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Tool Temperature Analysis on the Vegetable Oil Based Cutting Fluid in Turning of EN8 Steel

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ABSTRACT

Many problems such as health and environment issues are identified with the use of cutting fluids. There has been demand for developing new environmentally friendly cutting fluids such as vegetable based cutting fluids (VBCF) to reduce these harmful effects. In this study, performance of VBCFs from Palm oil with different ratio of additives likes tween 20 and tween 80 are evaluated for reducing tool temperature during turning of EN8 steel with carbide insert tool. In this present work different machining parameters were taken and their effect on tool temperature has been analyzed on vegetable oil based cutting fluid (VBCF) palm oil as non-conventional lubricant. Cutting parameter taken were spindle speed and 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 tool temperature was also done using Taguchi method to find the contribution of different cutting parameters on tool temperature. The results show that all the input process parameters affect the tool temperature of EN8 steel specimen but spindle speed affect most.

Keywords: EN8 steel, Taguchi method, tool temperature, turning, VBCF

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INTRODUCTION

In metal cutting industry, cutting fluids (CFs) have a crucial importance among machining factors, due to their lubricant and cooling properties 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 [1]. 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.

LITERATURE REVIEW

Temperature

Abhang and Hameedullah (2010) investigated the tool-chip interface temperature experimentally during turning of EN-31 steel with tungsten carbide inserts using a tool-work thermocouple technique. The metal cutting parameters considered was cutting speed, feed rate, tool nose radius and depth of cut. It could be seen from the first order model that the cutting speed, feed rate and depth of cut was the most significantly influencing constraints for the chip-tool interface temperature followed by tool nose radius. The results shown that increase in cutting speed, feed rate and depth of cut increases the tool temperature while increasing nose radius reduced the tool temperature [2, 3].

Das et al. (2012) worked on the optimization method of cutting parameters in dry turning of AISI D2 Steel to achieve low workpiece surface temperature and minimum tool wear. The experiment layout was designed based on the Taguchi's L9 Orthogonal array technique and analysis of variance was performed to identify the effect of cutting parameters on the response variable. The results showed that depth of cut and cutting speed were the most important parameter influencing the tool wear. Similarly, minimum workpiece surface temperature was obtained at cutting speed of 150 m/min, depth of cut of 0.5 mm and feed of 0.25 mm/rev.

Lathiya and Viswakarma (2012) discussed numerous methods of temperature distribution such as experimental, numerical analysis and analytical. In addition, temperature measurement techniques used in metal cutting were briefly reviewed. Furthermore, an attempt had been made to develop analytical thermal model to determine the temperature during the cutting process. The model was developed using MATLAB software and generated results was compared with the published work, for different cutting conditions and workpieces.

Chikalthankar *et al.* (2014) investigated average chip-tool interface temperature considering the effect of cutting parameters such as spindle speed, feed and depth of cut during turning of OHNS. Taguchi method was used for single characteristics optimization in order to establish a correlation between the input and output variables. it had been observed that the depth of cut was the most influencing parameter followed by spindle speed and feed [4].

Vegetable Oil Based Cutting Fluid (VBCF)

Gunerkar and Kuppan (2013) 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) 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) 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 [5].

Lawal *et al*. (2013) 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 research using full factorial method was employed in the method of the 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 considerable influence on the surface roughness and depth of cut (33.1%) and type of cutting fluids (51.1%) have considerable influence on the cutting force.

Ozcelik *et al*. (2011) 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 [6, 7].

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).

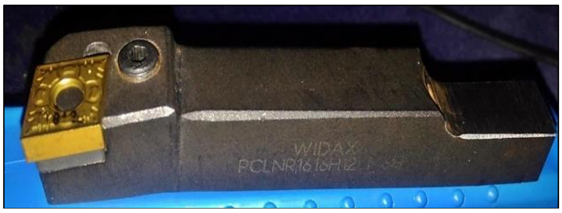

Fig. 3. *Tool holder with insert.*

Measurement of Tool Temperature

In present study, embedded thermocouple technique was used and a hole was drilled in the tool holder and shim to insert the thermocouple which was only 4 mm away from the cutting edge.

Temperature Indicators

The tool temperature measured with thermocouple was indicated with the help of a multimeter, having an in-built temperature measurement function. MASTECH MS8217 was the multimeter used. This meter used is a portable professional measuring instrument with a large LCD display shown in Figure 4.

Fig. 4. *MASTECH MS8217 multimeter.*

Specification of multimeter MASTECH MS8217 DC Voltage: 0.1 mV–1000 V, DC Current: 0.1 µA – 10 A, AC voltage: 0.1 mV – 1000 V, Temperature: –55–1000°C, least count (temperature): 0.1°C.

Thermocouple

A thermocouple is a type of temperature sensor, which is made by joining two dissimilar metals at one end. For the present work, K type thermocouple was used to measuring the tool temperature which is shown in Figure 5.

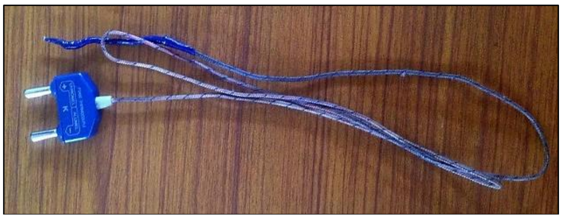

Fig. 5. *K-type thermocouple.*

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 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 tool temperature:

(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 tool temperature with the help of multimeter.
(5) After getting the different parameter to optimize the tool temperature by using Taguchi method.

RESULTS AND DISCUSSION

Table 3 indicates the values of tool temperature taken for various values 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. *Tool temperature values at different cutting parameters.*

Independent parameters		Dependent variable	S/N ratio
Spindle Speed (rpm)	Feed rate (mm/rev)	Maximum tool Temperature (°C)	
150	0.05	74.6	-37.4548
150	0.07	77.5	-37.7860
150	0.10	81.0	-38.1697
250	0.05	79.6	-38.0183
250	0.07	85.8	-38.6697
250	0.10	97.1	-39.7444
420	0.05	92.3	-39.3040
420	0.07	104.2	-40.3574
420	0.10	122.3	-41.7485

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 tool temperature is significantly influenced by feed rate and spindle speed, which are shown in Figures 5 and 6. Optimum condition for the tool temperature is achieved at a feed rate value of 0.1 mm/rev for a speed of 420 rpm and constant depth of cut 1 mm [8, 9]. Further, the model satisfactorily explains the total variance in cutting parameter and it is also reasonably a good fit (R-sq=92.50%, R-sq (adj) = 85.01%), shown in Table 5.

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

Level	Spindle speed	Feed rate
1	-37.80	-38.26
2	-38.81	-38.94
3	-40.47	-39.89
Delta	2.67	1.63
Rank	1	2

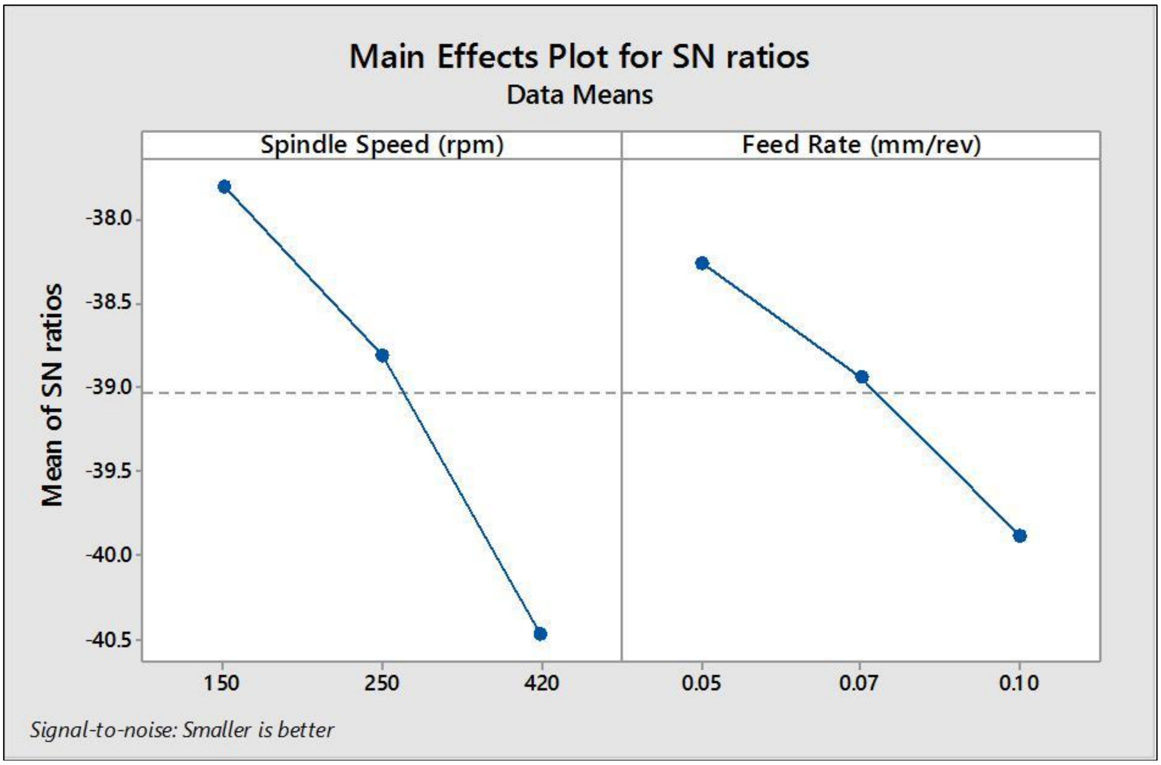

Fig. 5. *Main effects plot of S/N ratio.*

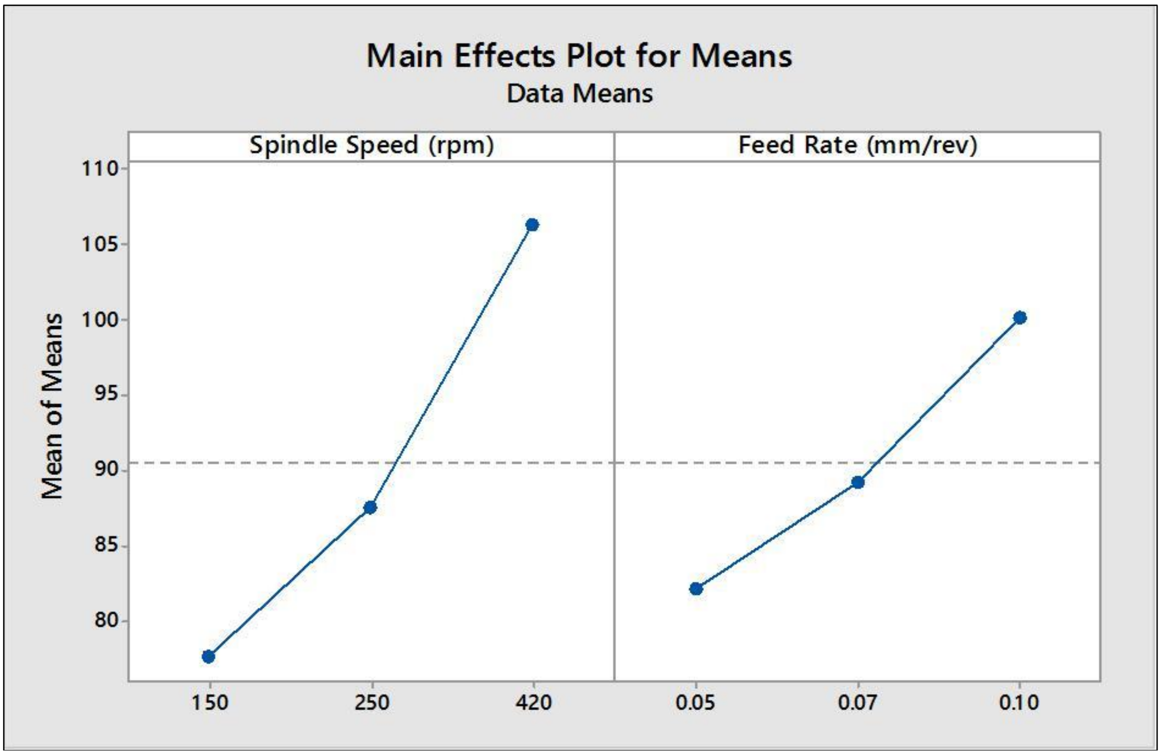

Fig. 6. *Main effect plot for means.*

Analysis of Variance

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

Table 5. *Response table for means.*

Source Value	DF	Seq. SS	Contribution	Adj. SS	Adj. MS	F value	P value
Spindle Speed (rpm)	2	1264.3	66.59%	1264.3	632.14	17.76	0.010
Feed Rate (mm/rev)	2	492.1	25.92%	492.1	246.03	6.91	0.050
Error	4	142.3	7.50%	142.3	35.58	–	–
Total	8	1898.7	100.00%	–	–	–	–
S = 5.96527			R-sq = 92.50%		R-sq (adj) = 85.01%		

It is clear from Table 5 that the effect of spindle speed and feed rate on tool temperature is 66.59% and 25.92%, respectively which is same as obtained from response table for S/N ratio. R-sq represents the significance of experiment work which is 92.50%. 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 [5–8]. From Table 5 it is seen that the spindle speed is more significant parameter as it has high F value feed rate is less significant parameter as it has less F value (Figure 7).

Interaction Plot

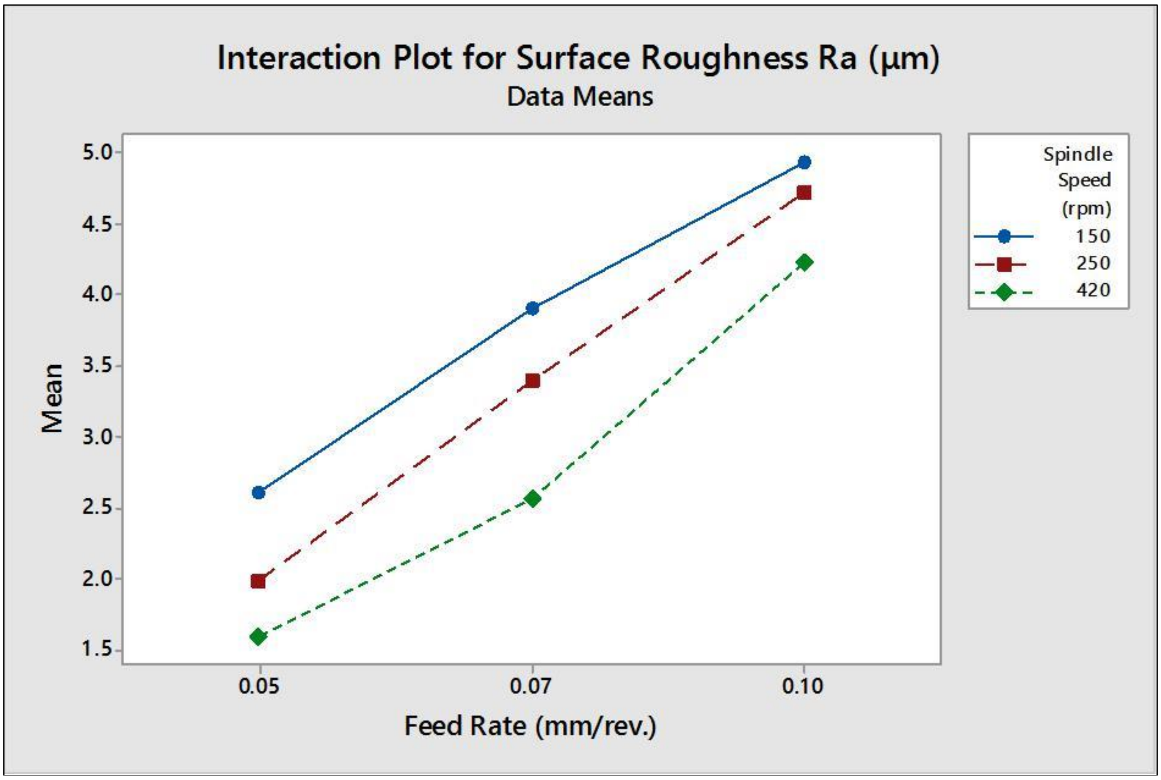

Fig. 7. *Interaction plot for tool temperature.*

CONCLUSION

In the present research, the tool temperature 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 the reasons:

to remove the heat generation and thus reducing the temperature which in turn leads to longer tool life. For the Palm oil (vegetable oil) based cutting fluid, tool temperature was analyzed following first-order modals. For tool temperature parameter, the most influential factor was spindle speed. The investigation results show that optimal condition of tool temperature, such as the depth of cut (1 mm constant), feed rate (0.1 rev/min) and seep (420 rpm) can be used to achieve better tool temperature reduction in EN 8 steel.

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