MQL Turning of EN-8 Steel Using Plant-Based Lubricant and its Performance analysis with Wet and Dry Turning

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Abstract: In this research work, Micro Mist Fluid ST-2020, plant-based cutting fluid has used as a cutting fluid. This cutting fluid has used under MQL mode for machining of EN-8 steel. The results obtained from MQL machining using the plant-based cutting fluid have been analyzed and compared with dry machining and conventional wet machining. During wet machining, a stable milky white emulsion with water of soluble cutting fluid had applied. The tiny droplet size of fluid generated during MQL provided lesser cutting forces and better surface finish. Hence MQL may be a better option for eliminating fluid waste while maintaining the benefits of using a lubricant. Therefore, the application of MQL will reduce the use of cutting fluids, but the application of plant-based lubricants will eliminate the use of petroleum-based lubricants. Petroleum lubricants cause environmental pollution and may cause health risks to workers who come in direct contact with the cutting fluid.

Keywords **- Plant-Based Cutting Fluid, MQL Turning, EN-8 Steel.**

1. INTRODUCTION

Minimum quantity lubrication (MQL) is a process that mixes a limited quantity of cutting fluid with pressurized air, which forms the fluid-air mixture. This fluid pressurized air mixture has then sprayed at the tool-chip interface by using a nozzle arrangement. This method ensures that it uses an only minute amount of cutting fluid compared to conventional lubrication (flood lubrication/wet lubrication) method used for machining. The cutting fluids used in the minimum quantity lubrication system had usually made from environment-friendly materials. Environment-friendly lubricants have costs higher than the lubricants made from crude oils. Still, MQL uses cutting fluid, which is approximately three or four orders of magnitude less than the quantity commonly used in wet lubrication method. Therefore the resultant cost of using environment-friendly lubricants is much less than the conventional way. The cutting fluid used for the current study is plant-based and biodegradable oil. The use of MQL has another benefit in terms of worker health. The use of conventional crude oil-based cutting fluids has hazardous health effects such as skin problems and difficulties in breathing.

EN-8 is a commonly used steel in industries. This steel has many useful properties, such as its being readily machinable and used for manufacturing parts, which include shaft, bolt, stud, gears, and axles. These things can be further surface-hardened to 50-55 HRC.

In the present investigation, the Taguchi approach has used to determine which cutting parameters are more suitable for turning of EN-8 steel. This investigation tries to find a better combination of cutting speed, feed, and machining environment. To achieve optimum cutting parameters for reducing cutting forces and getting a better surface finish, manufacturing companies have restored the use of handbook-based knowledge and operators' expertise.

2. EXPERIMENTAL DETAILS

2.1 Experimental Conditions

TNMG 16 04 08 carbide inserts mounted in MTJNL 2525 – M16 tool holder made by TRU-HOLD have used for the machining of EN-8. The insert having a double-sided chip breaker used having a triangular shape, 0° normal clearance, 0.8 mm corner radius, and 4.76 mm thickness. Commercially available EN-8 steel bar has used for the investigation with a test length of 40 mm and 30 mm diameter. MAXTURN Plus + (MTAB) CNC turning center has used to carry out turning operations, as shown in Fig. 1. This figure also shows photographs of cutting insert and tool holder. The depth of cut was set at 0.8 mm.

2.2 Environment Friendly Cutting Fluid

In the present study, Micro Mist Fluid ST-2020 has used as a cutting fluid. It is a premium plant-based metal cutting lubricant made by Nicotec™ India Corporation. As per the manufacturer's claim, this cutting fluid has properties like 100% environmentally safe, and it is excellent for cutting stainless steel material, useful for special-purpose cutting, etc. During the investigation, the supply air pressure has set at 5 bar, and the flow rate of cutting fluid was 100 ml/hr. The nozzle elevation angle was kept constant at 60° for each test. Table 1 describes the experimental parameters.

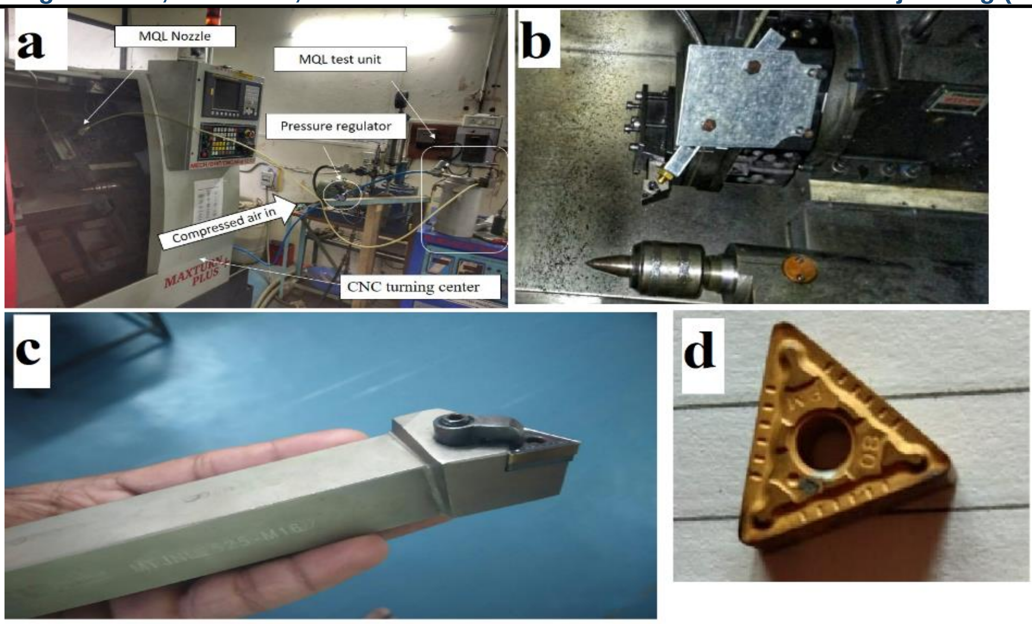

Fig. 1. (a) Experimental set up (b) Nozzle arrangement (c) Tool holder (d) Cutting tool insert

2.3 Output Responses

For the present investigation, the two output parameters recorded viz. cutting forces and surface roughness. Cutting forces are directly related to the tool wear, power requirement of machine tool, self-excited vibrations, aesthetics, and ergonomics of the machined surface. Surface roughness is also an essential parameter in terms of the quality of the machined workpiece surface. To record surface roughness, Taylor Hobson make surface profilometer, has used. The dynamometer made by Kistler has was there to monitor the cutting forces. A new cutting insert has used for every test to maintain uniformity during each test.

Table 1. Experimental Conditions for the study of effects of MQL in turning EN-8 steel

Machine tool – CNC Turning Centre	MAXTURN Plus + (MTAB) CNC
Work specimen	Material EN-8 steel
Size	Φ30 x 40 mm
Cutting insert	TNMG 16 04 08
Tool holder	MTJNL 2525 – M16
Corner radius	0.8 mm
Distance of cutting zone to the nozzle tip	20 mm
Nozzle elevation angle	60°
Cutting velocity (Vc)	60, 80, 100 m/min
Feed rate (f)	0.10, 0.12, 0.14 mm/rev
Depth of cut (t)	0.8 mm
Environment	Dry, Wet, Minimum Quantity Lubrication (MQL)
Cutting fluid	Micro Mist Fluid ST-2020 (Plant-Based Cutting Fluid)
Supply Air Pressure	5 bar
Cutting Fluid Flow Rate	100 ml/hr.

3. RESULTS AND DISCUSSIONS

3.1 Cutting Forces

This section discusses the evolution of cutting forces at different speeds, feed and cutting environments while keeping the depth of cut constant at 0.8 mm. In dry cutting mode, the cutting forces were continuously decreasing with an increase in speed. The average of cutting forces obtained in dry cutting mode was 461.935N. The maximum cutting force and minimum cutting force found in dry cutting were 501.275N and 364.13N, respectively. The implementation of MQL greatly reduced cutting forces compared to dry mode, and wet mode. The average of cutting forces recorded during MQL turning was 345.764N. The maximum cutting force and minimum cutting force obtained in MQL cutting were 366.255N and 315.485N, respectively. The lowest cutting forces have observed during the MQL cutting mode. The range of cutting forces have observed during the wet cutting mode has less than dry mode and more than MQL mode. The average of cutting forces during wet turning was 401.693N, with 364.13N minimum, and 431.057N maximum cutting force

Table 2. Response Table for Signal to Noise Ratios (For Cutting Force)

Level	Cutting Speed, Vc (m/min.)	Environmental Condition	Feed, f (mm/rev)
1	-52.66	-53.27	-52.08
2	-52.23	-50.76	-52.03
3	-51.2	-52.06	-51.97
Delta	1.46	2.51	0.11
Rank	2	1	3

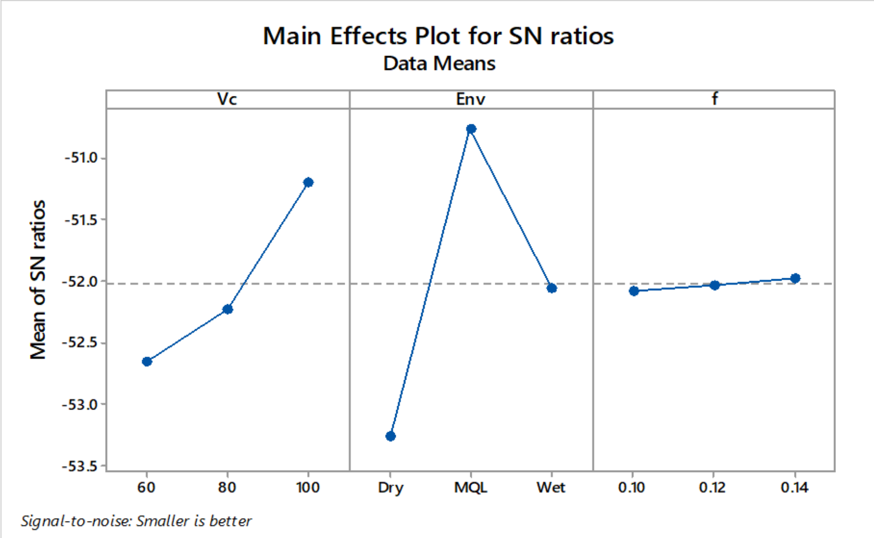

Fig. 2. Effects of Parameters of Cutting on Cutting Force

The effects of parameters of cutting on cutting force are measured, and trends have shown in Fig. 2 and Table 2 in tabular form. Hence as cutting speed, the S/N ratio for cutting force increases drastically from 60 m/min to 100 m/min, and as feed rate increases from 0.10 mm/rev to 0.14 mm/rev S/N ratio increases. Whereas when MQL cutting has used, the S/N ratio shows maximum value. Table 3 shows that the environmental condition contributes 73.49% for surface roughness as per ANOVA results.

Table 3. ANOVA Results for Cutting forces

Source	DF	Seq. SS	Contribution	F-Value	P-value
Cutting Speed	2	0.000028	26.53%	397.21	0.003
Environmental Condition	2	0.000079	73.34%	1098.23	0.001
Feed	2	0.00	0.07%	1.01	0.497
Error	2	0.00	0.07%	-	-
Total	8	0.000107	100.00%	-	-
R Square = 99.93%			R Square (adj.) = 99.73%		

3.2 Surface Roughness

The widely recognized arithmetic average height (Ra) value has determined by using the Taylor Hobson surface profilometer. The Ra value of each workpiece has measured five times and, the average of 5 readings has taken as Ra value of that corresponding workpiece to find out the surface roughness. The average Ra value obtained in dry cutting was 5.341 µm. The average Ra value obtained in MQL using Micro Mist Fluid ST 2020 was 3.358, which is much less than that found in dry cutting, as shown in Fig. 3. The average Ra value obtained in wet conditions has found 4.563 µm. The Ra value obtained in MQL turning is found most favorable than the Ra values in dry and wet turning. The least Ra value was recorded in MQL condition, which was 2.17 µm. The result table of general linear model ANOVA analysis has shown in Table 5, which indicates that the contribution of cutting speed is 59.49%. The contribution of the environmental condition is also significant, which has found 39.04%. The F-values of cutting speed and environmental condition obtained from general linear model are 126.50 and 83.09, respectively.

Table 4. Response Table for Signal to Noise Ratios (For Surface roughness)

Level	Cutting Speed, Vc (m/min.)	Environmental Condition	Feed, f (mm/rev)
1	-14.744	-14.422	-12.144
2	-13.176	-10.179	-13.006
3	-9.514	-12.834	-12.285
Delta	5.229	4.243	0.862
Rank	1	2	3

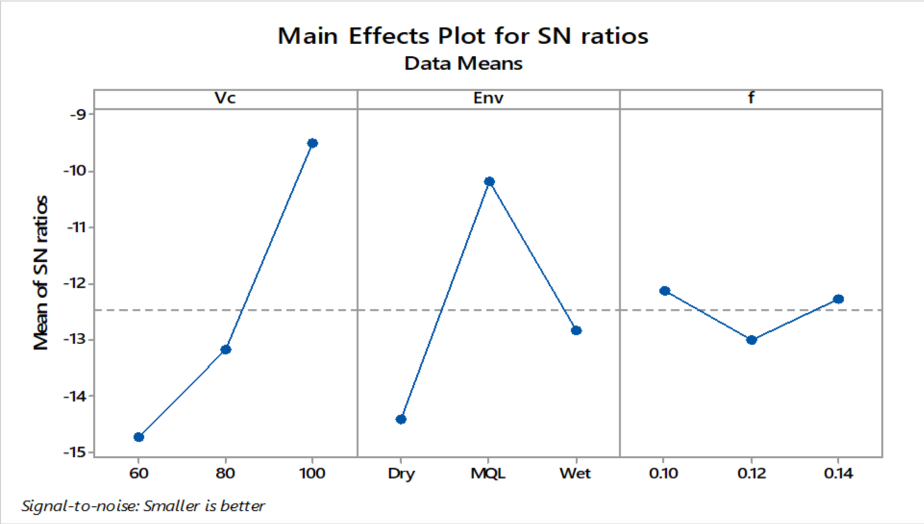

Fig. 3. Effects of Cutting Parameters on Surface Roughness

Table 5. ANOVA Results for Surface Roughness

Source	DF	Seq. SS	Contribution	F-Value	P-value
Cutting Speed	2	9.1150	59.49%	126.50	0.008
Environmental Condition	2	5.9868	39.04%	83.09	0.012
Feed	2	0.1629	1.06%	2.26	0.307
Error	2	0.0721	0.47%	-	-
Total	8	15.377	100%	-	-
R Square = 99.53%			R Square (adj.) = 98.12%		

4. CONCLUSION

Plant-based cutting fluid Micro Mist Fluid ST-2020 has used during the turning. Firstly machining parameters such as nozzle elevation angle, the distance of cutting zone to nozzle tip, etc. were selected by studying available literature and the lab conditions. Then the experiments were carried out by using appropriate settings. The following are the outcomes can be drawn from the present work:

- In the MQL method, surface roughness is highly impacted by particularly the cutting speed followed by environmental condition and feed.
- In the MQL method, cutting force is highly impacted by particularly the feed and then the cutting speed and environmental condition.
- Cutting speed of 100 m/min. provides better results in case of surface finish of EN-8 steel when compared with 60 m/min and 80 m/min.
- Cutting speed of 80 m/min. provides better results in case of cutting force of EN-8 steel when compared with 60 m/min and 100 m/min.
- The results obtained from MQL turning has showed less cutting forces than results obtained from dry and wet turning.

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