International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Articles available online http://www.ijoer.in

Vol.3., Issue.5., 2015
(Sept.-Oct.)

RESEARCH ARTICLE

ISSN: 2321-7758

FORMULATION OF ENVIRONMENTAL FRIENDLY VEGETABLE OIL BASED CUTTING FLUID FOR HARD TURNING OF OHNS STEELAND ANALYZING CUTTING ZONE TEMPERATURE

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International Journal of Engineering Research-online (IJOER)
ISSN:2321-7758
www.ijoer.in

ABSTRACT

Nowadays, the necessity of eco friendly cutting fluid is raised due to the increasing environmental problems. In the present work, Vegetable based cutting fluids which are bio degradable in nature is formulated and applied as the cutting fluid when machining Oil Hardening and Non Shrinking (OHNS) steel. Numbers of experiments are determined based on Taguchi's design of experiments. In order to control the pollution effects, the cutting fluids are applied during machining using minimal fluid application system. Minimal fluid application provides environmental friendliness by maintaining neat, clean, dry working area thereby avoiding the inconvenience and health hazards due to heat, smoke, fumes, gases, etc. It also prevents the pollution of surroundings and improves the machinability characteristic etc. Formulation of vegetable based cutting fluid involves improvement in performance of the cutting fluid used for lubrication. The machinability studies is carried out to find out the effect of input parameters like cutting velocity, feed rate, depth of cut and the composition of cutting fluid on the measured output responses like cutting zone temperature. The optimal values of the input parameters for getting the minimal values of measured responses are found out using Taguchi analysis method and Response Surface Methodology. The performance of the formulated vegetable based lubricating oil is compared with the performance of existing mineral based cutting fluid and raw coconut oil. The experimental results shows the improvement in performance when machining OHNS steel using the formulated vegetable based cutting fluids when compared with the other conventional cutting fluids.

Key words: vegetable oil based cutting fluid, formulation, minimum fluid application, response surface methodology, machinability

I. INTRODUCTION

Considering environment protection awareness under law and regulation, Eco-Friendly cutting fluids has become a general trend since 21st century,. During machining process, cutting fluid is required to reduce the cutting force and to lower the cutting temperature of working tools.This will help to tool life and enhance machining efficiency and surface finish quality during machining. Performance enhancers for increasing chip curl, improving rake face lubrication and increasing extraction of heat from the cutting tool are going to discuss. An attempt was made to develop a cutting fluid based on vegetable oil and the issues related to the use of vegetable oils as metal cutting fluids. Procedure for the formulation of cutting fluid with coconut oil as the base and testing of this cutting fluid in hard turning of OHNS steel was done in this work. It is reported that cutting fluids based on coconut oil offered better cutting performance when compared to mineral oil based cutting fluids. As it is pure biodegradable, it does not possess any problems connected with disposal. It is highly environment and user friendly and causes no skin problems to workers exposed to it. It has got high oxidative and thermal stability. The long chain molecules of coconut oil are dipolar in nature and can create a dense, homogeneous and strong lubricating film on the contact surfaces that can absorb high pressures and offer better lubrication very small quantities of cutting fluid is consuming in minimum fluid application system during hard turning operation of OHNS steel. The various methods available for minimum quantity lubrication, narrow pulsed jet stream method have used during the machining work.

II METHODOLOGY

In this work, data which are available in the previous turning process with mineral as well as synthetic lubrication were collected. The effect of input parameters on the output responses like cutting temperature, cutting force and surface roughness were studied. The cost incurred, when using the mineral or petroleum cutting fluids in the turning process and the amount of environmental pollution that taken place during the hard tuning process were analysed. The entire work can be classified into two phases. In the first phase of the project, formulation of vegetable oil based cutting fluid was carried out by using coconut oil, oleic acid and triethanol amine. Also, Taguchi's Design of Experiments was used to choose the number of running experiments. The second phase of the project includes selecting the material, which is OHNS steel with hardness of 48HRC, and carrying out the turning process using this material. The second phase also constitute of Analysis and optimization of the experimental results.

A. TAGUCHI DESIGN OF EXPERIMENTS

The methodology developed by Taguchi is used for determining the design of experiments from the exclusive world of the statistician and brought it more fully into the world of manufacturing. His contributions have also made the practitioner work simpler by advocating the use of fewer experimental designs, and providing a clearer understanding of the variation nature and the economic consequences of quality engineering in the world of manufacturing. Taguchi introduces his approach, using experimental design for, designing process so as to be robust to environmental conditions. Designing and developing product or process so as to be robust to component variation. Minimizing variation around a target value.

Taguchi techniques have been used widely in engineering design. The main thrust area of the Taguchi techniques is the use of parameter design, which is an engineering method for product or process design that focuses on determining the parameter settings producing the best levels of a quality characteristic like performance measure with minimum variation. Taguchi designs provide a powerful and efficient method for designing processes that operate consistently and optimally over a variety of conditions. To determine the best design requires the use of a strategically designed, experiment, which exposes the process to various levels of design parameters. Grey based Taguchi method is used to determine the optimum process parameters for multiple responses. Design matrix is the representation of input parameters and its values in a tabular form. The values of Cutting velocity in this investigation taken as 80, 90 and 100 m/ min. Feed rate is taken as 0.07, 0.08 and 0.09 mm/rev. The three levels of composition are 10%, 20%, 30% of concentrate (formulated vegetable oil based cutting fluid) and rest of water respectively. The levels of depth of cut are 0.3, 0.6, 0.9 mm respectively. Input parameters and its values described in design matrix shown in Table 1.

B. SELECTION OF PROPER ORTHOGONAL ARRAY WITH MINITAB SOFTWARE

Minitab software, it can be used for learning about statistics as well as statistical research. Statistical analysis computer applications have the advantage of being accurate, reliable, and generally faster than computing statistics and drawing graphs by hand. Minitab is relatively easy to use once we know a few fundamentals. In Minitab software, different methods for design of experiments like Taguchi method, regression analysis are available.

In this investigation, there are four input parameters; each one varies at three different levels. In Taguchi method, minimum number of optimum combinations is considered. Using Minitab software, the proper optimum combinations are decided as per the steps explained below. In this experiment selected L9 array. That is 9 run experiments had been chosen.

Table 1 Design matrix

Input Parameters	**Level 1**	**Level 2**	**Level 3**
Cutting Velocity (m/min)	80 (V_1)	90 (V_2)	100 (V_3)
Feed rate(mm/rev)	0.07 (F_1)	0.08 (F_2)	0.09 (F_3)
Composition	Formulated oil 10%+ water (C_1)	Formulated oil 20%+ water (C_2)	Formulated oil 30%+ water (C_3)
Depth of cut(mm)	0.3 (D_1)	0.6 (D_2)	0.9 (D_3)

C. FEASIBILITY STUDIES

It was decided to evaluate the feasibility of the formulated cutting fluid for hard turning with minimal fluid application. The minimal fluid application system was also used in the present investigation. Cutting experiments were conducted to various composition of different percentage level of concentration. The performance of the coconut oil based formulated cutting fluid was compared with a commercial available mineral based cutting fluid and pure coconut oil during hard turning of OHNS steel with minimal fluid application. This was accomplished by conducting a variable speed test, a variable feed test, three level of depth and a tool life test. In this work, the rate of fluid application for turning operation as 5ml/min, pressure of the fluid injector as 80bar and the frequency of the pulsing as 300pulses/min were maintained throughout the experiment. After setting the above constant values, time was set as 60 seconds for the variable speed test, variable feed test, and variable depth of cut test. The output measurable responses like cutting zone temperature were measured. The output responses which are measured for all the trials are tabulated. Minitab software provides the optimum result. Single response optimization and multiple response optimizations are the two methods to optimizing the output values. In the Minitab software analysis of Taguchi design experiment provide the single response optimization.Analyses of Taguchi design show the individual characteristic performance with varying input parameters. For example, when the values of cutting temperature for all the experiments be given, the software will generate the optimized value of input parameters for obtaining the desired values of the output responses (cutting temperature). Also since these results have the graphical representation like temperature versus varying parameters, at every level of the parameters, the force measured can be seen graphically. Also we can determine the optimum values of input parameters

Response surface methodology is a collection of mathematical and statistical techniques for empirical model building. By design of experiments, the objective is to optimize a response (output variable) which is influenced by several independent variables (input variables). An experiment is a series of tests, called runs, in which changes are made in the input variables in order to identify the reasons for changes in the output response. Some extensions of response surface methodology deals with the multiple response problems. Multiple response variables create difficulty because what is optimal for one response may not be optimal for other responses. Other extensions are used to reduce variability in a single response while targeting a specific value, or attaining a near maximum or minimum while preventing variability in that response from getting too large.

After obtaining the optimum combinations of input parameters, which are predicted by Response surface methodology, the turning experiments (validation experiments) were conducted for checking the effectiveness of the cutting fluid. The experiments were conducted with different cutting fluids like raw coconut oil, mineral oil based cutting fluid and formulated vegetable oil based cutting fluid and the measured values of the output responses were tabulated.

III. RESULT AND DISCUSSION

Table 2 presents the output values of cutting zone temperature for the varying values of input parameters like cutting velocity, feed rate, depth of cut and composition.

Table 2 Experimental results

Cutting Velocity (m/min)	Feed rate (mm/rev)	Compo-sition (%)	Depth (mm)	Temp.(ºc)
80	0.07	C1	0.3	176.43
80	0.08	C2	0.6	174.87
80	0.09	C3	0.9	183.08
90	0.07	C2	0.9	189.45
90	0.08	C3	0.3	179.88
90	0.09	C1	0.6	205.76
100	0.07	C3	0.6	185.58
100	0.08	C1	0.9	219.08
100	0.09	C2	0.3	198.76

Here C1 is the composition which has 10% of concentration and 90% of water, C2 is the composition which has 20% of concentration and 80% of water and the C3 composition has 30% of concentration and 70% of water. The above table shows the 9 run experiment results, like the values cutting zone temperature of the work piece and tool wear. Calculations were done with the help of excel sheet and Minitab 16 software.

A. ANALYSIS OF CUTTING ZONE TEMPERATURE VS INPUT PARAMETERS

Random Order Trial no	Standard Order Trial no	Response value(cutting temperature)	VELOCITY m/min			FEED RATE mm/rev			COMPOSITION			DEPTH OF CUT mm		
			V1	V2	V3	F1	F2	F3	C1	C2	C3	D1	D2	D3
			80	90	100	0.07	0.08	0.09	C1	C2	C3	0.3	0.6	0.9
1	1	176.43	176.43			176.43			176.43			176.43		
2	2	174.87	174.87				174.87			174.87			174.87	
3	3	181.08	181.08					181.1			181.08			181.08
4	4	189.45		189.45		189.45				189.45				189.76
5	5	179.88		179.88			179.88				179.88	179.88		
6	6	205.76		205.76				205.8	205.76				205.76	
7	7	185.52			185.52	185.52					185.52		185.52	
8	8	219.08			219.08		219.08		219.08					219
9	9	198.76			198.76			198.8		198.76		198.76		
Total		1710.83	532.38	575.09	603.36	551.4	573.83	585.6	601.27	563.08	546.48	555.07	566.15	589.84
No. of Values		9	3	3	3	3	3	3	3	3	3	3	3	3
Average		190.092	177.46	191.697	201.12	183.8	191.28	195.2	200.42	187.69	182.16	185.023	188.717	196.613

Fig: 1 Excel sheet of cutting zone temperature Vs input parameters

Figure 1 shows the results, response value of cutting zone temperature with different values of input parameters. At 80, 90, 100 m/min of cutting velocities, the corresponding output cutting temperatures are 177.46, 191.697, 201.12 °C. At 0.07, 0.08, 0.09 mm/rev of feed rate provides 183.8, 191.28, 195.2°C cutting temperature respectively. In case of compositions, at C1 composition the cutting zone temperature is 200.42°C, at C2 composition provides 187.69°C cutting temperature and at C3 composition it gives 182.16°C. The values of cutting zone temperature at varying levels of depth of cut of 0.3, 0.6, 0.9 mm are 185.023, 188.717, and 196.613ºC. Hence the excel data sheet shows the exact values and average of each varying parameters.

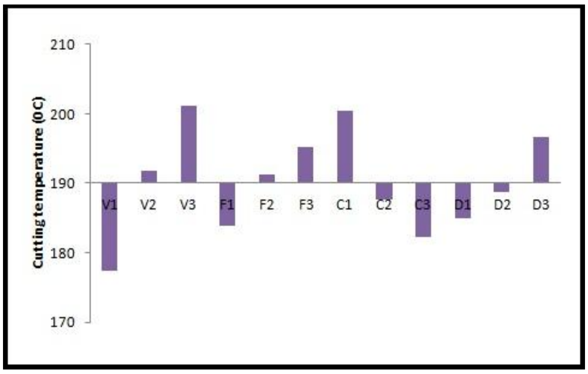

Fig: 2 Cutting zone temperatures with variable parameters

Figure 2 shows the graphical representation of excel sheet result. Cutting zone temperatures with different parameters are arranged in X-Y axis, X have the different parameters and Y axis shows the cutting zone temperature. Excel sheet average values of cutting temperatures are graphically represented on X axis. So we can easily identify which values are small and which combination is optimum, V1, F1, C3 and D1 combination provides the optimum results for cutting temperature. At 80m/min velocity, 0.07mm/rev feed rate, 30% concentrate+70% of water composition and 0.03 mm depth shows the optimum combination for cutting force when machining OHNS steel.

B. ANALYSIS OF TAGUCHI DESIGN EXPERIMENT FOR CUTTING ZONE TEMPERATURE

The effect of various input parameters on getting the minimum values of cutting zone temperature is analyzed. Graphical representation of cutting zone temperature versus cutting velocity, feed rate, composition and depth of cut are obtained by the Minitab software through main effects plot for means. In the plot, the lowest value of each graph from the main effects plot for means by the Taguchi technique is chosen as the optimum value of result. The figure 3 shows the result of analysis by means of various graphs like cutting temperature versus velocity, cutting force versus feed, cutting force versus composition and cutting force versus depth of the cut. The main effects plot for means is the response table, and the smaller value of the graph is the desired one. The first graph shows the cutting temperature versus the cutting velocity. The smaller values of cutting velocity give the smaller cutting temperature. Similarly, lower feed provide lower cutting temperature, 30% of concentration gives the lower cutting temperature and the lower value of depth of cut provides the lower cutting zone temperature. Taguchi analysis response table gives different ranks for each parameter, according to the contribution of that particular input in determining the desired output response. Response table and analysis of variance give the exact rank and exact percentage of influence about each parameter.

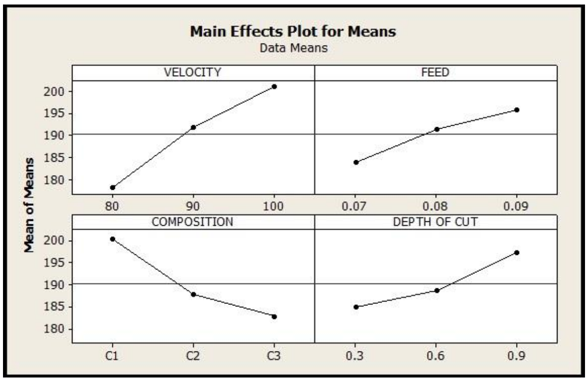

Fig: 3 Cutting zone temperature Vs velocity, feed, composition and depth

A. RESPONSE SURFACE METHODOLOGY (RSM)

Response surface methodology is a collection of mathematical and statistical techniques for empirical model building. By careful design of experiments, the objective is to optimize a response which is influenced by several independent variables. An experiment is a series of tests, called runs, in which changes are made in the input variables in order to identify the reasons for changes in the output response. Some extensions of response surface methodology deals with the multiple response problems. Multiple response variables create difficulty because the optimal solution for one response may not be the optimal solution for the other responses.

Table 3 Set up values

Parameter	**Target value**	**Max. value**
Cutting Temperature (ºC)	155	205

The table 3 shows some values like target and maximum values of desired outputs. After the experiments, different values of output responses are obtained at different combinations of input parameters. In the case of using formulated vegetable oil based cutting fluid one of the objectives is the safety concern. Low cutting zone temperature will be desirable for a better machining. For obtaining the predicted values of optimal input parameters for getting the desired values of output responses, the target value and tolerable maximum values are given to response surface methodology as shown in the above table.

Table 4 is the predicted values of optimum value from the nine run experiment. The validation experiments are conducted at these predicted values of input parameters. Also the experiments are conducted at the same values of predicted input parameters using raw coconut oil and mineral based oil as the cutting fluid.

Table 4: Optimum value

Predicted Input values of Parameters		**Predicted output values of parameters**
Cutting velocity (m/min)	80.00	Cutting Temp. (ºC) 158.833
Feed rate(mm/rev)	0.07	
Composition (concentrate %)	30	
Depth of cut(mm)	0.3	

A. COMPARISON WITH RAW COCONUT OIL AND MINERAL OIL BASED CUTTING FLUID

Using the predicted values of the input parameters from response surface methodology and taking the parameter level at constant, the experiments was conducted using the same minimum fluid application system. The system condition of 5ml/min rate of fluid application, 80 bar pressure of the fluid injector, the frequency of pulsing is 300pulses/min is maintained. Instead of varying the composition, different cutting fluids especially raw coconut oil, mineral oil based cutting fluids were compared with the formulated vegetable oil based cutting fluid. Again the constant parameters and comparison results were shown in the tables 5 and 6 respectively.

Table 5 Constant parameter

Velocity(m/min)	Feed (mm/rev)	Depth (mm)
80.00	0.07	0.3

Table 6 Comparison result

Cutting fluids	Cutting Temp. (ºc)
Formulated vegetable oil based	158.833
Raw coconut oil	280.32
Mineral oil based	180.5

Table 6 comparison results shows the performance results of formulated vegetable oil, raw coconut oil and mineral based cutting fluid. From the tabulated results, we can conclude that the formulated vegetable oil based cutting fluid gives better results for the machining OHNS steel with minimum fluid application

V: CONCLUSION

A cutting fluid was formulated with coconut oil as the base which can act as oil in water emulsion during turning of hardened OHNS steel with minimal fluid application. The performance of the new cutting fluid was compared with that of a conventional mineral oil based cutting fluid and raw coconut oil by conducting various turning experiments. Predicted Input values of Parameters are cutting velocity 80.00 m/min, feed rate 0.07 mm/rev, composition 30 (concentrate %) and depth of cut 0.3mm. This produced the predicted output values of parameters like cutting temp. 158.833ºC. It was observed that the formulated coconut oil based cutting fluid offered better cutting performance of cutting zone temperature when compared with the mineral oil based cutting fluid and raw coconut oil. It was also observed that the percentage of concentrate in the cutting fluid can be maintained as 30% to achieve better cutting performance during turning of hardened OHNS steel with minimal fluid application. Cutting fluid with coconut oil as the base is environment as well as human friendly. It is biodegradable in nature and hence free from problems associated with disposal.Coconut oil based cutting fluid can fetch saving in terms of foreign exchange as it does not need mineral oils which are to be imported.

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