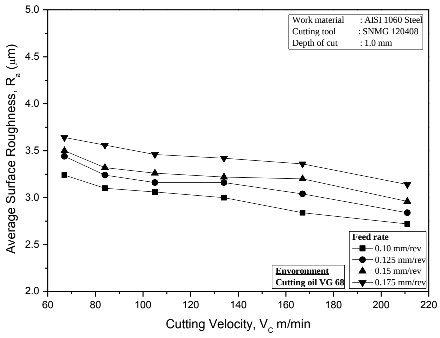
Dry Condition



Wet Condition



MQL (Vegetable oil) condition



MQL (Cutting Oil VG 68) condition

Fig. 4: Variation of average surface roughness (R_a) with different speed and feed under different cutting conditions during machining AISI 1060 steel

4. DISCUSSION ON RESULT

The cutting temperature generally increases with the increase in cutting speed and feed, though in different degree, due to increased energy input and it could be expected that MQL would be more effective at higher values of cutting speed and feed. The average chip-tool interface temperature has been determined by using non-contact type infrared thermometer and plotted against cutting speed for different work-tool combinations, feed rates and environments undertaken. Fig. 2 is showing how and to what extent cutting temperature has decreased due to application of MQL application under the different experimental conditions. With the increase in cutting speed and feed, cutting temperature increased as usual, even under MQL conditions, due to increase in energy input. The difference in cutting temperature noted for the different work-tool combinations under dry machining and same cutting speed-feed conditions has been mainly due to difference in specific energy requirement.

Apparently more drastic reductions in cutting temperature are expected by employing MQL. But practically it has not been so because the MQL has been employed in the form of thin jet along the cutting edge and towards only the chip-tool interface instead of bulk cooling. Also the jet, like any cutting fluid, could not reach deeply in the chip-tool interface for plastic or bulk contact, particularly when cutting speed and feed are large. The MQL is more effective using cutting oil VG 68.

The variation in value of $\boldsymbol{r_c}$ with speed and feed at various conditions has been plotted which is shown in Fig.3. Chip thickness ratio, r_c (ratio of chip thickness before and after cut) is an important machinability index of chip formation and specific energy consumption for a given tool-work combination. For given cutting conditions, the value of chip thickness ratio depends upon the nature of chip-tool interaction, chip contact length and chip form all of which are expected to be influenced by MQL in addition to the levels of cutting speed and feed rate.

In machining conventional ductile metals and alloys producing continuous chips, the value of r_c is generally less than 1.0 because chip thickness after cut becomes greater than chip thickness before cut due to almost all sided compression and friction at the chip-tool interface. Smaller value of r_c means larger cutting forces and friction and is hence undesirable.

Surface finish is an important index of machinability because performance and service life of the machined/ground component are often affected by its surface finish, nature and extent of residual stresses and presence of surface or subsurface micro cracks.

Several factors will influence the final surface roughness in a machining operation. The surface roughness might be considered as the sum of two independent effects: (1) the ideal surface roughness is a result of the geometry of the tool and feed rate and (2) the nature of surface roughness is a result of the irregularities in the cutting operation. Factors such as spindle speed, feed rate and depth of cut that control the cutting operation can be setup in advance and factors such as tool geometry, tool wear, chip loads and chip formations, or the material properties of both tool and work piece are uncontrolled. The variation in surface roughness observed with advancement of machining of steel by the coated carbide SNMG insert at a particular set of cutting speed (V), feed rate (f), and depth of cut (t), under dry, wet and different MQL conditions which have been shown in Fig. 4.

5. CONCLUSIONS

This study led to the evaluation of the effectiveness of the MQL system. The results clearly indicate the advantages of using MQL over dry and flood cooling while machining the material. Based on the observations made and the experimental results obtained, the following conclusions are made:

i. The present MQL system enabled reduction in average chip-tool interface temperature.

ii. Due to MQL jet, the form of the steel chips became favourable for more effective cooling and improvement in nature of interaction at the chip-tool interface. Friction is reduced at the chip-tool interface due to the fragmentation of the chip by the impinging jet which prevents intimate contact at the chip-tool interface.

iii. The surface finish obtained is much better than that obtained in the case of dry machining. The welding of hot chip to the cutting edge which is a common problem while machining ductile steel is completely eliminated with the application of MQL jet, leading to an improvement in surface quality.

6. REFERENCES

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7. NOMENCLATURE

Symbol	Meaning	Unit
MQL	Minimum quantity lubrication	Dimention less
V	Cutting speed	m/min
f	Feed rate	mm/rev
t	Depth of cut	mm