EFFECT OF MQL ON TOOL WEAR AND SURFACE ROUGHNESS IN TURNING OPERATION

Ayush Chaturvedi[1], Parinay Gupta[2], Rabesh Kumar Singh[3], Dr. N.K Singh[4]

[1,2,34] *Department of Mechanical Engineering, IIT (ISM) – Dhanbad, Jharkhand (India)*

ABSTRACT

For improvement of tool life and increasing production cutting fluid are vital for an industry. However, due to various drawbacks a paradigm shift was seen toward dry machining and MQL machining. In present work dry machining and MQL machining of AISI 316 in turning operation are compared on the basis of surface roughness and tool flank wear. Furthermore, the effect of feed, velocity and depth of cut is seen in both the cases to find out the parameter that affects surface roughness and tool flank wear the most. It has been found that both surface roughness and tool flank wear were minimum in MQL machining. With increase in all three parameters the change surface roughness and tool wear is also studied.

Keywords: Dry machining, MQL, Surface roughness, Tool wear, Turning

I. INTRODUCTION

In industries, cutting fluid provides the perfect cutting conditions by reducing heat generated, providing lubrication and flushing the chips off the tool work piece interface thereby increasing tool life. But cutting fluids have adverse effect on environment and is often detrimental to the health of an operator. More over sometimes cutting fluid do not reach to the interface of tool and work piece. In addition to these disposals of cutting fluids is also a major problem. So recent years have seen a shift towards dry machining and MQL.When machining is done in the absence of cutting fluid then it is called dry machining. *Sreejith et al.* [1] represented that there is a shift towards dry machining because of its least effect on environment, the residue on the swarf i.e. solid waste generated during machining is absent and sometimes dry machining requires less cutting force than wet machining. Sometimes the cutting fluid cost is more than twice the tool-related costs [2]. However, hardness of tool is affected by high temperature generated at the machine zone. Hence tool life is affected by absence of cutting fluid MQL i.e. Minimum Quantity Lubricant or Near Dry Machining is process of spraying cutting fluid at the tool work interface at high pressure so that it can penetrate properly and was clearly represented by Braga et al. [3] reduction in surface roughness and tool wear was seen by *Dhar et al.* [4] while turning AISI 4340 steel with uncoated carbide tool with MQL as compared to dry and wet machining. *Beatrice* et al. [5] also concluded that there is decrease in surface roughness while using MQL. *Sarıkaya et al.* [6] by using Taguchi's orthogonal array compared the effect of various parameters in wet, dry and MQL machining and came to the conclusion that feed rate is most effective parameter on surface roughness. *Chinchanikar et al.* [7] performed turning using HiPIMS-coated carbide tool under dry and MQL machining and studied the tool wear and found a reduction of about 20%-25% tool wear in MQL. *Dr. Raoa et al.* [8] analyzed by using Taguchi's L27 and found that feed rate effects the cutting force and surface roughness both while cutting speed in insignificant in both the cases however, depth of cut influences only cutting force and not the surface roughness. A study by *Basavarajappa et al.* [9] reveals that in turning of AISI H13 steel feed rate has highest influence on surface finish. *N. Satheesh Kumar et al.* [10] performs turning in a CNC lathe and reveals that feeds and speeds have direct impact on surface roughness. *Swapnagandha S. Wagh et al.* [11] also focussed his work towards environment friendly machining and found that value of Ra at high cutting speed because of low built-up edge formation gives improved surface finish. Dry turning of cast duplex stainless steels using TiC and TiCN coated cemented carbide cutting tools was performed by *Selvaraj et al.* [12] and it was revealed that surface roughness first decreases and then increases when cutting speed is increased. However, surface roughness decreases with decrease in feed rate. Therefore, it can be concluded that MQL reduces surface roughness and increases tool life by minimizing the flank wear. To predict tool life in Near Dry Machining a new model was developed by *Marksberry et al.* [13] that can predict tool life in near dry machining within 10% and it was revealed that tool life can be increased to almost four times using NDM than in case of dry machining. . However, Bruni et al. [14] and Diniz et al. [15] observed that MQL did not significantly reduce tool wear. Attanasio et al. [16] experimental study also concluded that although, MQL gives some advantage during turning operation, but it presents some difficulty in exactly reaching the lubricant at the cutting zone. *D. Dudzinskia et al.* [17] reviews the developments towards dry and high speed machining and state that it is not desirable to use coolants because of adverse impact on environment as well as human health. They also state that tool material should have high hot hardness, low adhesion and low friction properties so as to overcome the disadvantages of not using coolant or cutting fluids.

In present work turning of AISI 316 steel is done under dry condition and MQL condition. The Effect of feed rate, cutting velocity, and depth of cut is observed on surface roughness of machined surface and tool flank wear for both dry and MQL technique. The different parameters are chosen according to Taguchi L9. Surface roughness and tool flank wear are compared in dry and MQL. Simulation is done and tool wear is compared with dry and MQL techniques

II. EXPERIMENTAL DETAILS

2.1 Material

The work material chosen was AISI 316 stainless steel of length 40mm and diameter 50mm. The composition of material is shown in table 1

Table 1 Composition of AISI 316

Element	% Fe	% Cr	% C	% P	% Mn	% Mo	% Ni	% S	% Si
Wt. %	62	18	0.08	0.045	2	3	14	0.03	1

2.2 Cutting conditions

The experiments were conducted in HMT lathe having maximum spindle power of 11kw and the spindle speed from 400 rpm to 1000 rpm under dry and MQL conditions. WIDIA cemented carbide tools CCMT 09T304-TN2000 were used for turning. The experiment set up is shown in Fig. 1. A fresh cutting edge was used for conducting each experiment. In order to remove irregularities and to avoid oxidation, material of 0.5mm depth was removed. The Minimum Quantity Lubrication (MQL) delivery system used in this study is a commercially available MQL fluid delivery system from UNIST Coolubricator as shown in Fig. 3.the air compressor used to maintain the pressure for MQL is in Fig 2. The cutting fluid was prepared by mixing of 5%vol. of 'Servo Cut S' oil.

Fig. 1 HMT NN22 Lathe

2.3 Tool wear measurement

Olympus BX51M microscope is used to measure the tool wear. The flank wear is observed at 5x and 10x magnification. At both the magnifications the surface features of tool were observed.

2.4 Surface roughness measurement

Surftest SJ-210- Series 178-Portable Surface Roughness Tester was used to determine the average roughness of the machined surface. It is a stylus type surface tester with stylus tip radius of 2μm. The surface roughness was measured for 6 locations and then average all was calculated.

Table 2 Equipment and materials

Workpiece	AISI 316 Stainless steel
Workpiece Dimensions	
Machine tool	Lathe (HMT, India)
Cutting tool	WIDIA cemented carbide tools
Cutting fluid	5%vol. of 'Servo Cut S' oil with distilled water
Tool wear analyzer	Olympus BX51M microscope
Surface Roughness tester	Surftest SJ-210- Series 178-Portable

2.5 Design of experiment

In engineering analysis and optimization Taguchi is widely used for robust parameter design to find factor settings that minimize response variation, while adjusting the process on target. Taguchi designs provide a powerful and efficient method for designing products that operate consistently and optimally over a variety of conditions. In this way the number of experiment are reduced using orthogonal array and thereby reducing the effect of uncontrollable factors [19]. According to Taguchi Design of Experiment 3- Level Design with 3 independent factors L9 was carried out.

Speed, Feed and Depth of cut are the independent factors. Effect of these parameters was seen on the temperature variation in dry and MQL condition and it was obtained that for both dry and wet machining feed has the most significant effect. However, in case of dry machining speed is the second most significant parameter followed by depth of cut but in MQL machining depth of cut has more significant effect than cutting speed. Values of the independent parameters were set according to 3- levels and the range was selected as shown in table 2.

.Table 3 Value of Independent Parameters

	Low	Medium	High
Speed (m/min)	30	60	90
Feed (mm/rev)	0.04	0.1	0.16
Depth of cut (mm)	0.4	0.8	1.2

III. RESULTS AND DISCUSSION

TABLE 4 Experimental Data for surface roughness (Ra) and flank wear (Vb)

Exp No.	Speed	Feed	Depth of cut	Dry Machining			MQL		
				Ra	vb	Simulated V_b	Ra	Vb	Simulated V_b
1	30	0.04	0.4	1.272	191.44	207.43	1.005	104.93	110.25
2	30	0.1	0.8	1.894	238.24	255.98	1.176	214.07	220.11
3	30	0.16	1.2	2.707	240.50	259.48	1.901	193.54	206.02
4	60	0.04	0.8	1.206	194.86	211.25	1.076	138.69	145.12
5	60	0.1	1.2	1.404	197.80	218.77	1.387	83.14	97.22
6	60	0.16	0.4	2.075	227.18	248.27	1.549	179.05	187.95
7	90	0.04	1.2	1.399	212.32	227.21	1.319	142.48	157.44
8	90	0.1	0.4	1.406	190.45	202.12	1.263	132.16	145.35
9	90	0.16	0.8	1.906	228.03	254.05	1.777	201.79	219.74

A simulation was carried out in similar conditions in both MQL and dry machining as shown in figure 4 that shows the operation being carried out at 90m/s speed, 0.16mm/rev feed and with depth of cut of 0.8mm and figure 5 shows the operation being carried out at 90m/s speed, 0.1mm/rev feed and with depth of cut of 0.4mm

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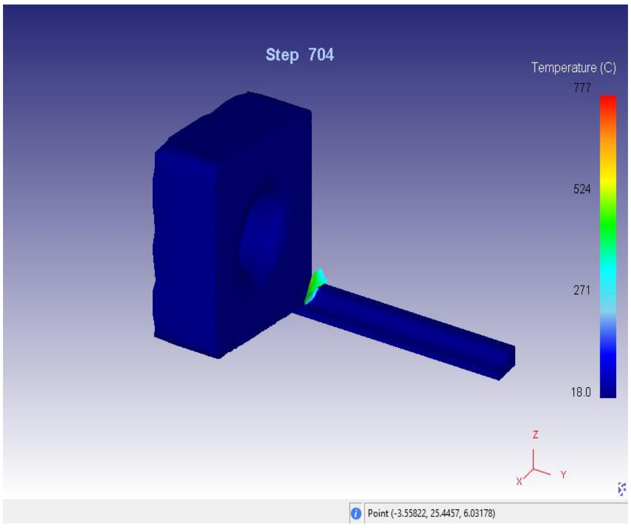


Figure 4 Simulation at 90m/s speed, 0.16mm/rev feed and 0.8mm depth of cut

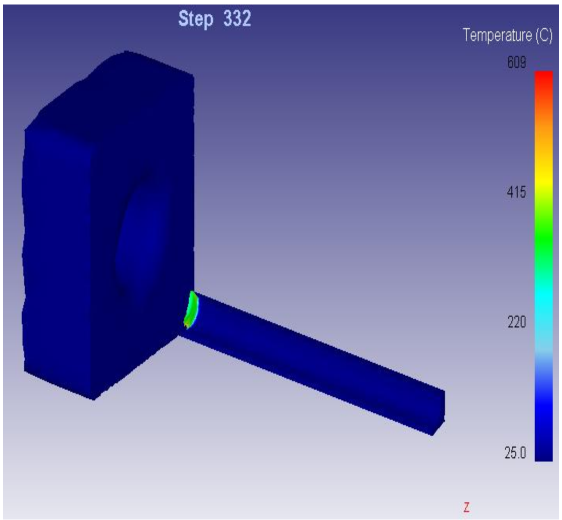
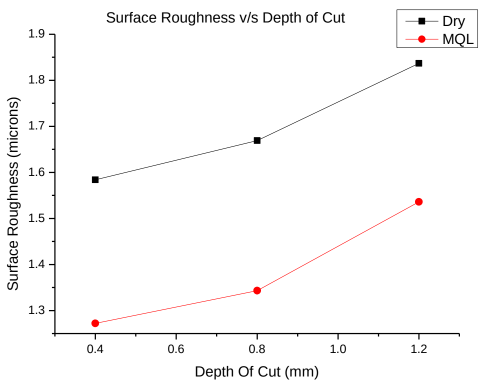


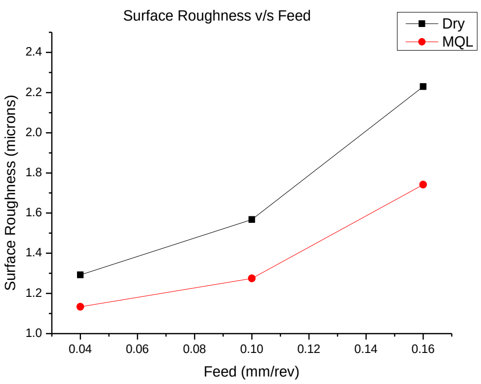
Figure 5 Simulation at 90m/s speed, 0.1mm/rev feed and 0.4mm depth of cut

3.1 Surface Roughness

Arithmetic Mean Value of Roughness (Ra) was investigated. The surface roughness (Ra) value is calculated for 6 different positions for every experiment and the average is calculated and thus formulated in table 4. On the basis Ra value, a plot is plotted showing the different value of average surface roughness for both dry machining and MQL machining.



a) Ra v/s Depth of Cut



b) Ra v/s Feed

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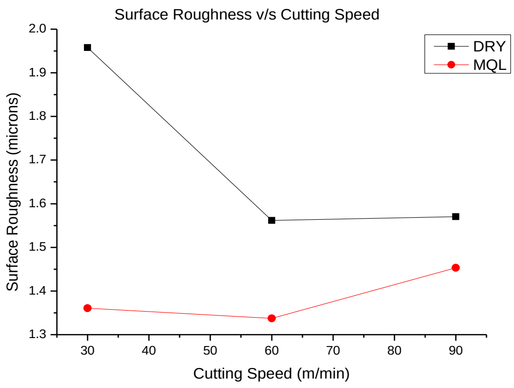


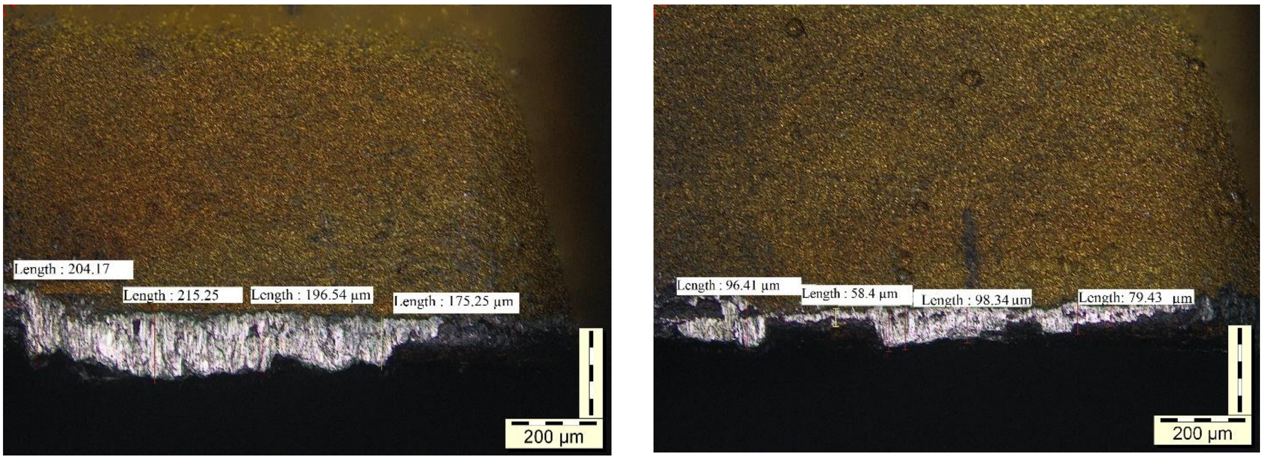
c) **Ra v/s Cutting Speed**

Figure 6. Surface roughness v/s Process parameters

The plots in figure 6 show that the feed has highest impact on surface roughness in both conditions. With increase in cutting speed the surface roughness first decreases and then increases because of the BUE formation at low seed which is higher in dry condition. From these three plots it is evident that with respect to all parameters higher surface finish will be obtained in MQL conditions.

3.2 Flank Wear

The tool surface is observed under Optical Microscope and from each experiment 4 values of flank wear were taken. From them average Flank wear was calculated. These values have been tabulated for Dry and MQL setup in table 4. The average flank wear is taken in dry machining and compared to corresponding experiment in MQL. Flank wear of experiment 5 for dry machining and MQL at 10x magnification are shown in the figure 7.



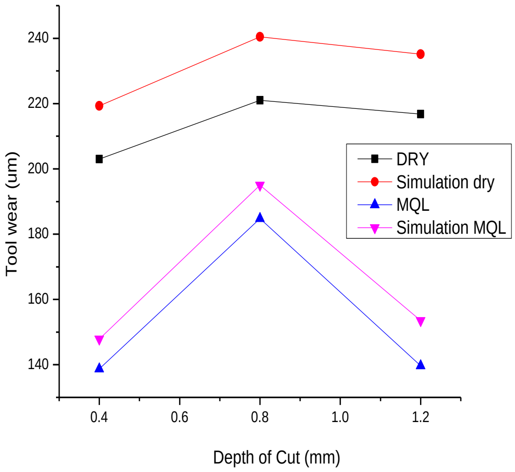
Experiment 5 Dry

Tool flank Wear (V_b) = **197.803 µm**

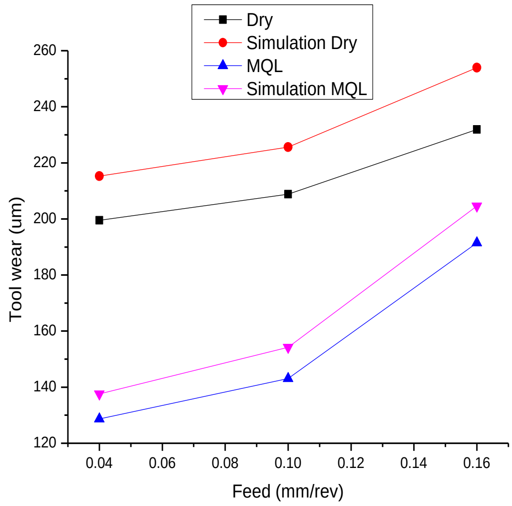
Experiment 5 MQL

Tool flank Wear (V_b) = **83.145 µm**

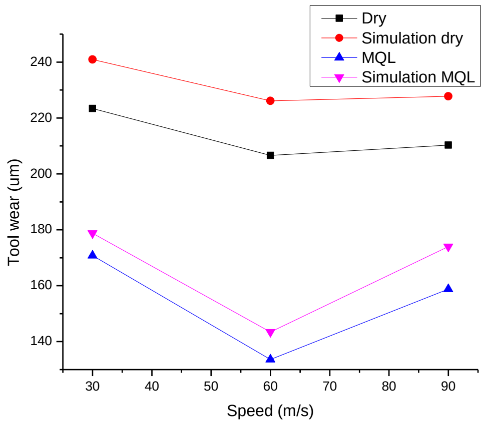
Figure 7 Tool Wear at 10x resolution



a) Flank Wear v/s Depth of Cut



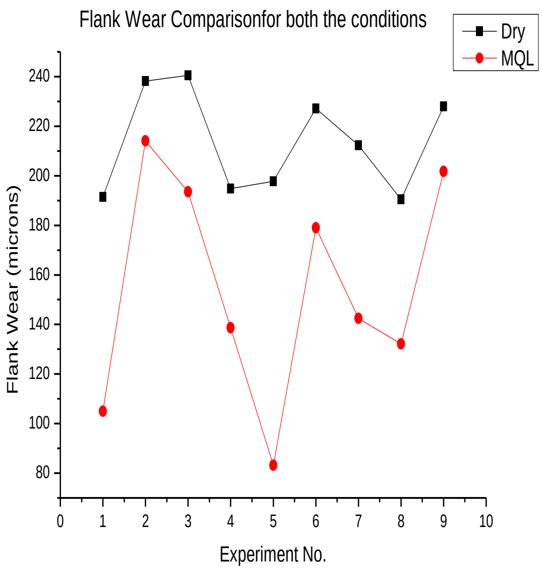
b) Flank Wear v/s/ Feed



c) Flank Wear v/s Cutting Speed

Figure 8 Flank Wear v/s Process Parameters

Tool wear as shown in plots of Figure 8 is less for every experiment in MQL environment. After plotting the tool wear with respect to all the parameters individually in both conditions it was seen the trend in both conditions was similar and the tool wear was considerably less in case of MQL. Similar trends were seen in Simulations.Figure 9 clearly represents that in each experiment the flank wear and surface roughness were less in MQL machining as compared to dry machining.



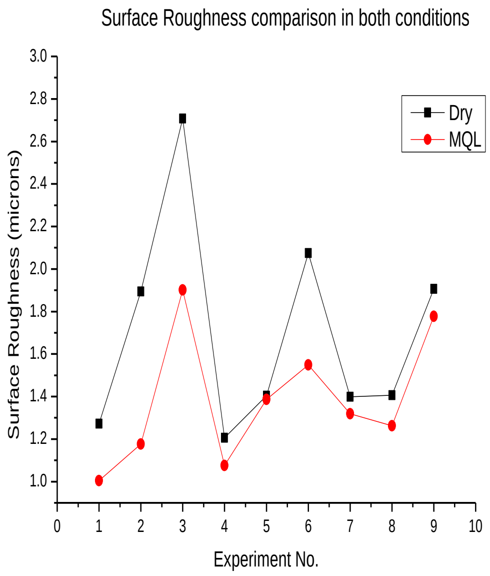


Figure 9 Comparison of MQL and Dry machining

IV. CONCLUSION

In the machining of AISI 316 stainless steel with cemented carbide tools under dry and MQL conditions. The following results can be deduced from this study:

- To get a good surface finish use of MQL over dry condition is justified.
- The feed of the tool is most responsible for surface roughness of the machined surface. With increase in feed the average surface roughness (Ra) increases and vice versa.
- Due to the formation of Built-up Edge on tool in low speed higher value of Ra is observed but at high velocity the tool wear is more hence again the higher value of Ra is obtained.
- Flank wear in case of MQL is also reduced increasing the life of tool hence the tool cost will reduce.
- The use of MQL as the flank wear is always less in MQL with respect to individual parameters.
- Simulation done is also valid as the flank wear in all cases is within ±10% of the wear measured by optical microscope.

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