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ANALYSE THE SURFACE ATTRIBUTES DURING THE TURNING OF C-24 STEEL UNDER MQL AND DRY CONDITION

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Abstract: Cutting fluids are very important in any metal cutting operation, cooling the cutting tool and workpiece surface by lubricating the tool-workpiece interface and removing chips from the cutting zone. Recently, many researchers have been focusing on Minimum Quantity Lubrication (MQL), among the many approaches to coolant application, because it reduces coolant usage by spraying a mixture of compressed air and cutting fluid in an improved manner instead of flood cooling. Minimum quantity lubrication (MQL) approach provides good lubrication but results in inadequate cooling due to the low thermal properties of the fluid, although the fluid is consumed in large quantities. Furthermore, excess fluid usage results in additional costs. On the other hand, dry cutting has the advantage that it does not require fluids, which also eliminates the need for additional equipment to supply fluids and reduces cleaning and disposal costs. However, dry machining also presents some disadvantages, such as insufficient chip evacuation, rapid tool wear, sudden tool breakage, and reduced surface quality. There is a need to replace conventional overflows with sustainable and clean methods, thereby reducing the amount of fluid used and improving process efficiency. This scenario has been questioned by many researchers, and promising results have been found in the past. Therefore, by considering above points in mind, MQL has effectively applied on C24 steel and its effects are measured. This research focused on to analyse the dry and MQL condition with C24 steel. The parameters such as cutting force, tool wear, surface roughness, and temperature have been examined at two different cutting speeds that are 80 m/min and 120 m/min. Also the results are executed for two different texture of metal that are plain (un-textured) and texture (perpendicular).The results show that MQL provides better results compared to dry condition.

Keywords: MQL, Surface Textured Tool, cutting force, Temperature, Turning, C-24 Steel

1. Introduction

In this modern world, High Speed Machining (HSM) technology is emerging due to the availability of new and smart machine tool and control system. In contrast to conventional systems, HSM is better and remove metal with higher rate with lower cutting force, good surface finish etc [1]. HSM technique is mostly applied in die and mold manufacturing. The results show that it is competitive to electric expulsion in some respects. However, the problem of too fast tool wear rate due to the high cutting temperature generated during machining has not been solved. In general, the cutting fluid used in the machining process is considered to act as a cooling and lubricant, which can reduce the cutting temperature, improve the tool life as well as the machined surface finish [2]. However, in irregular cutting processes such as milling, particularly in high-speed cutting, large fluctuations in cutting temperature can cause thermal cracks in the cutting edge, which in turn leads to failure of the cutting tool due to edge fracture [3]. Furthermore, there are serious environmental pollution and waste disposal problems when flooded coolant is used. To improve the above mentioned points, minimum quantity lubrication (MQL) technique was introduced. A number of researched has been published by using MQL technique in steel machining [4]. It has been observed that MQL technique can be used in drilling and turning process. It also finds application in milling process particularly, research in high speed milling is rarely been studied.

In turning process, an engineer has to be worked on the surface of metal. Mostly there are three surfaces of metals first one is work surface second one is machine surface and third one is transient surface. The pictorical representation of these surfaces is shown in figure 1 [5].

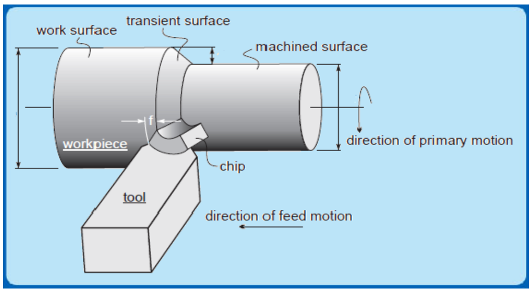

Fig. 1. Surfaces in Turning Process

To increase the lifetime of tool, the mechanical load applied on the tool should be lower than the load that a tool can handle. The tool's load capacity can be analysed by the material from which it is made of and its geometry shape as well as the coating material. Also the cutting speed, cutting depth of tool and the feed rate affects the tool life as well as the good surface finish [6]. Tool with higher feed rate but with lower cutting depth and lower cutting speed may provide better results. It one need better productivity, it can be achieved with higher cutting speed, lower cutting depth as well as feed which gain minimizes the cutting force [7].

A number of parameters such as geometry of tool, material of workpiece, feed rate and many more influenced the cutting force. With the increase in above mentioned parameters, the cutting force increases, but the cutting process is not performed in a dangerous manner, the feed rate has a greater effect on the chip thickness, which means that increasing the feed rate increases the load on the cutting edge [8]. One parameter that has a great influence on the cutting force is the cutting depth, for an example by increasing its value three times, the cutting force will be increases in the same value but the load on the tool will be the same as the cutting edge will increase in action as it cuts [9, 10]. One more parameter that affects the cutting force is the cutting speed, by increasing it, the cutting force will decrease, there will be a big problem when the cutting speed decreases, because the cutting force will increase and built-up edge will appear, this phenomenon is not suitable for a very Good indicator of cutting speed. In this paper, Effects on different parameters has been analysed using MQL and dry condition. Mainyl two types of smaple has been taken one is without texture and other is perpendicular texture [11, 12].

2. Related Work

Patel et al. (2019) have prepared two work pieces one is cut at an angle of 90°, and the other is cut at an angle of 60°. The grooves were prepared on rake face of WC/Co. This material was employed in turning titanium alloy Ti-6Al-4V. The micro grooving process has been performed by changing the width, depth and spacing of the grooves. In this paper, static depth of cut with static cutting speed has been utilized [13]. **Abbas etal. (2019)** have used nano fluid as advanced cooling lubrication for machining. The experiment has been performed to improve surface quality, reduce power consumption and machining cost. The factors such as minimize management wastes, take care of the safety and health issues along with the environment. The outcomes proved that the nano-fluid used with MQL technology delivered better results with minimum surface roughness and power consumption [14]. **Mikołajczyk et al. (2020)** have investigated the effect of different cutting angles greater that 60° but less than 0° of C45 steel. The results reveal that with the increase in the cutting angle, minimum uncut chip thickness decreases. It opens up a new direction from bevelling to finishing of the cutting edge, and gave a new thought for the abrasive wear difficulty that may take place in micro-cutting [15]. **Abidi (2021)** have studied the tool life and machining productivity of ceramics along with its surface roughness during turning of hardened C45 steel. The research has been performed on selected and the optimal combination of cutting parameters. The analysis is carried out based on the single factor programming method of cutting speed and rate of feed. The results show that hybrid ceramic tools were suitable for turning hardened steel C45 (40 HRC). It was concluded that it performed well in terms of tool life, productivity and surface quality, feed (0.08 mm)/rev) and depth of cut (0.3 mm) at a combination of cutting speed (200 m/min) [16]. **Salur et al. (2021)** have studied the performance of MQL as well as dry milling on AISI 1040 steel. Cutting speed and feed rate were taken as input attributes while the specimen performance has been evaluated on the basis of tool wear, cutting temperature and consumption of power. ANOVA test has been performed to examine the parameters. N addition to this Taguchi approach has also been determined to know the best quality responses. The outcomes stated that the MQL system performed better and improves the quality responses compared to the dry milling process. The ANOVA test reveals that the around 37 % of the cutting temperature, and 94 % of power consumption has been affected by the cutting environment. On the other hand around 74 % of the tool wear is affected by the cutting speed. For MQL condition cutting speed of 100 m/ min and feed rate of 0.10 mm. rev has been selected. This has been done to make sure minimum tool wear along with minimum power consumption. For better temperature operation higher speed of 0.15 mm/rev has been selected. The comparison between MQL and dry condition proved that MQL system performed better compared to dry condition [17]. **Makhesana et al. (2022)** have studied the graphine along with hexagonal boron nitride (hBN) nanoparticles that were applied to machine including plam oil. This process has been performed by MQL setup. The experiments have been performed under three different conditions that are dry, wet, simple MQL and MQL with hBM integrated with palm oil. The performance has been analysed based on the tool wear, surface roughness, chip morphology and the surface quality of the specimen under test. The examined result revealed that the specimen treated with hBM and plam oil shows better results using MQL system [18]. **Aslan et al. (2022)** have tested the MQL technology to test the quality of machine while used for milling the structure strenx 900. Also a comparison has been provided between the MQL and the dry condition technology. The results show that MQL technology performed better, improved machining features such as surface roughness by 35 %, flank wear by 94 % and cutting temperature by 14 % [19]. **Çamlı et al. (2022)** have used ER7 steel grade for experiment. This grade is used in rail industry for rail wheels. These wheels are designed by pressing and rolling using turning process to shape them in final dimension. Due to its high mechanical features such as quick tool wear and thermal cracking may happens. Their performance can be increased by using coolant technology. And an alternative way is MQL technology. This technique delivers coolant mixed with air to the cutting area to obtain a dry space near the cutting zone. In this research, experiments have been performed in dry, with MQL condition. The performance has been analysed based on the cutting speed, rate of feed, surface roughness, energy consumption and the cutting temperature. The research shows better results with MQL as well as with the improvement of nano additives in MQL technology [20].

3. Material and Methods

C 24 steel is used as a specimen for this research. To cut the considered specimen, TNMA 160408 tool has been used. It looks like triangle having hole at the centre. The tool image is shown in Figure 2.

Fig. 2 TNMA 160408

For cutting and surface finishing of the considered specimen, lathe machine has been used. Cutting of specimen has been performed in both dry and MQL technology.

Fig. 3 Lathe Machine

The cutting speed has been set at 80 m/min and 120 m/min. The feed rate is set to be 0.16 mm/rev and cutting depth is set at 0.5 mm to perform the entire experiments.

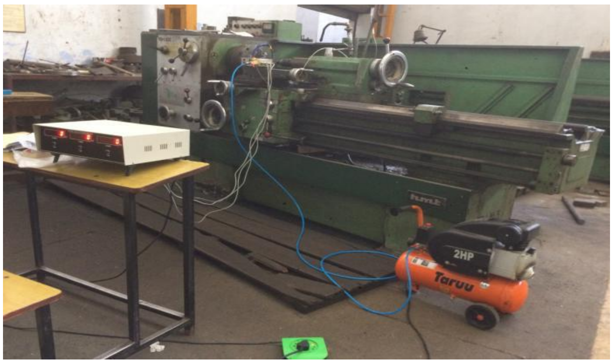

Fig. 4. work piece set up

Surface toughness was measured using a **Mitutoyo tester**. This is used to measure surface texture with various parameters. Temperature is measured using **laser gun**. This is because laser beam is used to determine the temperature of the specimen. To measure rotational speed **tachometer** is used. To measure force **Dynamometer** is used.

4. Result and Discussion

In this section the results in dry condition and with MQL techniques are discussed and explained. Under dry condition, experiments have been performed without cooling with perpendicular texture impressed on the specimen. With the help of laser, texture is imprinted on the specimen.

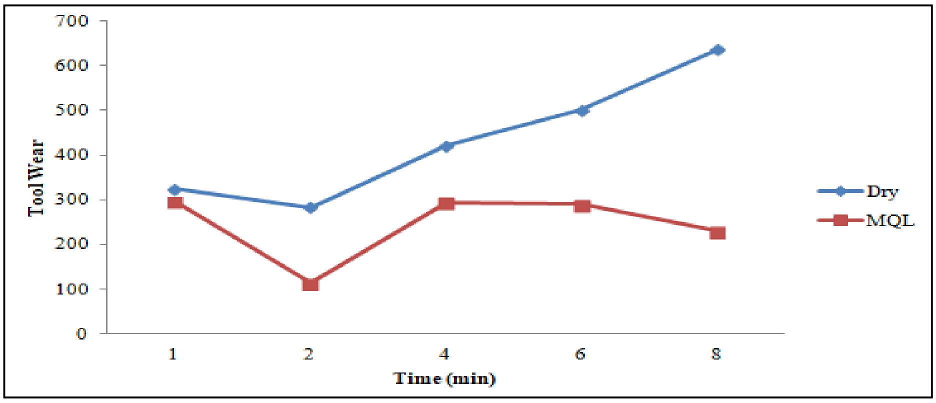

Fig. 5. Comparison of Dry and MQL condition (SPEED 120 UNTEXTURED)

Tool wear parameters are used to study the micro-failures caused by the continuous running of the tool. The term is usually used for pointed tools, or the tools that are used in machines.

The values observed at 120 m/mint for un-textured structure for tool wear for both dry and MQL condition is shown in Figure 5. The blue line graph indicates the values obtained for Dry conditions whereas, red line indicates the values observed for MQL conditions. Tool wear value obtained for Dry condition is more than the MQL condition.
respectively. The average value obtained after performing experiments five times on single specimen has been observed as 356.89 and 231.25 for the dry and MQL conditions respectively.

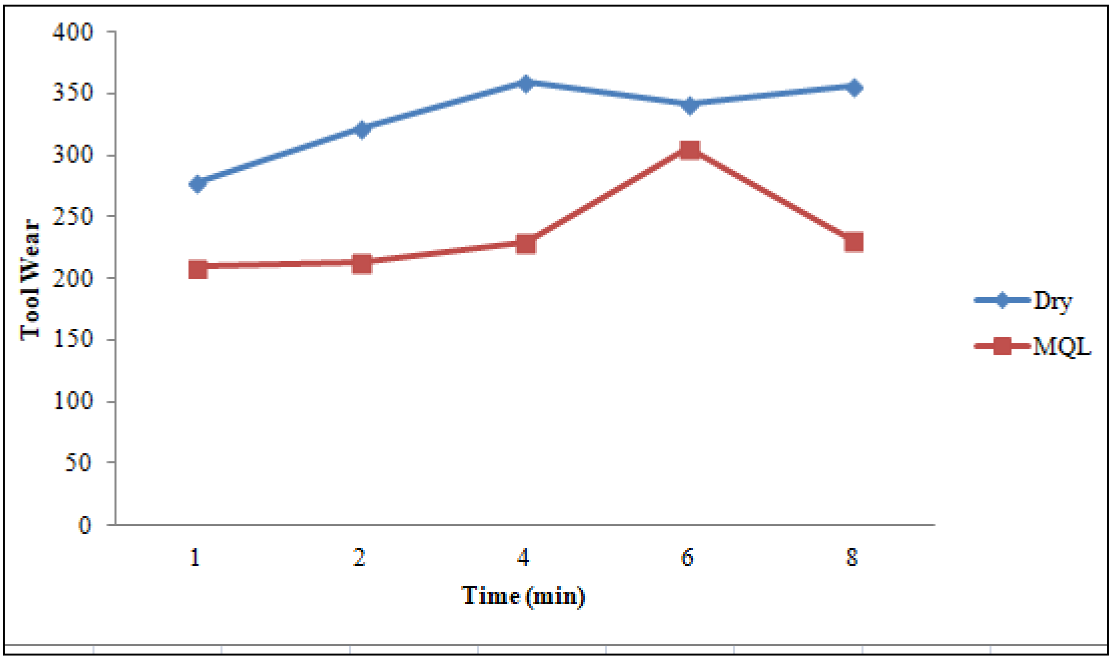

Fig. 6 Tool wear verses Time (s=80m/min untextured)

Fig.6 represents the graph between tool wear and time for both dry and MQL condition for textured (perpendicular) work piece. The average value of tool wear examined for both dry and MQL condition are observed as 383.128 and 382.14 respectively.

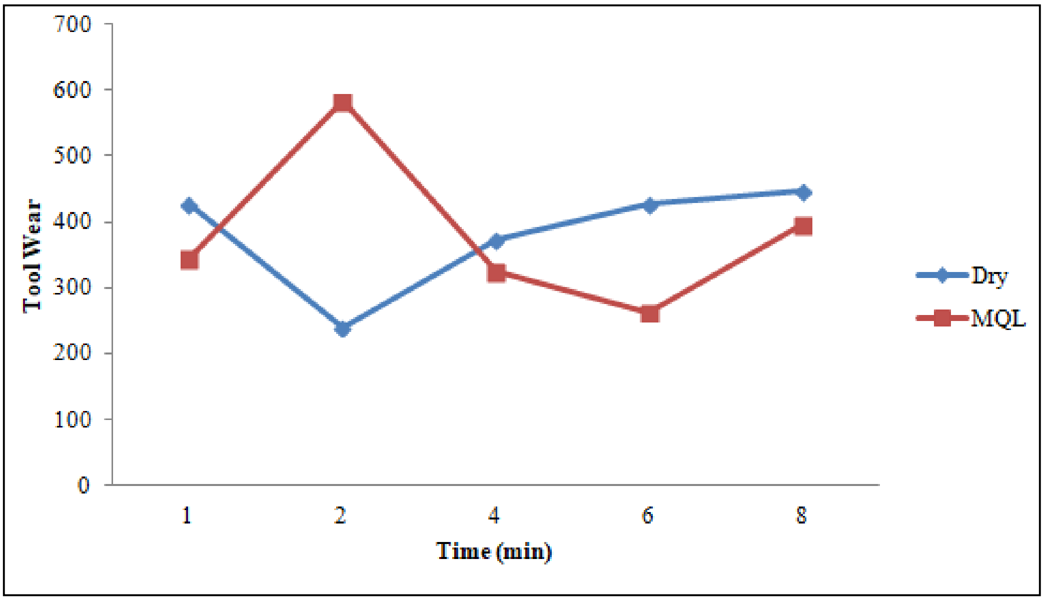

Fig.7 Tool wear verses Time (s=120m/min for Texture PR)

The graph in Fig. 7 depicts that the average value of tool wear obtained for dry condition is 369.664 whereas the average value obtained for tool wear for MQL condition is 300.108.

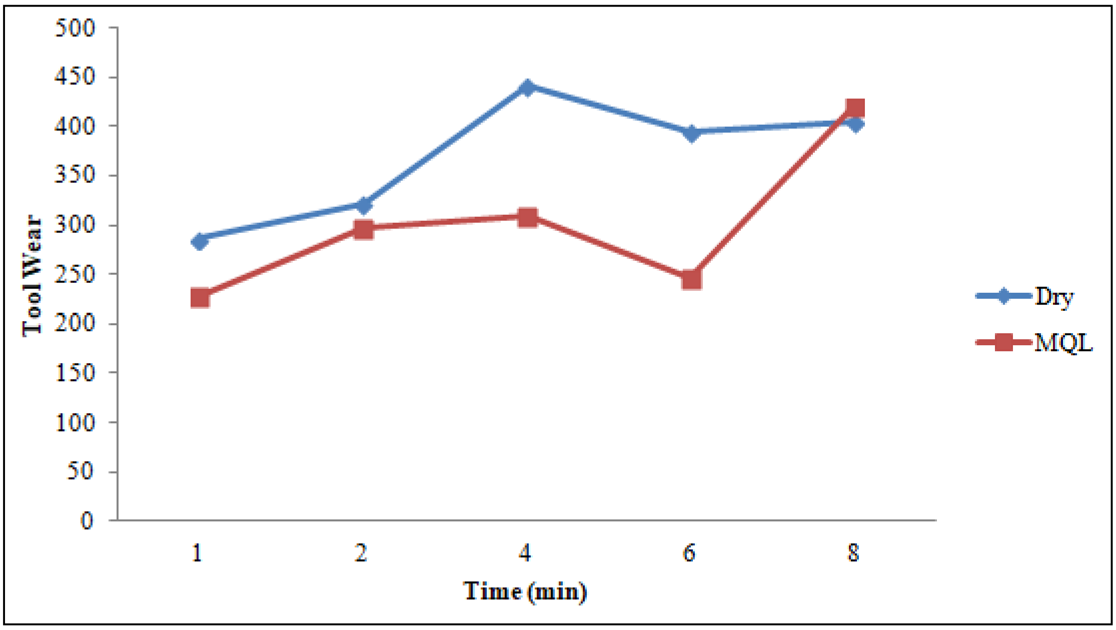

Fig.8 Tool wear verses Time (s=80 m/min for Texture PR)

Table 1. Time verses cutting force X

		Speed 80 Un-textured		Speed 120 Un-textured		Speed 80 Textured PR		Speed 120 Textured PR	
S. No	Time in minutes	Force X		Force X		Force X		Force X	
		Dry	MQL	Dry	MQL	Dry	MQL	Dry	MQL
1	1	29.43	58.86	49.05	44.145	19.62	88.29	73.57	103.005
2	2	24.525	186.39	19.62	58.86	19.62	103.005	34.34	142.245
3	4	24.525	353.16	34.335	39.24	49.05	541.512	29.43	235.44
4	6	9.81	29.43	49.05	117.72	39.24	34.335	137.34	171.675
5	8	29.43	39.24	58.86	230.535	49.05	49.05	63.76	206.01

Table 2. Time verses cutting force Y

S. No	Time in minutes	Speed 80 Un-textured		Speed 120 Un-textured		Speed 80 Textured PR		Speed 120 Textured PR	
		Force Y		Force Y		Force Y		Force Y	
		Dry	MQL	Dry	MQL	Dry	MQL	Dry	MQL
1	1	147.15	215.82	176.58	156.96	103.005	279.585	161.86	245.25
2	2	112.815	402.21	127.53	127.53	112.815	299.205	142.1	220.725
3	4	152.055	588.6	156.96	166.77	196.2	431.64	98.1	377.685
4	6	109.2	137.34	206.01	235.44	215.82	156.96	274.68	304.11
5	8	166.77	156.96	230.535	353.16	147.15	196.2	156.96	323.73

The cutting force has been observed for both un-textured and textured work-piece. The values of cutting force for X , Y and for Z axis for different time period is listed in Table 1, Table 2, and Table 3 respectively.

Table 3. Time verses cutting force Z

S. No	Time in minutes	Speed 80 Un-textured		Speed 120 Un-textured		Speed 80 Textured PR		Speed 120 Textured PR	
		Force Z		Force Z		Force Z		Force Z	
		Dry	MQL	Dry	MQL	Dry	MQL	Dry	MQL
1	1	98.1	63.765	58.86	9.81	44.145	73.575	147.15	98.1
2	2	34.335	137.34	39.24	29.43	29.43	78.48	63.76	196.2
3	4	68.67	186.39	49.05	44.145	88.29	24.525	53.95	274.68
4	6	73.575	29.43	78.48	152.055	103.005	49.05	235.44	196.2
5	8	49.05	49.05	83.385	294.3	53.95	78.48	103.01	382.59

5. Conclusion

Based on experiments performed on specimens made of material C-24 steel, during which parameters such as surface roughness, temperature, cutting forces and tool wear have been observed. Experiments were carried out under two conditions called dry and MQL for different machine speeds, 80 m/min and 120m/min. The experiment has been performed on two types of samples, untextured and perpendicular. The following points are derived from experiments.

Speed=80m/min

- For un-textured work piece, the average value of tool wear for dry and MQL condition at speed =80m/mint has been observed as 433.004 (μm) and 244.636 (μm) respectively. Cutting force for x, y, and z plane has been observed as 26.81 KN, 142.9 KN, 49.516 KN respectively.
- The results obtained for perpendicular texture when speed of machine is 80m/min are: average Tool wear of 369.664 (μm) for dry condition and 300.108 (μm) for MQL condition has been observed. Cutting force for x, y, and z plane has been observed as 82.316 KN, 126.756 KN, 55.834 KN respectively.

Speed=120m/min

- For un-textured work piece, the average value of tool wear for dry and MQL condition at speed =120 m/mint has been observed as 433.004 (μm) and 244.636 (μm) respectively. Cutting force for x, y, and z plane has been observed as 142.9 KN, 49.516 KN, 46.924 KN respectively.

The results obtained for perpendicular texture when speed of machine is 120 m/min are: average Tool wear of 369.664 (μm) for dry condition and 300.108 (μm) for MQL condition has been observed. Cutting force for x, y, and z plane has been observed as 126.756 KN, 55.834 KN, 48.068 KN respectively.

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