Turning Performance of AISI 1045 Steel using MQL Technology

[1]Sagar Sakharkar, [2]Shashikant Goilkar, [3]Manthan Patil, [4]Babani Naik, [5]Bhushan Sawant, [6]Sahil Sawant
[1]Assistant Professor, [2]Associate Professor, [3,4,5,6]Graduate Students
Department of Mechanical Engineering
Finolex Academy of Management and Technology, Ratnagiri, India 415639

Abstract : Minimum quantity lubrication play an important role in reduction in environmental impact and improve quality of products. Commercially available lubricants such as mustard oil and palm oil is used as lubrication environment in turning performance of AISI 1045 steel material. Comparative machinability assessment of mustard oil and palm oil shows some effective difference in surface roughness value. Viscosity plays an important role in machinability condition. Surface roughness in term of Ra and Rq value are measured and compared with Mustard and palm oil using response surface methodology. Higher cutting speed of 200m/min observed better impact in reduction of surface roughness for mustard oil and medium cutting speed is suitable for palm oil of 120m/min cutting speed.

***IndexTerms* – MQL, Turning, RSM, Surface roughness.**

I. Introduction

Machining processes has remarkable contribution in secondary manufacturing operations. Manufacturing of high accuracy products required final trimming material removal operation which can becomes possible due to machining operations. Heavy duty materials like steels used for crank and cam shaft assembly which can bear higher load during dynamic conditions. Manufacturing of crank required high strength steel category material such as AISI 1045. Therefore more focus is given to turning performance of AISI 1045 steel. Today industrial sector forced to acquire environmental norm to sustain product in market certification. It get impact on working environment to make ecological and environmentally friendly manufacturing process. Reduction in machining coolant and lubrication help to minimize disposal and maintenance problem. The new minimum quantity technology is widely used to overcome flood lubrication in machining operation. Biodegradable edible oil is tried to replace cutting flood solution using MQL technique. Palm oil and mustard oil helped to reduce friction in cutting zone due to their lubricity property in flood condition. Therefore, researcher focused to work on edible oil using minimum quantity lubrication technique.

Some of researchers has conducted work in machinability with MQL technology which tried to focus on targeted application of different material, tools and machining conditions. Few of literatures deals with machinability of crank using different materials and machining operations. Sakharkar and Pawade [1] work on comparative machinability assessment in flood, dry and MQL environment and explained details of effective parameters effects in turning operation. Austempered ductile iron is machined with LRT 30 MQL oil grade which given more favourable results in machining operation. Medium cutting speed of 125 m/min given higher cutting performance than other machining speed for effective lubrication at high temperature. Feed and depth of cut reduced machining surface finish performance due to improper lubrication and bulkiness of chip formation. Hadad and Sadeghi [2] explained machining performance in AISI 4140 alloy steel. MQL system is derived for high temperature lubricant action which given better performance at high temperature sustainable lubrication. Tool chip interaction effect explained graphically. Machinability effect explained based on speed, feed and depth of cut parameter for medium temperature generation range. Dhar et al [3] explained machinability of medium carbon steel using MQL technology. They found better effect of machining parameter at 300ml/ hr volume flow rate. The machinability explained in term of tool wear for uncoated and coated carbide. Coated carbide of Ti/Al/TiN observed better performance in machinability of medium carbon steel. Dhar and Islam [4] explained detailed in chip formation in medium steel of AISI1040 steel. They observed continuous ribbon chip and explained chip morphology and tool wear criterion during continuous cutting operation. Effect of feed and depth of cut observed significant impact on machining condition which shows bulkier segmentation chip formation. Increase in feed and depth of cut convert continuous ductile chip into brittle transition serrated chip. Hence, overview of these papers conclude to study performance of Austempered ductile iron using Minimum quantity lubrication with help of Palm and Mustard oil.

II. Experimental Work

Turning experimentation is carried out on Jobber XL CNC lathe machine (shown in Figure 1) using response surface centre cube method. RSM-CCD designed 20 experimental runs using rotatable design concept. SJ301 Mittutoyo surface roughness tester is used to measure surface roughness value of Ra and Rq. Surface roughness is measured for 8mm cut off length which become more effective to surface topography. Minimum quantity lubrication method used for Palm and mustard oil. MQL environment is created for machining zone using 300ml/hr oil flow rate and 5 Bar air pressure which helped to convert oil into aerosol particle and provide effective lubrication effect. Experimental test results are shown in Table 1.

Figure 1. Experimental work setup and CNC lathe machine

Following table shows turning performance for AISI 1045 steel for surface roughness values.

Table 1 Turning Performance results of surface roughness for AISI 1045 steel

Experimental Run	Cutting Speed (m/min)	Feed (mm/rev)	Depth of Cut (mm)	Surface Roughness			
				Mustard Oil		Palm oil	
				Ra (um)	Rq (um)	Ra (um)	Rq (um)
1	150	0.14	0.85	0.961	4.603	1.832	5.603
2	150	0.14	0.85	1.293	5.416	1.532	5.416
3	150	0.14	0.85	1.81	6.215	1.821	6.215
4	200	0.1	1.2	1.891	6.49	1.891	11.498
5	150	0.14	0.85	1.879	7.037	1.879	7.037
6	100	0.18	1.2	1.871	6.954	1.871	6.954
7	100	0.1	1.2	2.323	9.859	2.43	6.599
8	200	0.18	0.5	0.707	3.377	0.9	3.377
9	150	0.14	1.438627	2.725	13.778	2.725	3.778
10	100	0.18	0.5	1.721	6.904	1.721	6.904
11	65.91	0.14	0.85	2.679	12.981	2.679	5.981
12	200	0.18	1.2	0.938	3.859	0.912	3.859
13	100	0.1	0.5	0.647	3.206	1.215	5.206
14	150	0.14	0.85	1.162	4.775	1.623	4.775
15	150	0.20	0.85	0.556	3.578	2.102	8.578
16	234.0896	0.14	0.85	0.935	4.053	0.9	4.053
17	150	0.072728	0.85	1.46	5.208	0.8	4.208
18	200	0.1	0.5	1.483	5.772	1.511	3.772
19	150	0.14	0.85	1.394	4.884	1.56	4.884
20	150	0.14	0.261373	1.565	6.861	1.116	6.861

Table 2 shows analysis of variance for surface roughness Ra value. It observed that cutting speed is more significant factor for surface roughness value. The experimental model for Ra explained that the Model F-value of 4.63 implies the model is significant. There is only a 1.26% chance that an F-value, this large could occur due to noise. P-values less than 0.0500 indicate model terms are significant. In this case cutting speed and depth of cut are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve model. The Lack of Fit F-value of 1.21 implies the Lack of Fit is not significant relative to the pure error. There is a 41.99% chance that a Lack of Fit F-value, this large could occur due to noise. Non-significant lack of fit is good. The Predicted (coefficient of determination) R^2 of 0.0221 is not as close to the Adjusted R^2 of 0.6321 as one might normally expect; i.e. the difference is more than 0.2. This may indicate a large block effect or a possible problem with model and/or data. Things to consider are model reduction, response transformation, outliers, etc. All empirical models should be tested by doing confirmation runs. Adeq Precision measures the signal to noise ratio. A ratio greater than 4 is desirable. Ratio of 7.441 indicates an adequate signal. This model can be used to navigate the design space. Following equation 1 shows regression analysis for machinability parameters.

Table 2 ANOVA for surface roughness Ra value

Source	Sum of Square	df	Mean Square	F Value	p-value	
ANOVA for Ra value using Mustard oil						
Model	6.043657	9	0.671517	4.627745	0.012619	Significant
A-Cutting Speed	1.467028	1	1.467028	10.10999	0.009826	Significant
B-Feed	0.505455	1	0.505455	3.483326	0.091553	
C-Depth of Cut	1.427854	1	1.427854	9.840017	0.010566	
AB	0.6909	1	0.6909	4.761319	0.054058	Significant
AC	0.176121	1	0.176121	1.213734	0.296403	
BC	0.362526	1	0.362526	2.498339	0.145047	
AÂ^{2}	0.120976	1	0.120976	0.833701	0.382691	
BÂ^{2}	0.52501	1	0.52501	3.61809	0.086319	
CÂ^{2}	0.642351	1	0.642351	4.426743	0.061663	
Residual	1.451069	10	0.145107			
Lack of Fit	0.794311	5	0.158862	1.209444	0.419897	Not significant
Pure Error	0.656758	5	0.131352			
Cor Total	7.494726	19				
ANOVA for Ra using Palm oil						
Model	4.26	9	0.4734	2.49	0.0859	not significant
A-Cutting Speed	1.84	1	1.84	9.68	0.0110	significant
B-Feed	0.0219	1	0.0219	0.1150	0.7415	
C-Depth of Cut	1.46	1	1.46	7.67	0.0198	significant
AB	0.2953	1	0.2953	1.55	0.2412	
AC	0.1183	1	0.1183	0.6221	0.4486	
BC	0.2567	1	0.2567	1.35	0.2724	
A^2	0.0005	1	0.0005	0.0026	0.9602	
B^2	0.2272	1	0.2272	1.19	0.3001	
C^2	0.0236	1	0.0236	0.1238	0.7322	
Residual	1.90	10	0.1902			
Lack of Fit	1.78	5	0.3570	15.19	0.0048	significant
Pure Error	0.1175	5	0.0235			
Cor Total	6.16	19				

Ra = -3.94955+0.010228 Cutting Speed+63.55745 Feed+1.39451 Depth of Cut-0.146938 Cutting Speed * Feed-0.008479 Cutting Speed * Depth of Cut-15.20536 Feed * Depth of Cut+0.000037 Cutting Speed^2-119.29226 Feed^2+1.72345 Depth of Cut^2 ..…(1)

The equation in terms of actual factors can be used to make predictions about the response for given levels of each factor. Here, the levels specified in the original units for each factor. This equation 1 should not be used to determine the relative impact of each factor because the coefficients are scaled to accommodate the units of each factor and the intercept is not at the centre of the design space.

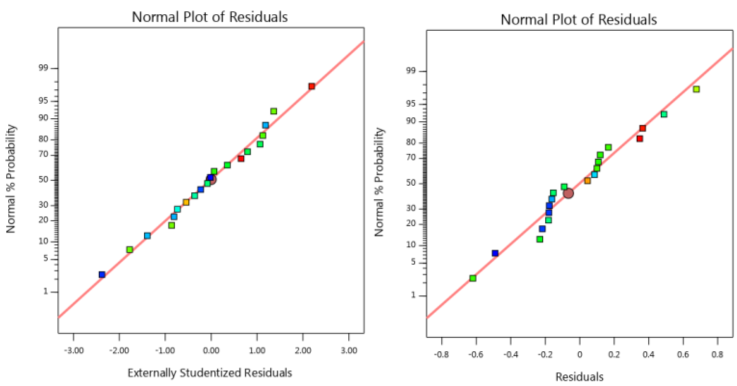

Figure 2. Normal Probability plot for Surface roughness for Mustard and Palm oil respectively.

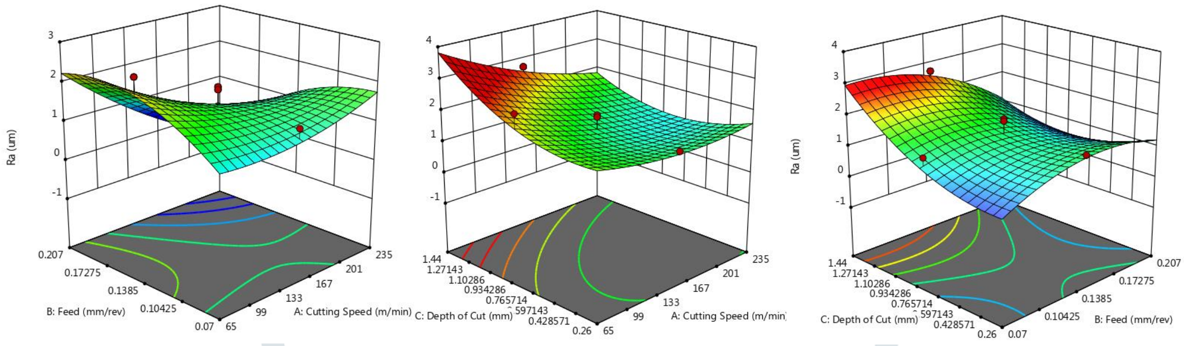

Figure 3. 3D surface cum contour plots of machinability parameters for Ra value using Mustard oil

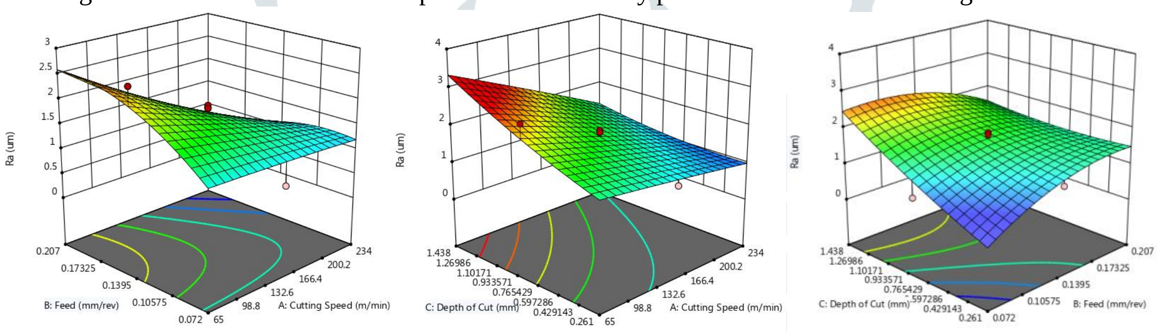

Figure 4. 3D surface cum contour plot of machinability parameters for Ra value of Palm oil

Figure 3 and 4 shows surface cum contour plots for machinability performance for surface roughness using Mustard and Palm oil respectively. It cutting speed is significantly increase in roughness value in mustard oil than palm oil due to effect of viscosity of mustard oil. In case feed and depth of cut, mustard and palm oil both shows increase in roughness value but tendancy of increase in palm oil is more in comparison with Mustard oil due to effective lubricity of Mustard oil. Hence from desirability approach it observed that mustard oil is more effective at high temperature of around 200m/min cutting speed and palm oil can used to upto 120m/min cutting speed for effective minimum quantity lubrication system.

III. CONCLUSION

Comparative assessment of mustard oil and palm oil machinability shows mustard oil is better solution than palm oil for 300ml/hr MQL supply. Mustard oil achieved minimum surface value at higher temperature of 200 m/min and palm oil given at 120m/min of cutting speed. ANOVA for surface roughness for Mustard and Palm oil expressed as cutting speed and depth of cut becomes more significant factor in machinability performance.

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