

Experimental Investigation of Non-Edible Vegetable Based Cutting Fluid in Metal Cutting Process

M.Nizamuddin¹, S.M.Agrawal²P.G. Student, Department of Mechanical Engineering, DIEMS, Aurangabad, Maharashtra, India¹Assistant Professor, Department of Mechanical Engineering, DIEMS, Aurangabad, Maharashtra, India²

ABSTRACT: The Petroleum derived cutting fluids are used across the world. It causes the environmental pollution viz. water contamination, air and soil pollution due to low biodegradability and also affects the health adversely. Vegetable based cutting fluids are less toxic, high biodegradability and environmental friendly. The objective of work is to introduce Karanja oil in water based cutting fluid in turning operation using EN8 steel. Further attempt has been made to identify the influence of karanja oil in water based cutting fluid on thrust force, feed force, radial force. The performance of developed cutting fluid is also compared conventional cutting fluid. The result shows that karanja oil in water based cutting fluid lower thrust force and radial force by 21% and 15% respectively. There is no improvement observed in feed force when using developed cutting fluid.

KEYWORDS: Karanja oil in water based cutting fluid (KOWCF), Conventional cutting fluid (CCF), EN8 steel, Toxic.

I. INTRODUCTION

The use of lubricants in metal cutting operations is relatively recent as compared to the use of fats to grease chariot wheels to date back to the times of the ancient Egyptians. The widespread use of cutting fluids coincided with the industrial revolution in the late Eighteenth century. Mineral oils were being extensively used as cutting fluids in the machining area by the mid-nineteenth century [6]. Mineral-based oils are non-renewable, whereas vegetable oils are renewable. Lubricant formulations are also denoted as bio-based, biodegradable, or environmentally acceptable to express a certain degree of eco-sustainability. Emulsifiers have the function of dispersing the oil in water in order to make a stable oil-in-water emulsion. The thermal conductivity, kinematic viscosity and pH increased with an increase in the content of emulsifier whereas flash and fire points decreased with an increase in the amount of emulsifier [25].

The increased demand for petroleum derived cutting fluid as well as their resulting environmental concerns provides the incentives for the development of alternate cutting fluid from renewable resources. Now days cutting fluids used in machining area contain environmentally harmful chemical substances [17]. These chemicals have a negative effect on the environment and human health as well. And most of the cutting fluids used in machining are petroleum-based cutting fluids causes water contamination, air and soil pollutions. Cutting fluid derived from animal fat and vegetable oils can be used as the environmental conscious cutting fluid. Karanja is a non-edible oil seed grown throughout India is presently being underutilized [25].

In this paper, new Karanja oil in water based cutting fluid is introduced in turning EN8 steel due to it's renewable, vegetable based, biodegradable, environmentally friendly. The Workpiece material is having high strength, high wear resistance and high hardness experimentally investigate cutting forces which is thrust force, feed force and radial force under flood condition by using response surface methodology.

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II. LITERATURE REVIEW

Reddy et al. (2016) demonstrate the effect of solid lubricant assisted minimum quantity lubrication (MQL) turning of Inconel 718 on the finish quality of the machined surface. Results show that, the surface quality of machined work material during WS2 solid lubricant assisted MQL machining showed a much improvement on the finish quality of work material by on average about 35% when compared to MQL machining alone [1]. Talib and Rahim (2015) evaluate the performance of chemically modified jatropha oil-based trimethyl propane (TMP) ester from crude jatropha oil (CJO) as bio-based cutting fluids [2]. Mohamed et al. (2015) evaluate the performance of MQL using castor oil as cutting fluid. The workpiece is hardened stainless steel with 48 HRC [3]. Khalil et al. (2015) in his work investigates the effect of Al₂O₃ nano lubricant with surfactant Sodium Dodecylbenzene Sulfonate (SDBS) on tool wear during turning the process of AISI 1050. The results exhibit positive influence of Al₂O₃ nano lubricant with surfactant in alleviating tool wear during turning operations [4].

III. EXPERIMENTAL DETAILS

The performance of karanja oil in water based cutting fluid and conventional cutting fluid in water (Servo cut S) on Turning En8 steel is carried out on CNC lathe (Model: Simple turn 5075, Ace micromatic, Simens 802C controller) as shown in Photo No. 1. The experiment was carried out by using five cutting speed, feed, depth of cut. The selected cutting speeds(V) were 100, 125, 150, 175, 200 m/min, selected feeds(f) were 0.1, 0.15, 0.2, 0.25, 0.3 mm/rev and selected depth of cuts(d) were 0.5, 0.75, 1, 1.25, 1.5 mm. The two workpiece of 625mm length and 40mm diameter is used for two different type of cutting fluid with a flow rate of 76 ml/sec. PVD (TiN/TiAlN) coated carbide inserts having four cutting edges designated as SNMG 120408 is used. For every experimental run a new cutting edge was used. Suitable tool holder - PCNLR 2525M 12 was used to conduct the experiment. Before carrying out actual experiment some rough turning pass is made in order to completely remove surface irregularities and oxidized layer. Initially turning operation is done by using conventional cutting fluid and afterward with karanja oil in water based cutting fluid. The thrust force, feed force and radial force is measured using Lathe tool dynamometer (Model: Kistler Dynamometer 9257 BA Control unit 5233A1). The complete experimental setup of CNC lathe with Lathe tool dynamometer and supply cutting fluid arrangement is shown in Photo No.1.

To prepare the cutting fluid karanja oil (non-edible vegetable oil) with Tween 80 emulsifier mix in water. The oil to water percentage ratio is 5:95 means 5% oil is mixed with 95% of water as shown in Photo No. 2. The properties of cutting fluids are checked. The density, viscosity at 40^oC, flash point and ph of karanja oil in water based cutting fluid is 0.943gm/cm³, 1.73 cSt, 262^oC and 7.43 respectively. Similarly, The density, viscosity at 40^oC, flash point and ph of conventional cutting fluid (Servo cut S) is 0.88gm/cm³, 1.289 cSt, 234^oC and 8.1 respectively.



Photo No.1 Experimental Setup



Photo No.2 Karanja oil in water based cutting fluid

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Turning experiment was performed varying the cutting speed, feed and depth of cut as mention above. The cutting force is measured during each operation. Regression equations for a component of cutting forces were developed based on experimental data. The values of the coefficients involved in equations were calculated by using stat-ease design expert software. Equations developed for component of cutting forces using conventional and karanja oil in water based cutting fluid in terms of actual factors are given below:

For Conventional cutting fluid:

$$\text{Thrust Force (Ft)} = 4680.15 - 42.2031 * V + 790.3739 * f - 263.755 * d - 14.715 * V * f + 0.1962 * V * d + 490.5 * f * d + 0.113618 * V^2 + 4369.909 * f^2 + 135.5564 * d^2 \quad (1)$$

$$\text{Feed Force (Ff)} = 211.4749 - 0.2053 * V + 105.517 * f + 14.13341 * d - 0.753 * V * f - 0.079 * V * d - 13.7 * f * d + 0.000545 * V^2 + 90.36364 * f^2 + 0.914545 * d^2 \quad (2)$$

$$\text{Radial Force (Fr)} = 1224.776 - 12.894 * V + 2810.164 * f + 27.97634 * d - 10.791 * V * f + 0.981 * V * d - 98.1 * f * d + 0.03456 * V^2 - 2151.07 * f^2 - 89.1818 * d^2 \quad (3)$$

For Karanja oil in water based cutting fluid:

$$\text{Thrust Force (Ft)} = 461.9797 - 1.8435 * V + 767.0528 * f - 18.2644 * d - 16.3238 * V * f - 0.12557 * V * d + 1828.584 * f * d + 0.012921 * V^2 + 3230.165 * f^2 + 31.10662 * d^2 \quad (4)$$

$$\text{Feed Force (Ff)} = 257.6852 - 0.60293 * V + 31.64091 * f + 6.513182 * d - 0.668 * V * f - 0.0224 * V * d - 0.2 * f * d + 0.001431 * V^2 + 191.2727 * f^2 - 0.96909 * d^2 \quad (5)$$

$$\text{Radial Force (Fr)} = 2822.949 - 21.0298 * V - 6162.23 * f - 48.9185 * d + 19.35513 * V * f + 0.2099 * V * d - 26.487 * f * d + 0.04414 * V^2 + 5364.732 * f^2 + 18.3892 * d^2 \quad (6)$$

The adequacies of the developed equations were checked by Analysis of Variance (ANOVA) technique. R-Squared (R^2) is a correlation coefficient, which measures variation proportion in data points, ranging from -1 to +1. The values of R close to +1 indicate that equation is significant. On the other hand, the Adjusted R-Squared which is a measure of the amount of variation about the mean and the Predicted R-Squared which is a measure of how good the model predicts response value should be within about 0.20 of each other. Otherwise, there may be a problem with either the data or the model. Adequate precision or a signal-to-noise ratio value which is a measure of the range in predicted response about its associated error should be 4 or more. ANOVA results for a component of cutting forces models are depicted in Table 1. It can be seen that the values of R-Squared for all developed equations (Eqns. (1) to (6)) are close to 1 and Adjusted and predicted R-Squared values are in reasonable agreement. Adequate precision values are more than 4; therefore the equations obtained are significant. The model F-value obtained for all the equations also implies that the model is significant as shown in Table No. 1.

Factors	Conventional cutting fluid			Karanja oil in water based cutting fluid		
	Ft	Ff	Fr	Ft	Ff	Fr
R-Squared	0.9643	0.9708	0.9568	0.9730	0.9697	0.9622
Adj. R-Squared	0.9493	0.9535	0.9359	0.9578	0.9515	0.9552
Pred. R-Squared	0.8609	0.8522	0.8356	0.8683	0.8378	0.8467
Adeq. Precision	55.5032	31.4636	27.04	53.0744	30.63047	41.7723
Model F-value	196.73	56.7726	46.758	64.5986	53.7688	142.293

Table No. 1 ANOVA result for component of cutting forces

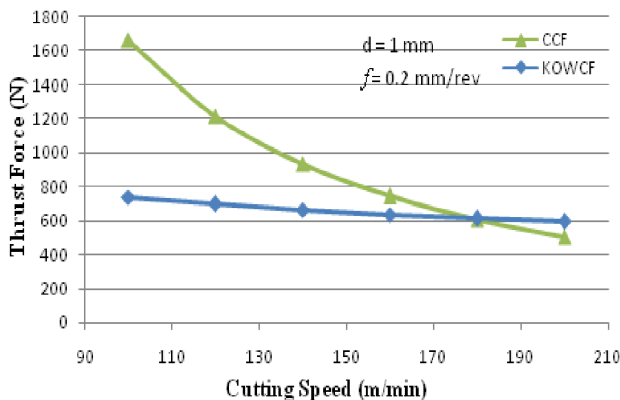
If the values of 'Prob > F' is less than significant level then it indicates that the model is significant. The significant level for a given hypothesis test is a value for which a p-value less than or equal to significant level is considered statistically significant (Montgomery, 2001). In the present study, the significant level was taken as 0.05. Values greater than 0.05 indicate that the model terms are not significant. ANOVA results for F-values of a component of cutting forces are shown in Table No. 2. The factors which were having a significant effect on cutting forces are shown by underlining the F-value. However, some of the element in interaction effects and having a significant effect on a component of Cutting forces. The element in interaction effect with their higher order provided secondary contributions to different responses, their contribution can be seen less prominent as depicted in Table No. 2.

Elements	Conventional cutting fluid (F-values)			Karanja oil in water based cutting (fluid F-values)		
	Ft	Ff	Fr	Ft	Ff	Fr
V	<u>1540.31</u>	<u>494.9794</u>	<u>365.475</u>	<u>182.2578</u>	<u>469.1127</u>	<u>815.174</u>
f	<u>35.23296</u>	<u>6.061408</u>	<u>5.786</u>	<u>40.5544</u>	<u>1.037448</u>	<u>308.139</u>
d	<u>23.74242</u>	<u>1.266579</u>	<u>1.392</u>	<u>36.0506</u>	<u>0.596182</u>	<u>1.172</u>
V f	<u>3.53193</u>	<u>4.765489</u>	<u>3.879</u>	<u>7.327953</u>	<u>2.408606</u>	<u>27.779</u>
V d	<u>0.015697</u>	<u>1.311329</u>	<u>0.801</u>	<u>0.01084</u>	<u>0.067709</u>	<u>0.082</u>
F d	<u>0.392437</u>	<u>0.157746</u>	<u>0.032</u>	<u>9.195341</u>	<u>2.160987</u>	<u>0.005</u>
V ²	<u>15.4427</u>	<u>1.964714</u>	<u>31.261</u>	<u>3.607216</u>	<u>8.685841</u>	<u>113.514</u>
f ²	<u>3.915804</u>	<u>0.862759</u>	<u>1.938</u>	<u>3.607216</u>	<u>2.482582</u>	<u>26.829</u>
d ²	<u>2.355028</u>	<u>0.055232</u>	<u>2.082</u>	<u>0.209078</u>	<u>0.03983</u>	<u>0.197</u>

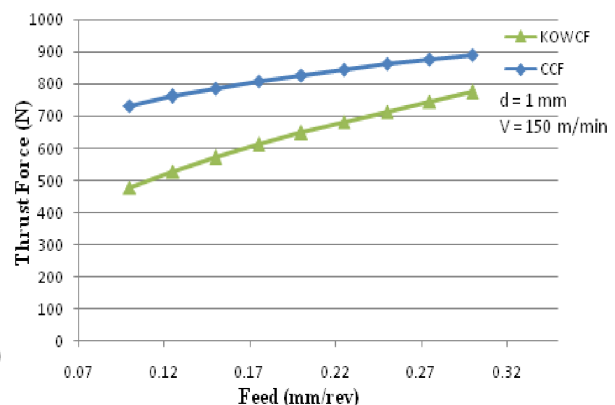
Table No. 2 ANOVA results for F-values of different parameters on components of cutting forces

Effect of cutting parameters on surface roughness

The curves showing the component of cutting forces are plotted by varying one of the input parameters and keeping the other parameters constant. Graph No. 1 depicts the variation of thrust force with cutting speed, plotted using feed value of 0.2 mm/rev and depth of cut of 1mm, obtained under both conventional and karanja oil in water based cutting fluids. It can be seen that the thrust force produced is higher when using conventional cutting fluid and lower when using karanja oil in water based cutting fluid. At one point the both cutting fluids have same effect on thrust force.



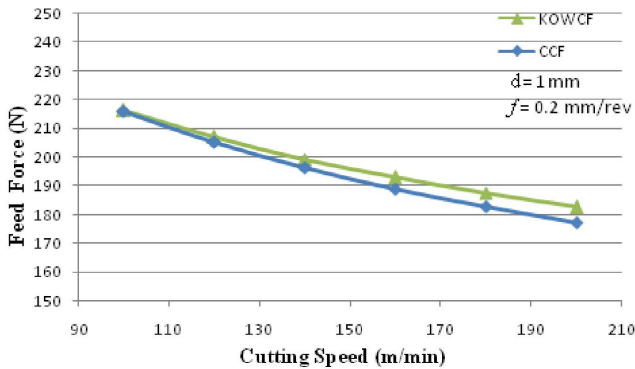
Graph No. 1 Effect of cutting speed on Thrust force



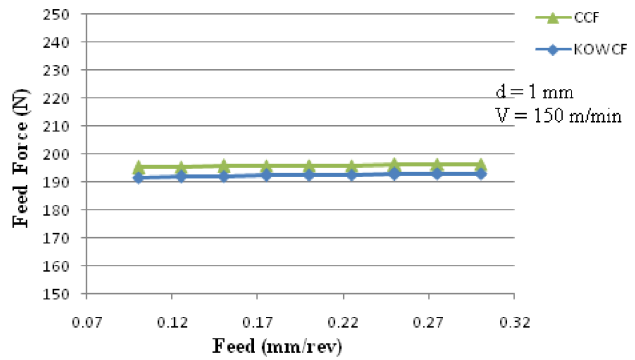
Graph No. 2 Effect of cutting speed on Thrust force

Variation of Thrust force with respect to feed as shown in Graph No. 2. It can be seen that thrust force produced is lower when using karanja oil in water based cutting fluid and higher when using conventional cutting fluid. Effect of cutting speed on feed force at a constant depth of cut 1 mm and varying feed rate shown in above. It can be seen that at all the levels feed the thrust forces decreases with the increase in cutting speed. This is because of the fact that with an increase in cutting speed shear plane energy and frictional energy increases, therefore, the temperature at the shear plane increases and the material becomes softer. Effect of varying feed on thrust force at a constant cutting speed of 150 m/min and different depth of cut as shown in Graph No 2. It can be seen that at all level of depth of cut the components of thrust forces increases with the increase in feed. This is because of the fact that with an increase in feed shear plane area of the chip increases and forces required for cutting increases.

Graph No. 3 depicts the variation of feed force with cutting speed, plotted using feed value of 0.2 mm/rev and depth of cut of 1mm, obtained under both conventional and karanja oil in water based cutting fluids. It can be seen that the feed force produced is lower when using conventional cutting fluid and higher when using karanja oil in water based cutting fluid. Considering all the parameters it can be seen that the both cutting fluids have the same effect on feed force. . Effect of varying feed on feed force at a constant cutting speed of 150 m/min and different depth of cut as shown in Graph No. 4. This is because of the fact that with an increase in feed shear plane area of the chip increases and forces required for cutting increases.

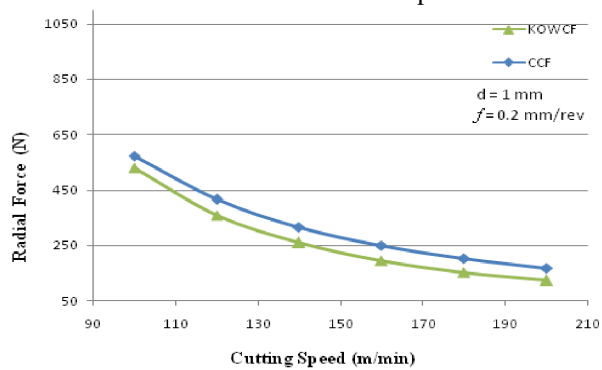


Graph No. 3 Effect of cutting speed on Feed force

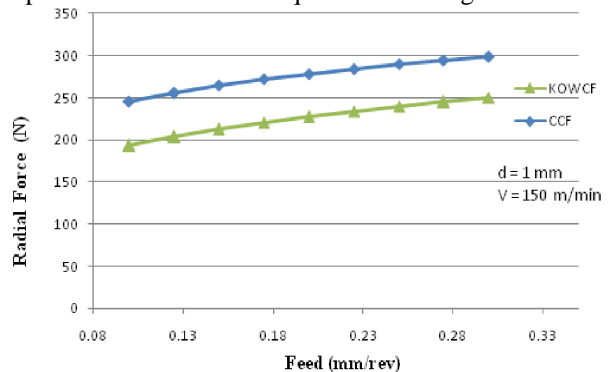


Graph No. 4 Effect of cutting speed on Feed force

Similarly, Graph No. 5 depicts the variation of radial force with cutting speed, plotted using feed value of 0.2 mm/rev and depth of cut of 1mm, obtained under both conventional and karanja oil in water based cutting fluids. It can be seen that the radial force produced is higher when using conventional cutting fluid and lower when using karanja oil in water based cutting fluid. It can be seen that turning with karanja oil in water based cutting fluid produces lower Radial force as compared to conventional cutting fluid. Lower Radial force is desirable. Effect of varying feed on radial force at a constant cutting speed of 150 m/min and different depth of cut as shown in Graph No. 6. . This is because of the fact that with an increase in feed shear plane area of the chip increases and forces required for cutting increases.



Graph No. 5 Effect of cutting speed on Radial force



Graph No. 6 Effect of cutting speed on Radial force

The cutting conditions were optimized to obtain the minimum value of a component of cutting forces using in built module of Design Expert software. The ranges of cutting parameters were selected as depicted in Table No. 3. Optimum cutting conditions found for minimum component of cutting forces using conventional cutting fluid and karanja oil in water based cutting fluid are given below in Table No. 3:

Different fluids	Cutting	V (m/min)	f (mm/rev)	d (mm)	Ft (N)	Ff (N)	Fr (N)	Desirability
	CCF	174.3	0.19	1.5	697.16	49.50	196.1	0.9836
	KOWCF	169.2	0.2	1.07	640.02	74.82	163.9	0.9657

Table No. 3 Optimum cutting condition for minimum component of cutting forces during turning EN8 steel

3-D response surfaces showing interaction effect

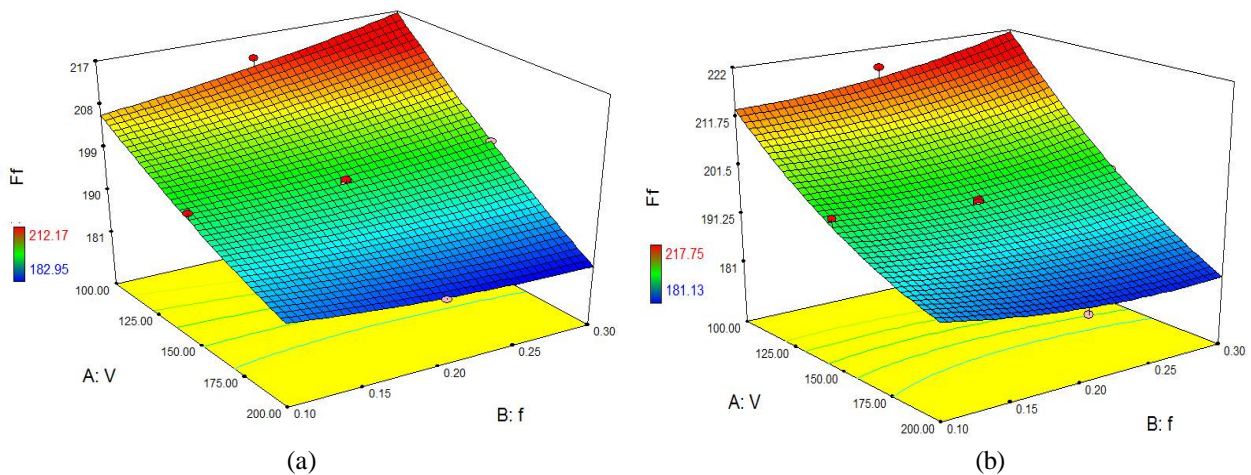
In order to have clear understanding of the effect of a given input parameter on thrust force using conventional cutting fluid (CCF) and karanja oil in water based cutting fluid 3D response surfaces are plotted with varying two input parameters and considering value of one of the input parameter at center point as shown in Graph No. 7 and Graph

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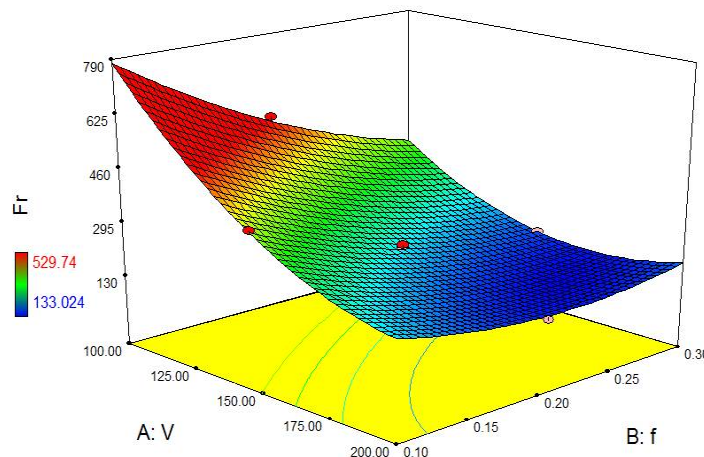
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No.8. Response surfaces of a component of cutting force for KOWCF are plotted using the developed model of thrust force. Graph No. depicts the 3D response surface showing interaction of cutting speed and feed.



Graph No.7 3D response surface showing interaction of cutting speed and feed for (a) Thrust (b) Feed force

As per ANOVA Table No. 2 only karanja oil in water based cutting fluid shows the interaction effect in Graph No. 7 and Graph No. 8. The response surface of interaction between cutting speed and feed for thrust force as shown in Graph No. 7(a), for feed force as shown in Graph No. 7(b) and for radial force as shown in Graph No. 8 using KOWCF. There are no interaction effect shows by the conventional cutting fluid. It can be seen from above the component of cutting force decreases with increase in cutting speed and increases with increase in feed. It can be seen that thrust force, feed force and radial force is mostly affected by cutting speed and followed by feed with least effect of depth of cut as shown in Graph No. 7(a), Graph No. 7(b) and Graph No. 8. The Graph No. 7 and Graph No. 8 also show the combine effect cutting speed and feed on a component of cutting forces.



Graph No. 8 3D response surface showing interaction of cutting speed and feed for Radial force

V. CONCLUSION

A new class of green cutting fluid was developed using non-edible vegetable based oil (karanja oil) and emulsifier (Tween 80). The present work replaces the conventional cutting fluid with non-edible vegetable oil as an alternative. Formulated cutting fluid was tested in machining. The experiments were conducted under various parameters such as speed, feed, and depth of cut using both conventional and karanja oil in water based cutting fluid based on Response

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surface methodology. Design expert software was used for analysis of data and Based on experimental result following conclusion is made.

- a) The Thrust force is reduced by 21% when using karanja oil in water based cutting fluid as compared to conventional cutting fluid.
- b) There not much effect on feed force when using karanja oil in water based cutting fluid but produces lower feed force using conventional cutting fluid.
- c) Radial forces obtained with karanja oil in water based cutting fluid were 15% lesser than in conventional cutting fluid.
- d) Experimental tests gave good agreement between the predicted and experimental values for cutting forces.

REFERENCES

- [1] U.M. Reddy, Y.R. Maddua, R.R. Maruria, S.K.R. Narala, "Measurement and analysis of surface roughness in WS2 solid lubricant assisted minimum quantity lubrication (MQL) turning of Inconel 718", 13th Global Conference on Sustainable Manufacturing., Vol. 6, pp. 138-143, 2016.
- [2] N. Talib and E. A. Rahim, "Performance Evaluation of Chemically Modified Crude Jatropha Oil as a Bio-based Metalworking Fluids for Machining Process", 12th Global Conference on Sustainable Manufacturing, Vol. 26, pp. 346-350, 2015.
- [3] Mohamed.H, D. Kurniawan, M.Y. Noordin, "Use of Castor Oil as Cutting Fluid in Machining of Hardened Stainless Steel with Minimum Quantity of Lubricant", 12th Global Conference on Sustainable Manufacturing, Vol. 26, pp.408-411, 2015.
- [4] A.N.M Khalil, "Effect of Al₂O₃ nano lubricant with SDBS on tool wear during turning process of AISI 1050 with minimal quantity lubricant", 2nd International Materials, Industrial, and Manufacturing Engineering Conference, Indonesia, Vol. 2, pp. 130-134, 2015.
- [5] R.R. Srikant, N.V. Ramana, "Performance evaluation of vegetable emulsifier based green cutting fluid in turning of AISI 1040 steel-an initiative towards sustainable manufacturing", Journal of Cleaner Production, Vol. 15, pp. 901-917, 2015.
- [6] P.C. Priarone, M. Robiglio, L. Settineri, V. Tebaldo, "Effectiveness of minimizing cutting fluid use when turning difficult-to-cut alloys, The 22nd CIRP conference on Life Cycle Engineering", Vol. 29, pp. 341-346, 2015.
- [7] S. Debnath, M.M. Reddy, Qua Sok Yi, "Influence of cutting fluid conditions and cutting parameters on surface roughness and tool wear in turning process using Taguchi method, Journal of International Measurement", pp.143-148, 2015.
- [8] R. Padmini, P. Vamsi Krishna, G. Krishna Mohana Rao, "Effectiveness of vegetable oil based nanofluids as potential cutting fluids in turning AISI 1040 steel, Journal of Tribology International", pp. 01-44, 2015.
- [9] Mohamed.H, D. Kurniawan, M.Y. Noordin, "Tool Life of Coated Carbide Cutting Tool when Turning Hardened Stainless Steel under Minimum Quantity Lubricant using Castor Oil", 2nd International Materials, Industrial, and Manufacturing Engineering Conference, pp.563-567, 2015.
- [10] Y.Shokoohi, E.Khosrojerdi, B.h.Rassolian, "Machining and Ecological Effects of a New Developed Cutting Fluid in Combination with Different Cooling Techniques on Turning Operation", Journal of Cleaner Production, pp. 107-113, 2015.
- [11] I.H. mulyadi, V. Balogun, Dr. P.T. Mativenga, "Environmental performance evaluation of different cutting environments when milling H13 tool steel, Journal of Cleaner Production", Vol. 15, pp. 01-31, 2015.
- [12] Alberto, F. fracaro, Oliveira, "The Jatropha curcas vegetable base soluble cutting oil as a renewable source in the machining of aluminum alloy 7050-T7451", Industrial Lubrication and Tribology, pp. 181-195, 2015.
- [13] S.Chinchankar, A.V. Salve, "Comparative evaluations of surface roughness during hard turning under dry and with water based and vegetable oil based cutting fluid", International Conference on Advances in Manufacturing and Materials Engineering, pp. 1966-1975, 2014.
- [14] M.Amrita, S.A.Shariq, "Experimental investigation on application of emulsifier oil based nano cutting fluids in metal cutting process", 12th global congress on manufacturing and management, Vol. 97, pp.115-124, 2014.
- [15] A. Saini, S. Dhiman, R. Sharma and S. Setia, "Experimental estimation and optimization of process parameters under minimum quantity lubrication and dry turning of AISI-4340 with different carbide inserts", Journal of Mechanical Science and Technology, pp. 2307-2318, 2014.
- [16] M.Sayuti, Ahmed A.D. Sarhan, F.Salem, "Novel uses of SiO₂ nano-lubrication system in hard turning process of hardened steel AISI4140 for less tool wear, surface roughness and oil consumption", Journal of Cleaner Production, pp. 265-276, 2014.
- [17] D.A. Stephenson, S.J. Skerlos, A.S. King, S.D. Supekar, "Rough turning Inconel 750 with supercritical CO₂-based minimum quantity lubrication, Journal of Materials Processing Technology", pp. 673-680, 2014.
- [18] Geoff Burton, Chan-Seo Goo, Yanqiao Zhang, Martin B.G. Jun, "Use of vegetable oil in water emulsion achieved through ultrasonic atomization as cutting fluids in micro-milling", Journal of Manufacturing Processes, pp.01-09, 2014.
- [19] C. Alberto J. Fracaro, J. Gomes, J. Gheller, "Performance of the jatropha vegetable-base soluble cutting oil as a renewable source in the aluminum alloy 7050-T7451 milling", CIRP Journal of Manufacturing Science and Technology, pp.210-221, 2014.
- [20] C.Y. Chan, W.B. Lee, H. Wang, "Enhancement of surface finish using water-miscible nano-cutting fluid in ultra-precision turning, International Journal of Machine Tools & Manufacture", Vol. 73, pp. 62-73, 2013.
- [21] S.A. Lawal, I.A. Choudhury, Y. Nukman, "Evaluation of vegetable and mineral oil-in-water emulsion cutting fluids in turning AISI 4340 steel with coated carbide tools", Journal of Cleaner Production, pp. 01-09, 2013.
- [22] B. Davoodi, A.H. Tazehkandi, "Experimental investigation and optimization of cutting parameters in dry and wet machining of aluminum alloy 5083 in order to remove cutting fluid", Journal of Cleaner Production, Vol. 13, pp. 01-26, 2013.
- [23] M. Hadad, B. Sadeghi, "Minimum quantity lubrication-MQL turning of AISI 4140 steel alloy", Journal of Cleaner Production, pp. 332-343, 2013.
- [24] D.V. Lohar, C.R. Nanavaty, "Performance Evaluation of Minimum Quantity Lubrication (MQL) using CBN Tool during Hard Turning of AISI 4340 and its Comparison with Dry and Wet Turning", International Journal of Industrial Engineering and Management Science, pp. 102-106, 2013.



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(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 9, September 2016

- [25] S. Debnath, Moola Mohan Reddy, Qua Sok Yi, "Environmental friendly cutting fluids and cooling techniques in machining: A Review", *Journal of Cleaner Production, Malaysia*, pp. 01-07, 2013.
- [26] M. Winter, R. Bock, C. Herrmann, "Investigation of a new polymer-water based cutting fluid to substitute mineral oil based fluids in grinding processes", *CIRP Journal of Manufacturing Science and Technology*, pp. 248-256, 2013.
- [27] K.D Reddy, P.Venkataramaiah, "Experimental investigation on responses in turning of aluminium with carbide tipped tool at different coolant conditions", *International Journal of Mechanical Engineering and Technology*, pp. 189-199, 2012.