OPTIMIZATION OF CUTTING PARAMETER DURING TURNING USING DIFFERENT CUTTING FLUIDS

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ABSTRACT

Efforts were made to completely eliminate the toxic cutting fluids. In this regards interest in vegetable oil is growing. Minimum quantity lubrication using vegetable based cutting fluids can be used to improve the productivity and avoid environmental detriment. The main objectives of this research are to develop low cost MQL system and to evaluate performance of vegetable oil based on surface roughness. The performance of different vegetable oils such as blasocut-4000, soyabean oil, sunflower oil, groundnut oil and coconut oil is compared during turning AISI 4130. Analysis of the experimental results is performed using response surface methodology. Mathematical model for each performance parameter is developed showing relation between significant parameters such as cutting speed, depth of cut and feed rate. ANOVA test is performed to check the competency of the developed model. Optimization of the process parameter is carried out using response surface optimizer. Desirability is calculated to show the feasibility of optimization. The experimental results show that vegetable oil outperforms the mineral based fluid. Among all the vegetable oil soyabean oil gave the best result.

KEYWORDS: *MQL; Surface roughness; Vegetable oil*

1.0 INTRODUCTION

Due to high heat, poor surface finish, ecological concern and government protocols, immense efforts are made to reduce the petroleum based cutting fluids. Dry cutting is one of the replacement but increased wear rate, raised temperature are major concern issues. Practice of using mineral oil is potentially perilous. Increased use of cutting fluids results into environmental degradation like soil pollution, water contamination, disposal and dumping problems. Recycling cost of the waste cutting fluid is high. It requires separate setup for waste disposal and management. Most significant issue is health of the operator. The operator may suffer from dermatological, respiratory disease that may lead to cancer. The use of the mineral oil is hazardous. The mineral oils which are used as cutting fluids are not renewable sources. They are depleting. Gases exerted from theses oils also results into ozone depletion and contribute to global warming. (Sokovic & Mijanovic, 2001) Thus mineral oil based cutting fluids are accountable for upsetting the eco-system balance. This disruption has long term effect on mankind and next generation. In order to maintain the natural equilibrium, every country is now imposing strict restrictions for the use of mineral oil based cutting fluids. (NIOSH,1998) The minimization of cutting fluid leads to saving of the cutting fluid, reduces the

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machining cycle time hence reduces the chances of the contact of the operator with cutting fluid.

Minimum quantity lubrication is emerged as substitute for dry machining and flood cutting. The minimization of cutting fluids lead to saving of lubricant cost. Reduced quantity of cutting fluid lessens exposure level of the cutting fluid. Conventional flood lubrication system uses cutting fluid at the rate of one-liter to ten-liter per min. MQL uses very small amount of cutting fluid (Heisel & Lutz, 1994). MQL consist of mixture of high-pressure air and cutting fluid applied directly into the interface of cutting tool and work piece The vegetable oils are considered as viable alternative to petroleum based cutting fluids due to high flash point, high boiling point and greater molecular weight. (Ghuge & Mahalle, 2016). For turning operations, the input parameters like depth of cut, speed, feed, tool geometry etc. will decide the performance parameter. Proper selection on input parameter is very essential to get the desired output. Performing experiment trial and deciding the optimum values from the experience is very skilled, time consuming and costly affair. The selection of optimal cutting parameters such as cutting speed, feed rate and depth of cut for every machining process is a very important issue in order to maintain the quality of machined products to reduce the machining costs and to increase the production rate. Taguchi and response surface methodology is one tool for obtaining the optimum values for anticipated goal (Satish, Salve, Netake, More, Kendre & Kumar, 2014).

2.0 EXPERIMENTATION

Since number of input and output parameters are more, there are huge number of possibility of combination to perform the experiments. 3^3 full factorial design by one replica is selected for investigation. Testing is conducted on AISI 4130 bar of 60 mm diameter. Carbide tipped single point cutting tool is used for the investigation. Testing is done for three different cutting conditions namely dry cutting, flood cutting and MQL cutting.

Figure 1. Experimental set up

Blasocut-4000, soyabean oil, sunflower oil, ground nut oil and coconut oils are used as cutting fluid during MQL cutting. A portable stylus-type profilometer is used for surface roughness measurement. Figure 1 shows experimental set up consisting of medium duty lathe and MQL system.

Turning experiment were performed varying cutting speed, feed and depth of cut as shown in table 1.Analysis of the experimental results was carried out using response surface methodology. Regression equations for surface roughness were formulated on the basis of the experimental data. In RSM, generally regression model are fitted to experimental data and ANOVA test is used to check the adequacy of the regression model. Software Minitab17 is used for RSM analysis.

Table 1. Experimental Condition and Machining Parameter

Experimental Condition	Description
Parameter	Cutting speed V (m/min)= 34.27,53,79.73 Feed Rate ,f (mm/rev)=0.35,0.40,0.45 Depth of cut ,d(mm)=0.5,1,1.5
Coolant Condition	Dry, Flood cut-1 L/hr., MQL-50ml/hr.
Cutting Insert	Carbide tipped single point cutting tool, rake angle=12°

3.0 MATHEMATICAL MODELING AND OPTIMIZATION

Regression analysis is a statistical instrument for the study of relationships between variables. Regression is mainly used for prediction and contributing inference. Regression equations 1 to 7 are formulated for surface roughness under different cutting condition.

Regression equations for dry cutting

$$Ra_{Dry}=12.38- 0.0439\ V- 49.2\ f+ 0.586\ dp- 0.000061\ V*V+ 68.9\ f*f - 0.338\ dp*dp+ 0.1054\ V*f+ 0.00248\ V*dp+ 0.93\ f*dp \quad \ldots \quad (1)$$

Regression equations for flood cutting (Flood cutting)

$$Ra_{flood}=10.30- 0.2347\ v- 8.2\ f- 0.261\ dp+ 0.001377\ v*v+ 9.3\ f*f+ 0.080\ dp*dp + 0.1157\ v*f- 0.00090\ v*dp+ 0.80\ f*dp \quad \ldots \quad (2)$$

Regression equations for MQL cutting (Blaso cut-4000)

$$Ra_{\ Blassocut} = 3.38 - 0.1171\ v + 4.79\ f + 0.817\ dp + 0.000886\ v*v + 4.4\ f*f - 0.089\ dp*dp - 0.0125\ v*f - 0.00249\ v*dp - 0.567\ f*dp \quad \ldots \quad (3)$$

Regression equations for MQL cutting (Soyabean Oil)

$$Ra_{Soyabean} = -1.76 - 0.0973\,v + 25.1\,f + 0.447\,dp + 0.000863\,v*v - 18.4\,f*f + 0.036\,dp*dp - 0.0404\,v*f - 0.00196\,v*dp - 0.367\,f*dp \quad \ldots \quad (4)$$

Regression equations for MQL cutting (Sunflower Oil)

$$Ra_{Sunflower} = 1.36 - 0.09825\,v + 10.75\,f + 0.094\,dp + 0.000852\,v*v - 0.89\,f*f + 0.0978\,dp*dp - 0.0396\,v*f - 0.00066\,v*dp + 0.033\,f*dp \quad \ldots \quad (5)$$

Regression equations for MQL cutting (Ground nut Oil)

$$R_{aGroundnut} = 3.04 - 0.0778\,v - 0.8\,f + 0.328\,dp + 0.000641\,v*v + 13.6\,f*f + 0.016\,dp*dp - 0.0297\,v*f - 0.00137\,v*dp - 0.000\,f*dp \quad \ldots \quad (6)$$

Regression equations for MQL cutting (Coconut Oil)

$$Ra_{coconut} = 2.76 - 0.10913\,v + 8.48\,f + 0.381\,dp + 0.000750\,v*v - 2.00\,f*f - 0.0600\,dp*dp - 0.0009\,v*f + 0.00220\,v*dp - 0.400\,f*dp \quad \ldots \quad (7)$$

3.1 Significance of F value, P value, R^2, R^2 adjusted and R^2 Predicted

The F value tells us how much we are deviated from hypothesis. The statistic F is compared to the critical Fcrit = F (α, f_{term}, f_{error}), where α is significance level (generally it is 0.05). If observed F-value is greater than the critical F, model is acceptable and accurate. The value of Fcrit is taken from statistical table. For, F (0.05, 2, 24), Fcrit value is 3.40. Larger value of F for parameter indicated that it has significant effect on the response. Percentage contribution of individual parameter can be calculated by dividing F value of each term by total sum of the F value of the all parameter. P value is the probability value. Smaller value of the P value indicates that the parameters has influence on the response. R^2 measures percentage of the variation of response, as per regression equation. For better assessment of regression equation to fit the trial data, R^2should be closer to one. The higher value of R^2 means the model fits data the better. Adjusted R^2 accounts for the number of predictors in model and is useful for comparing models with different numbers of predictors. Predicted R^2, indicates how well the model predicts responses for new observations. Larger values of predicted R^2 suggest models of greater predictive ability. (Satish Chinchanikar et al., 2014)

3.2 Competency of Developed Model

Using Minitab-17, the competency of the developed regression equations were verified by analysis of variance (ANOVA).R-squared is a correlation coefficient squared-measure the variations in the experimental results. The R squared values close to 100% indicate that the model is significant .i.e. experimental model provides an excellent relationship between factor and response. In this study the depth of cut, feed and cutting speed are the factors. Surface roughness is the responses. ANOVA results for each cutting conditions are shown in table.2.It can be seen that R-squared values for all the developed equations are approaching to one. Adjusted and predicted values are in reasonable agreement. The model F-values obtained for the all the equations indicates that the model is significant. Table 3 shows the percentage contribution of the individual parameter on surface roughness.

Table 2. ANOVA Result for Surface Roughness (Ra)

Factor/cutting conditions	Dry Cutting	Flood Cutting	Blaso Cut	Soyabean Oil	Sunflower Oil	Coconut Oil	Groundnut Oil
R^2 (%)	97.8	99	98.8	98.1	99.1	99.1	98.3
Adj. R^2 (%)	96.7	98.4	98.3	97.1	98.7	98.6	97.5
Pre.R^2 (%)	94.1	97.1	96.6	95.3	98.1	97.6	96.1
Model F-Value	86.1	187.7	167.5	99.9	230.8	211.4	114.6

Table 3. ANOVA Result for Contribution (%) of different parameter on surface roughness

Parameter /condition	Dry Cutting	Flood Cutting	Blaso Cut	Soyabean Oil	Sunflower Oil	Coconut Oil	Groundnut Oil
v	4.1	**65.4**	**57.9**	**39.7**	**21.9**	**60.1**	**42.4**
f	**82.2**	13.3	25.1	**38.9**	**32.0**	**25.2**	**43.7**
d	9.0	0.8	3.7	4.4	**30.3**	3.1	5.0
v*v	0.1	19.0	13.1	16.3	3.5	11.4	8.6
f*f	2.0	0.0	0.0	0.2	12.0	0.0	0.1
d*d	0.5	0.0	0.0	0.0	0.0	0.0	0.0
v*f	1.9	1.4	0.0	0.4	0.3	0.0	0.2
v*d	0.1	0.0	0.1	0.1	0.0	0.1	0.0
f*d	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total	100	100	100	100	100	100	100

Table 3 shows for different cutting fluid, the influencing factor is different. For dry cutting, feed (almost 82% contribution) is the most influencing factor. As there is no cutting fluid used during dry cutting, feed and depth of the cut affects the surface roughness remarkably. Increasing feed increases temperature and thus worsen the product quality. Surface roughness during flood cutting is mainly affected by velocity. As velocity increases frictional resistance decreases, this results into decreased roughness values while feed is most contributing factor for Blasocut. When soyabean is used as coolant surface roughness is affected by velocity and feed. The contribution of velocity and feed is approximately equal. When sunflower is used as a cutting fluid, surface roughness is influenced by feed rate and depth of cut. Sunflower oil and soyabean oil are vegetable oil with tri glyceride00 chain. This results into less frictional force as well less cutting forces. Heat generated at tool-work piece interface is less. Increasing feed rate and depth of cut affects the surface roughness values.

4.0 RESULTS AND DISCUSSIONS

Surface finish is a key factor of machinability because it affects the performance and service life of the machined component. Variation of surface roughness with respect to different cutting condition is shown in figure 2.Points 1 to 27 in the figure represents the observation number of experiment. Observation 1 to 9 indicates observation at speed 34.27 m/min. Observation while observation 10 to 18 shows cutting forces at 53 m/min. 19 to 27 observation numbers are at speed 79.27 m/min. The blue line and orange line corresponds to dry cutting and flood cutting as shown in figure 2. Both the lines are along outward side of the circle. Surface roughness decreases as speed decreases.

The lubricating action of the dipolar molecure of soyabean oil reduces the frictional force. This decreases the temperature and results in the lesser tool wear, thus resulting in surface quality improvement.Machining with soyabean oil shows 4% ,8% and 15% less roughness values as comapred to sunflower oil, ground nut oil and cocnout oil respectively

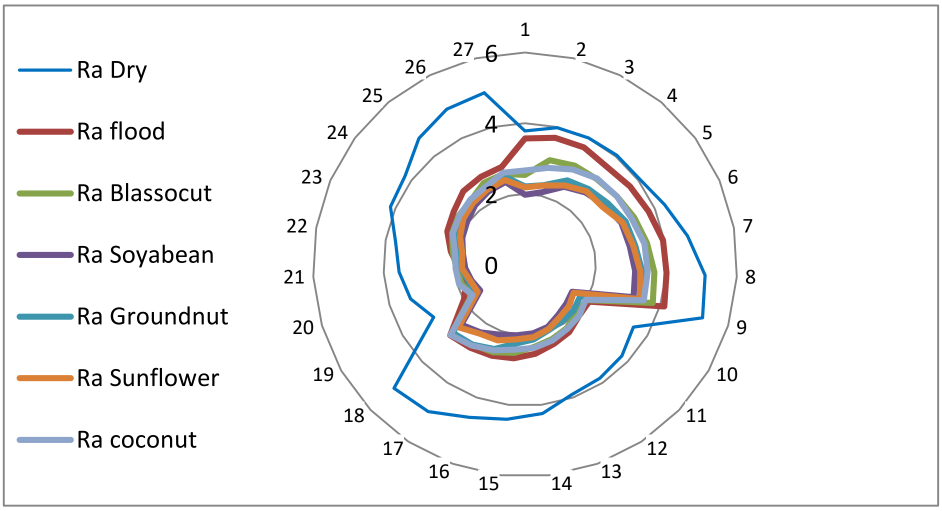

Figure 2. Surface roughness variation of at different cutting condition.

Surface roughness is more for dry cutting; flood cutting is more as compared to MQL cutting. There is average 8%, and 38% decrease in surface roughness in MQL cutting as compared to flood cutting and dry cutting respectively. It is noticed from figure 2 that there is drastic decrease in roughness value when speed is changed from 53 m/min to 79.72 m/min. When vegetable oils are used as cutting fluid with MQL,the sufrace roughness values are greatly reduced.MQL machining with soyabean oil shows average 16 % decrease in surface roughness value.This is due to less cutitng forces in case of soyabean oil

5.0 OPTIMIZATION AND CONFIRMATION EXPERIMENT

Response optimizer is used to find the optimum value. The goal decided is to minimize the surface roughness value. The optimum cutting speed is in between 50-60 m/min. The depth of cut and feed are 0.5 mm and 0.35 mm/rev respectively.

Desirability analysis carried out. Optimized model showed more than 90% level for all cutting conditions. This shows that optimized values are feasible.

The aim of the confirmation test is to validate inferences drawn during the analysis phase. Once the optimum level of the process parameters is selected, the final step is to predict and verify the improvement of the performance characteristics using the optimum level of the process parameters. In order to validate the results obtained from response optimizer, confirmation experiment were conducted at optimum values of the process parameter determined. Experimental results and optimum values are in good agreement with error within permissible limit as shown in table 4

Table 4. Optimum cutting condition and desirability

Condition	V(m/min)	f(mm)	dp(mm)	Ra pred.	Ra Expt	Desirability
Dry Cutting	52.6377	0.35	0.5	3.49442	3.54	0.9078
Flood Cutting	61.8215	0.35	0.5	1.82166	1.62	0.9235
Blaso Cut	58.6072	0.35	0.5	1.74043	1.75	0.9348
Soyabean Oil	50.8009	0.35	0.5	1.45677	1.57	0.9540
Sunflower Oil	52.1785	0.35	0.5	1.54195	1.64	0.943
Coconut Oil	60.9031	0.35	0.5	1.76844	1.87	0.9315
Groundnut Oil	57.2296	0.35	0.5	1.59412	1.72	0.9382

6.0 CONCLUSIONS

Based on the results of the experiments and analyses carried out the following general Conclusions are drawn:

- There is extensive difference in surface roughness produced by dry, flood and MQL cutting conditions. There is an average 8% reduction in roughness values for MQL as compared to flood cutting
- MQL technique is substitute for dry and flood cutting not only in terms of performance but also in terms of it is cost effectiveness and environment friendliness.
- Result shows that sunflower oil, groundnut oil ,blasocut and coconut oil have surface roughness values,4%,8%,15% and 16% more that of soyabean oil respectively
- Mathematical models are developed to validate the experimental data. ANOVA test carried out to check the adequacy of the model. Mathematical models developed for all parameters are accurate and acceptable.

- Multi-response optimization is carried out to get optimal values. The optimum value of depth of cut is 0.5mm, feed rate is 0.35mm /rev and speed value is between 50-60 m/min, which gives minimum surface roughness values. Desirability analysis indicates that the optimization process is feasible.
- Speed is most substantial factor while predicting surface roughness values.

REFERENCES

Heisel, U. & Lutz, M. (1994). Application of minimum quantity cooling lubrication technology in cutting processes. *Prod. Eng,*. II (1), 49-54.

Nilesh, G. & Mahalle, A.M. (2016). Comparative study of different vegetable oil during turning in terms of cutting force and power consumption. *Journal of Biological Science, 2* (5), 91-94.

Nilesh, G. & Mahalle, A.M. (2016). Performance evaluation of vegetable oil using MQL during turning of AISI 4130 in terms of temperature and surface roughness. *International journal of Engineering Science and computing (IJESC), 6* (5), 5879-5781,

Nilesh, G. & Mahalle, A.M (2016). Experimental investigation on the performance of soyabean oil and blasocut-4000 during turning of AISI 4130 in terms of cutting forces. *International Journal of Scientific Research in Science, Engineering and Technology (IJSRSET), 2*(3), 330-333,

Satish, C. & Salve, A.V., Netake, P., More, A., Kendre, S. & Kumar, R. (2014). Evaluation of surface roughness during hard turning under dry and with water based and vegetable based fluids. *Procedia Material Science*, *5,* 1966-1975,

Sokovic, M. & Mijanovic, K. (2001). Ecological aspects of the cutting fluids and its influence on the quantifiable parameters of the cutting processes. *Journal of Materials Processing Technology, 109*, 181-189.

U.S. Department of Health and Human Services, January 1998, Occupational Exposure to Metalworking Fluids". *NIOSH Publication,* 98-102.