Surface Roughness Analysis on the Vegetable Oil Based Cutting Fluid in Turning of EN8 Steel

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ABSTRACT
In the present work, properties of the present work of the non-ionic surfactants have been recognized to formulate vegetable oil based cutting fluid (VBCF) palm oil for the emulsion as non-conventional lubricant. Surface finish is an important indicator of quality in manufacturing industries and thus it is regarded as one of the most important parameter to be considered. In this present work different machining parameters were taken and their effect on surface roughness has been analyzed on vegetable oil based cutting fluid (VBCF) palm oil as non-conventional lubricant. Cutting parameter taken were spindle speed feed rate while the depth of cut was kept constant. EN8 steel was the workpiece material for the study. Further the analysis and optimization of surface roughness was also done using Taguchi method to find the contribution of different cutting parameters on surface roughness. The results show that all the input process parameters affect the surface roughness of EN8 steel specimen but feed rate affect most.

Keywords: EN8 steel, surface roughness, Taguchi method, VBCF

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INTRODUCTION

In metal cutting industry, cutting fluids (CFs) is the conventional choice to remove the heat generation and thus reducing the temperature and providing lubrication to tool and work piece, which in turn leads to longer tool life and improved surface finish.

Use of conventional lubricants in machining has many side effects such as environmental pollution, adverse effect on health of worker and manufacture cost. The use of conventional lubricants is under substantial criticism by the health professionals. However, the use of lubricant cannot be swayed away because of the high temperatures and forces that are generated during machining. The heat generated in machining adversely affects the quality of the products. Researchers worldwide have been find new options like vegetable oil based cutting fluid (VBCF) in machining so as to reduce the tool force and the amount of heat generation and improved surface finish aiding both the production cost and the health of the workers.

Surface roughness is an important factor to be considered in machining process. Surface quality of the machined parts or the product is most important quality indicators and also customer requirements indicators. The determination of surface finish in industries is a laborious and time-consuming job and thus gaining a lot of attention among researchers.

LITERATURE REVIEW

Surface Roughness

Nalbant *et al*. (2007) [1] worked on Taguchi method to find the optimal cutting parameters for surface roughness in turning operation. The orthogonal array, signal-to-noise ratio, and ANOVA were employed to study the performance characteristics in turning process of AISI 1030 steel bars using TiN coated tools. Three cutting parameters namely, feed rate, depth of cut and insert radius, were optimized with considerations of surface roughness. Experimental results were provided to illustrate the effectiveness of this approach.

Davim *et al.* (2008) [2] did study on the effects of cutting parameters during turning of 9SMnPb28k (DIN), free machining steel. The Artificial Neural Network model of surface roughness parameters (Ra and Rt) was developed with the cutting parameters such as cutting speed, feed rate, and depth of cut as the affecting cutting parameters. The experiments were planned as per L27 orthogonal array with three different levels defined for each of the parameter in order to develop the knowledge base for artificial neural network training using error back-propagation training algorithm. The analysis concludes that feed rate and cutting speed has significant effect in decreasing the surface roughness, while the depth of cut has the least effect.

Chockalingam and Wee (2012) [3] conclude the effect of different coolant conditions on milling of AISI 304 stainless steel. Cooling techniques used in this research were water-based emulsion, flooding of synthetic oil and compressed cold air. The surface roughness and cutting forces were studied and tool flank wears were observed. The experiment results indicate that water-based emulsion gave better surface finish and lower cutting force followed by compressed cold air and synthetic oil. Different cooling condition required different cutting parameters in order to obtain lower surface roughness and cutting force.

Singh *et al*. (2012) [4] studied the effects of electrical discharge machining (EDM) parameters on surface roughness. H 13 steel was used as work material. Experiments were conducted using Taguchi methodology to determine the effects of EDM process parameter. Peak current, pulse on time, polarity, gap voltage, duty cycle, and concentration of abrasives powder in dielectric fluid were taken as process input parameters. An analysis of variance was carried out to identify the significant factors that affect the surface roughness. The results indicate that all the input process parameters affect the surface roughness of H13 steel specimen.

Vegetable Oil-Based Cutting Fluid (VBCF)

Gunerkar and Kuppan (2013) [5] studied on the application of two different vegetable-based cutting fluids (VBCF) rapeseed oil and sunflower oil for the formation of emulsion as nonconventional lubricant. Cutting fluid, cutting velocity, feed rate, feed rate and depth of cut were considered as machining parameter. Machining with conventional and nonconventional lubricant in wet condition has been carried out upon SS16L work piece with carbide cutting inserts tool, to evaluate surface roughness, cutting force and tool life. The result shows that nonconventional lubricant performs better than conventional lubricant.

Saleem *et al*. (2013) [6] did a study on the application vegetable oil as alternative cutting fluid while performing turning operation on a lathe machine using single point cutting tool of H.S.S. Result on tool life and tool wear were compared against other conventional coolant such as (10% Boric acid + SAE-40 Base Oil). Result shows that the vegetable oil easily removed heat produced during the operation and give proper lubrication, thus reducing friction and wear, hence improving the tool life and surface finish.

Elmunafi *et al*. (2015) [7] used a technique called minimal quantity lubrication (MQL), which sprays small amount of cutting fluid (in the range of approximately 10–100 ml/h) to the cutting zone area with the aid of compressed air the advantages of both dry cutting and flood cooling are merged using MQL. Castor oil was used as the cutting fluid and the workpiece is hardened stainless steel, hardness 48 HRC. Results obtained were then compared with dry cutting and a significant improvement was found. Workpiece material was hardened stainless steel and coated carbide cutting inserts as cutting tools. A longer tool life was recorded as compared to dry turning, Surface roughness and cutting forces were also enhanced.

Lawal *et al*. (2013) [8] studied the selection of fluid additives for the formation of oil in water emulsion using palm kernel and cottonseed oils are not dangerous or problematic to environment or harmful to the workers. Design of experiment using full factorial method was employed in the process of cutting fluid formation, while the effect of formulated cutting fluid on the surface roughness and cutting force in the turning AISI 4340 steel with coated carbide using Taguchi method were investigated. Results show that cutting speed (64.64%) and feed rate (32.19%) have significant effect on the surface roughness and depth of cut (33.1%) and type of cutting fluids (51.1%) have significant influence on the cutting force.

Ozcelik *et al*. (2011) [9] did a study on the performance of both new developed environmental friendly vegetable-based cutting fluid (refined sunflower and canola oils) including different percentage of extreme pressure (EP) additive and two commercial cutting fluids were reported in this work. Performance of cutting fluids were compared with respect to the surface roughness, cutting and feed force and tool wear during longitudinal turning of AISI 304l. Experimental results were also compared with dry cutting condition. The results indicated that 8% of canola based cutting fluid performed better than the rest.

MATERIALS AND METHODS

Lathe Machine

As per the required objective of the present work a lathe machine LMT 20 is used to perform the experiments on surface roughness. The spindle speeds are selected at three level of 150, 250 and 420 rpm and feed rates are also selected at three levels at 0.05, 0.07 and 0.1 mm/rev which are available on the selected machine (Figure 1).

Fig. 1. *Lathe machine.*

Workpice Material

EN 8 steel is the workpiece material for the study with a hardness of 35 HRC. The diameter of rod is 25 mm with a length of 220 mm. The composition of EN 8 steel is given in Table 1 and the figure of raw workpiece is in Figure 2.

Table 1. *Chemical composition of EN8 steel.*

C	Mn	Si	S	P
0.36%–0.45%	0.6%–1%	0.2%–0.3%	0.025%	0.015%

Fig. 2. *EN 8 steel raw material.*

Cutting Tool

Carbide Inserts are used for the present work for which tool holder PCLNR1616H12 I 6H is taken, designation of carbide cutting insert is CNMG 120408 (Figure 3).

Fig. 3. *Tool holder with insert.*

Measurement of Surface Roughness

There are two different surface roughness measurement techniques, which are divided as in-process and post-process measurement. For the present work, post process measurement technique was used which is done after completion of the machining process and surface roughness of the finished workpiece material was measured using Mitutoyo SURFTEST SJ-210 which shown in Figure 4.

Specification of Mitutoyo SURFTEST SJ-210 gauge range: (–200 µm to +160 µm), probe movement (max): 21 mm, traverse speed: 1 mm/s.

Fig. 4. *Mitutoyo SURFTEST SJ-210.*

VEGETABLE OIL BASED CUTTING FLUID (VBCF)

The present work involves the application of palm oil with two different surfactants (tween 20 and tween 80) as vegetable oil based cutting fluid (VBCF) to evaluate its performance on tool temperature, cutting force and surface roughness by the change in spindle speed and feed in turning operation.

Palm oil in water emulsion as non-conventional lubricant is prepared using two different non-ionic surfactants (tween 20 and tween 80) in different proportion and their properties are shown in Table 2. The stability is evaluated by varying surfactant proportion. Higher the surfactant proportions higher the stability of the solution. Thus, maximum proportion of the surfactant used is 20% w/w (tween 20) and 15% w/w (tween 80).

Table 2. *Properties of non-ionic surfactants.*

Type of surfactant	**Chemical name**	**Class**	**HLB**	**MA (g/mol)**	**Density (g/cm^3)**
Tween 20	Polyoxyethelene (20) Sorbitan monolaurate	Non-ionic	16.7	1228	1.10
Tween 80	Polyxyethelene (80) Sorbitan monooleate	Non-ionic	15.0	1310	1.07

Experiment Procedure

Here are the steps for the experiment conducted to measure the surface roughness:

(1) Checking and preparing the lathe machine ready for performing the machining operation.
(2) Performing the initial turning on lathe machine to get the desired dimensions of the EN 8 steel workpiece.
(3) Performing the turning operation for the given condition of spindle speed and feed rate.
(4) Measuring surface roughness with the help of portable Surface roughness tester.
(5) After getting the different parameter to optimize the surface roughness by using Taguchi method.

RESULTS AND DISCUSSION

Table 3 indicates the values of surface roughness taken for various value of spindle speed and feed rate for EN 8 steel. Depth of cut was kept constant at 1 mm. Three levels of spindle speed and feed are used here. For spindle speed 150, 250 and 420 rpm are taken and for feed 0.05, 0.07 and 0.1 mm/rev are taken which are shown in Table 3.

Table 3. *Surface roughness values at different cutting parameters.*

Independent parameters		Dependent variable	S/N ratio
Spindle Speed (rpm)	Feed rate (mm/rev)	Mean surface Roughness (μm)	
150	0.05	2.604	-8.3128
150	0.07	3.910	-11.8435
150	0.10	4.939	-13.8728
250	0.05	1.989	-5.9727
250	0.07	3.400	-10.6296
250	0.10	4.725	-13.4880
420	0.05	1.589	-4.0225
420	0.07	2.558	-8.1580
420	0.10	4.234	-12.5350

Responses and Main Effect Plots

The response table for S/N ratio and means are shown in Table 4, respectively. The main effect plot for S/N ratio and means are shown in Figures 5 and 6, respectively. The main effects plot indicates that surface roughness is significantly influenced by feed rate and spindle speed, which are shown in Figures 5 and 6. Optimum condition for the surface roughness is achieved at a feed rate value of 0.05 mm/rev for a speed of 420 rpm and constant depth of cut 1 mm. Further, the model satisfactorily explains the total variance in cutting parameter and it is also reasonably a good fit (R-sq=98.84%, R-sq =97.68%), shown in Table 5.

Table 4. *Responses of S/N ratio for surface roughness using palm oil based coolant.*

Level	Spindle speed	Feed rate
1	-11.343	-6.103
2	-10.030	-10.210
3	-8.239	-13.299
Delta	3.105	7.196
Rank	2	1

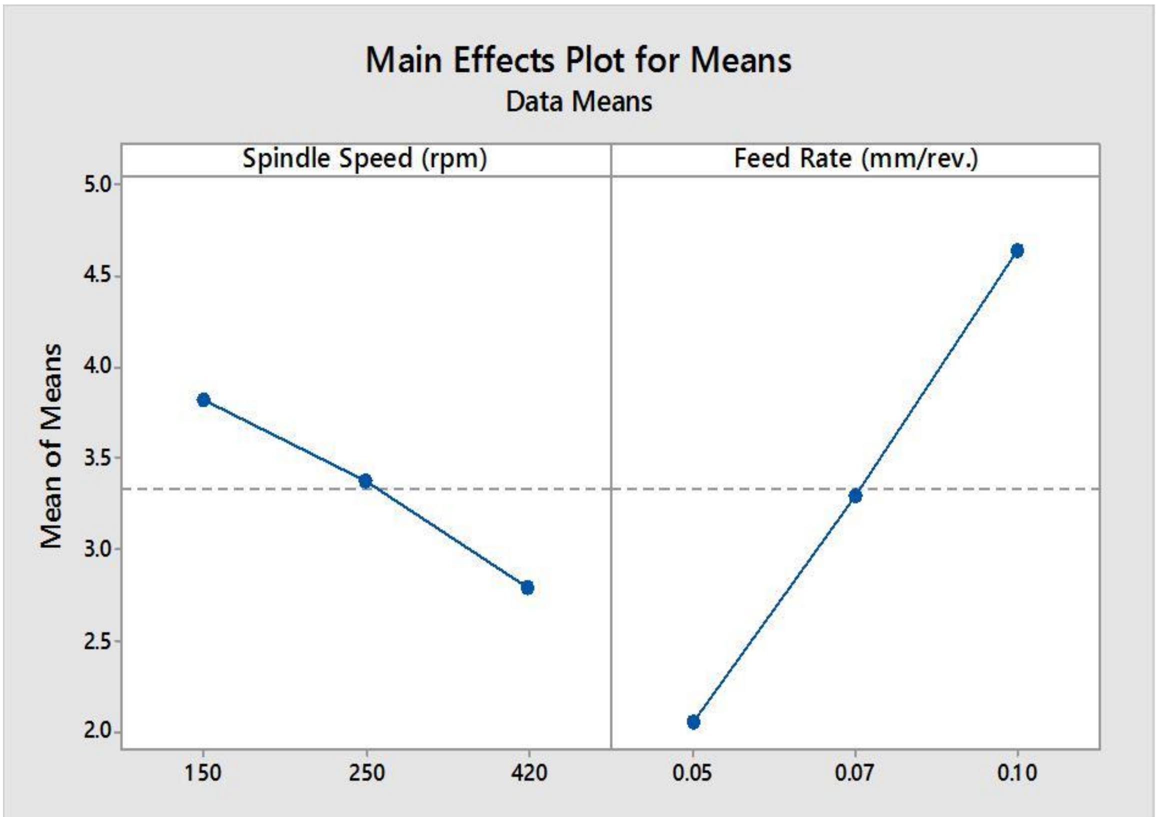

Fig. 5. *Main effects plot of S/N ratio.*

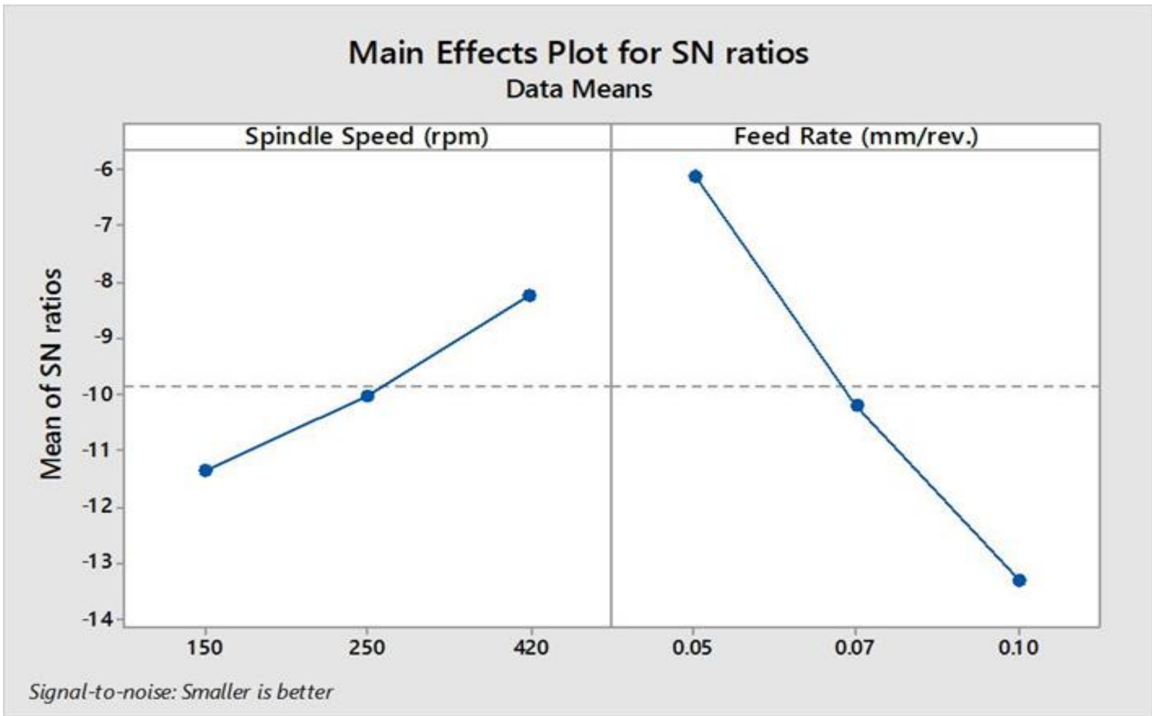

Fig. 6. *Main effect plot for means.*

Analysis of Variance

Table 5 shows variation of actual values of each input parameter with experimental results obtained. Average value of surface roughness (Ra) was statistically analyzed using Minitab 17 Software. Analysis of variance was performed to study the significant of input machining parameters on surface roughness.

Table 5. *Response table for means.*

Source value	DF	Seq. SS	Contribution	Adj. SS	Adj. MS	F value	P value
Spindle							
Speed (rpm)	2	1.5815	13.58%	1.5815	0.79074	23.44	0.006
Feed							
Rate (mm/rev)	2	9.9294	85.26%	9.9294	4.96468	147.15	0.000
Error	4	0.1350	1.16%	0.1350	0.03374	–	–
Total	8	11.6458	100.00%	–	–	–	–
S = 0.183679				R-sq (adj) = 97.68%			

It is clear from Table 5 that the effect of spindle speed and feed rate on Surface Roughness is 13.58 % and 85.26% respectively which is same as obtained from response table for S/N ratio. R-sq represents the significance of experiment work which is 98.84%.

In Analysis of variance, F value is also an indication of more and less affecting parameter. Parameter which has more or less F value indicates most and least affecting parameter. From Table 5 it is seen that the feed rate is more significant parameter as it has high F value spindle speed is less significant parameter as it has less F value.

Mathematical model is obtained to predict the desired surface roughness. For the present work, the following mathematical model for surface roughness was obtained according to experimental data (Figure 7).

$SR = 0.619 – 0.003751\ SS + 50.91\ FR$

where Ra = surface roughness, SS = spindle speed, FR = feed rate.

Interaction Plot

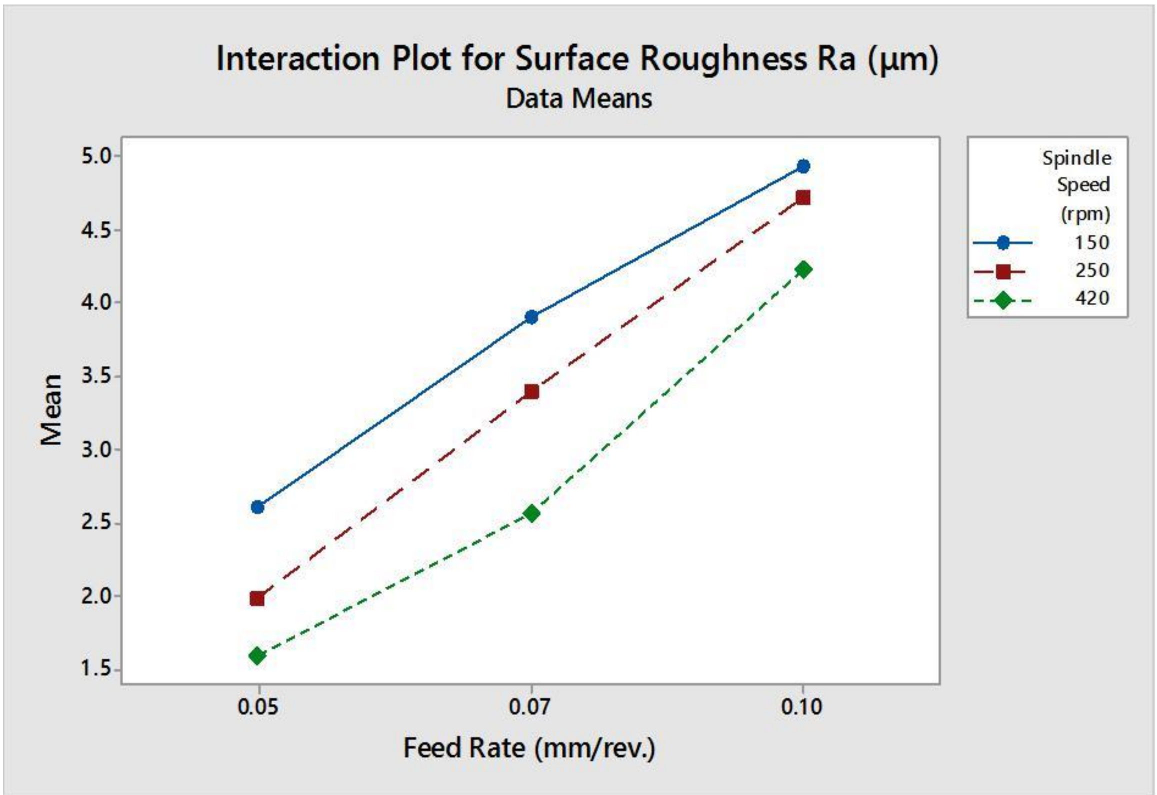

Fig. 7. *Interaction plot for surface roughness.*

CONCLUSION

In the present research, the surface roughness obtained in Palm oil (vegetable oil) based cutting fluid turning of EN 8 Steel has been studied. The interest of the study is due to two reasons: first, the importance that surface roughness has reached, in both economical and mechanical terms, and secondly, due to the industry demands of quality and precision in the manufacturing of parts.

For the palm oil (vegetable oil) based cutting fluid, surface roughness was analyzed following first-order modals. For Ra parameter, the most influential factor was feed rate. The investigation results show that optimal condition of surface roughness, such as the depth of cut (1 mm constant), feed rate (0.05 rev/min) and seep (420 rpm) can be used to achieve better surface roughness in EN 8 steel. The higher the feed rate value is the deeper the irregular on the surface roughness is produced.

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