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Taguchi Optimization of Surface Roughness of Neem *(Azadirachta Indica*) and Tamarind *(Tamarindus Indica)* Seed Oils Cutting Fluid in Turning Operation of Mild Steel

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Abstract:- Due to environmental effects of the wide use of soluble, synthetic and semi synthetic cutting fluids and the hazard involved in the use of these class of cutting fluid, it has become necessary to find alternative cutting fluid for machining operation. The use of biodegradable oils has yielded positive result as they are environmentally friendly and causes no hazard to machinists. Taguchi DOE L_9 (3^3) orthogonal array was used in this work to design the experiment and ANOVA was used to analyze the result of formulated Neem oil and Tamarind oil Cutting fluid. The investigation comprised of Three (3) experimental groupings of nine (9) experimental run of Neem, Tamarind and Mineral cutting fluid turned mild Steels. The result clearly indicated that Tamarind seed oil had the best surface quality when used as cutting fluid and the smallest was Mineral oil-based cutting fluid. The minimum surface roughness was 3.142 for Tamarind, 3.842 for Neem and 5.46 for Mineral oil. The optimum cutting parameters for the turning of mild steel was Spindle speed of 1700 rpm, Feed rate of 0.2mm/min and Depth of cut of 0.5 mm. The investigation from the contour plot reveals thatrise in the Spindle speed decreases the surface roughness of the mild steel. The temperature measurement of the cutting zone reveals that experiment 4 had a cutting zone temperature of 36°C, Neem cutting fluid had 39°C, Mineral cutting fluid had 39°C and dry machining temperature was 49°C; Tamarind cutting oil had percentage temperature reduction for the fourth experiment run of 26.53%, Neem and Mineral cutting fluid had the same percentage temperature reduction of 20.41%. Similar pattern was noticed for experiment run 8 where Tamarind had cutting zone temperature of 31°C, Neem cutting fluid 33°C, Mineral oil had cutting zone temperature of 33°C and Dry machining cutting zone temperature was at 40°C; The percentage temperature reduction rate was 22.5% for Tamarind cutting fluid, 17.5% for Neem and mineral oil cutting fluid. The two cutting fluids from the investigation can serve as a good alternative to mineral base cutting fluid.

Keywords:- *Cutting fluid, Taguchi DOE, Surface quality, Tamarind seed oil and Neem seed oil cutting.*

I. INTRODUCTION

When cutting metals, the materials are deformed plastically under tremendous pressure and sheared from the work piece along the cutting tool rake face in the form of continuous or discontinuous chips, causing friction between them [1]. Cutting fluids penetrate into the zone of contact between the tool and the freshly formed chip to reduce friction [2]; thereby enhancing productivity of machining and quality of product by decreasing cutting forces, vibrations and overheating of cutting zone,which leads to an efficient metal cutting operation as measured in terms of improved tool life and better surface finish. The outcome of using of cutting fluid in machining is cooling the tool, work piece and chip. The use of cutting fluid facilitates formation of chip and reduction in chip compression, built up edge and tool-chip seizure [3].

The selection of ideal machining parameters leads to a longer tool life, good surface finish and a higher rate of material removal only if suitable Cutting fluid is employed. There are numerous types of cutting fluids widely applied for metal cutting processes. However, due to their negative impact on the environment, their application in machining operation have been severely limited [4]. Recent research proved that Bio based cutting fluids have the prospective of reducing the waste treatment expenses due to their inherent higher biodegradability and may reduce the risks of associated with petroleum-oil-based cutting fluids since they have lower toxicity. The output of this is a healthier and cleaner work environment, with fewmist in the air [5].

[6] investigated in to formulated Vegetable based (coconut oil) cutting fluid which is biodegradable in nature as the cutting fluid when machining Oil Hardening and Non-Shrinking (OHNS) steel. Machinability studies were carried out to ascertain the effect of input parameters which were: Cutting velocities at 80 m/min, 90 m/min and 100 m/ min; Feed rates at 0.07 mm/rev, 0.08 mm/rev and 0.09 mm/rev; and depth of cut at 0.3 mm, 0.6 mm, 0.9 mm. The three levels of compositions of the formulated cutting fluid were 10%, 20%, 30% concentrate and rest were water. The new cutting fluid's performance was compared with that of a conventional mineral oil-based cutting fluid and raw coconut oil by performing various turning experiments. The results obtained were: At 80, 90, 100 m/min of cutting velocities, the resultant output cutting temperatures was 177.46°C, 191.697°C and 201.12°C. At feed rates of 0.07,

0.08, 0.09 mm/rev provides 183.8 °C, 191.28 °C, and 195.2°C cutting temperatures respectively. The values of cutting zone temperature at different levels of depth of cut of 0.3, 0.6, 0.9 mm are 185.023°C, 188.717°C, and 196.613ºC. it was also discovered that at 80 m/min velocity, feed rate of 0.07mm/rev, 30% concentrate70% of water composition and 0.03 mm depth shows the optimal combination for cutting force when machining aOHNS steel. 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 of 0.3mm. This gives the expected output values of parameters like cutting temperature 158.833ºC. It was seen that the formulated coconut oil-based cutting fluid gave a better cutting performance of cutting zone temperature compared with the mineral oil-based cutting fluid.

[7] performed an experimental study on EN24 medium alloy steel with a CNC machine with Tin (Sn) coated tungsten carbide inserts to optimize the effect of the turning process parameters for minimum surface roughness and maximum rate of material removal using the Taguchi method and Minitab 16 statistical software. The experiment was carried out on a steel specimen of diameter of 32 mm x 220 size using five parameters for the experimentations, four at three levels and one at two levels. Results were obtained on the effects of process parameters such as cutting speed, coolant condition, feed rate, depth of cut, nose radius, on response characteristics which are material chip removal rate and surface roughness on CNC turning of EN24 alloy steel material and concluded as follows: Analysis of Variance shows that the nose radius is the major factor and cutting environment is most minor factor for both surface roughness and rate of chip removal; ANOVA (S/N Data) results shows that nose radius, depth of cut, feed rate, cutting speed and coolant condition affects the material removal rate by 40.68%, 20.96%, 20.53%, 14.88% and0.023% respectively; ANOVA (S/N Data) results shows that nose radius, feed rate, depth of cut, cutting speed and coolant condition affects the surface roughness of the workpiece by 65.38%, 25.15%, 3.06%, 1.41% and 0.09% respectively.

[8] studied the influence of cutting fluids on surface roughness and tool wear during turning operation of AISI 304 austenitic stainless steel with carbide tool using three different kinds of cutting fluids (coconut oil, emulsion and a neat cutting oil-immiscible with water). The work was based on Taguchi's design of experiment (DOE) with L27 (3)4 orthogonal array, using critical input parameters such as cutting speed, depth of cut, feed rate and cutting fluid types. A model calculation using multiple linear regression models was developed to determine the rate of tool wear and surface roughness. The results indicated that coconut oil was having greater influenced on the surface roughness and tool wear than the other cutting fluid types.

[9] determined the effect of some biological oils (groundnut oil, coconut oil, palm kernel oil and shear butter oil) on cutting forces during the turning process of three materials (mild steel, copper and aluminum) using tungsten carbide tool. They used cutting variables during turning process such as; cutting speed, feed rate and depth of cut. The spindle speeds of 250 rpm, 330 rpm, 450 rpm and550 rpm were investigated at a constant feed of 0.15 mm/rev and depth of cut of 2 mm for each of the workpiece. The results showed that bio-oils were suitable for metal working fluids but the effects of the bio-oils on cutting force were dependent on the material used.

[10] performed a study on two different vegetable based cutting fluids produced from refined Canola and Sunflower oil and a viable type semi-synthetic cutting fluid to ascertain optimum conditions for tool wear and forces during milling of AISI 304 austenitic stainless steel with carbide tool material (Iscar HM90 APKT 100304PDR IC 908). Taguchi L9 (34) orthogonal array was used for the study plan. Feed rate, depth of cut, cutting speed and types of cutting fluids were taken as parameters for machining. Mathematical models for machining parameters and cutting fluids were obtained from regression analysis to forecast values of tool wear and forces. Signal-to-noise (S/N) ratio and ANOVA analyses were also performed to obtain significant parameters affecting tool wear and forces. The multiple linear regression analysis used for the modeling conformed with the results gotten for tool wear which were between the range of 0.010 mm and 0.980 mm for cutting speed (150 mm, 175 mm and 200 mm); feed rate (0.20 mm/rev, 0.25 mm/rev and 0.30 mm/rev); depth of cut (0.2, 0.3 and 0.4 mm), for various cutting fluids used. The depth of cut was found to be of greater effect on the tool wear and forces.

This research work is on the comparative study between the response factors obtained from machining Mild steel with Vegetable oil cutting fluid as coolant; Vegetable oil formulated cutting fluid and mineral oil cutting under same machining parameters. Experiments were conducted in different lubrication conditions including, conventional cutting fluid and vegetable oils with additives. The oil used for this research are not edible and the tamarind oil used for cutting fluid is generally seen as a waste product from the food industry thus cannot be competitive as some of the edible oils reported.

II. MATERIALS AND METHODS

A. Materials

The materials used include Mineral cutting fluid, Neem seed oil and Tamarind seed oil that was obtained by solvent extraction method and formulated as reported by [11]. While equipment includes Lathe Machine by Harison Model No. M300, Surface roughness tester by Landtek Model No. SRT-6210, thermocouple and samples of A1340 mild steel shown in Plate 1 with total length of rod L_t = 10cm, larger diameter D_1 = 3.0 cm, smaller diameter D_2 = 2.5 cm and length of the step turn = 5 cm.

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Plate 1: Stepped Turned mild steel workpiece.

B. Method

The experiments were conducted by varying three parameters (Depth of cut, spindle speed and feed rate) at three levels each. A total of 27 runs of turning operation were performed. Each run comprises of 9 pieces of mild steel rod for nine runs of Neem, Tamarind and convectional cutting fluid applied turning operation based on Taguchi's L9 Orthogonal array. Three surface roughness data were collected for each 27 pieces of mild steel samples and the mean obtained for each as well. The experiments were carried out based on Response surface methodology (RSM) so as to optimize the response surface affected by various process parameters. The design parameters and their levels of the parameters in the experiment are shown in Table 1.

Table 1: Process Parameters and their Levels.

Parameter	Level 1	Level 2	Level 3
Spindle Speed (rpm)	800	1200	1700
Feed rate (mm/rev)	0.12	0.2	0.3
Depth of Cut (mm)	0.5	1.0	1.5

Table 1

III. DISCUSSION OF RESULTS

A. Taguchi design of experiment and analysis of surface roughness

The major determining factor of machining performance is the surface roughness of a given workpiece. It is important to measure this parameter after conducting the turning operation on a lathe [12]. The average surface roughness of the workpiece was measured on the workpiece. The readings were taken three times using a surface roughness tester and an average computed for each workpiece/experimental run. The values were plotted on a Taguchi L9 orthogonal matrix. surface roughness values of the cutting fluids were obtained and presented in Figure 1. The result revealed that Tamarind seed cutting oil had the best effect on the surface quality of the workpiece. Neem seed oil cutting fluid effect on the surface quality was better when compared to conventional Mineral cutting fluid. The Tamarind cutting fluid improves the surface quality (surface roughness) by as much as 3.314 Ra (µm), which was about 37.32% compared to conventional Mineral oil cutting fluid. Neem seed also yield a better result, it improved the surface quality of the workpiece as much as 3.847 Ra (µm). This value is about 27.25% when compared to best surface roughness value of conventional Mineral oil machined mild steel.

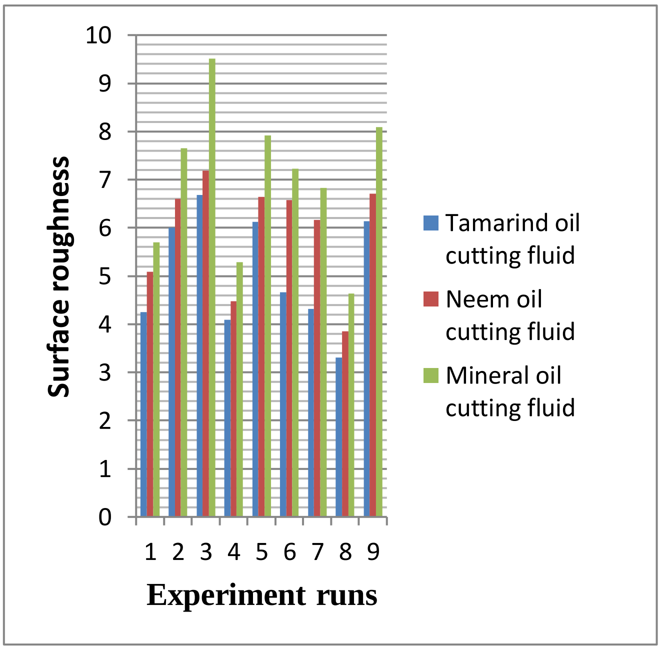

Fig. 1: A graph of surface roughness values of cutting fluids.

Experiment runs and Descriptions

- Run 1 spindle speed 800 rpm, feed rate 0.12 mm/min and depth of cut 0.5 mm.
- Run 2 spindle speed 800 rpm, feed rate 0.20 mm/min and depth of cut 1.0 mm
- Run 3 spindle speed 800 rpm, feed rate 0.30 mm/min and depth of cut 1.5 mm.
- Run 4 spindle speed 1200 rpm, feed rate 0.20 mm/min and depth of cut 1.0 mm
- Run 5 spindle speed 1200 rpm, feed rate 0.02 mm/min and depth of cut 1.5 mm
- Run 6 spindle speed 1200 rpm, feed rate 0.30 mm/min and depth of cut 0.5 mm
- Run 7 spindle speed 1700 rpm, feed rate 00.12 mm/min and depth of cut 0.5 mm
- Run 8 spindle speed 1700 rpm, feed rate 0.20 mm/min and depth of cut 0.5 mm
- Run 9 spindle speed 1700 rpm, feed rate 0.30 mm/min and depth of cut 1.0 mm

The effect of input parameters such as Depth of cut, Feed rate and Spindle speed on obtaining the minimum value of surface roughness is shown in Figure 2. The Main effect plot for mean and Surface roughness of the cutting fluids was obtained using Minitab 16 software. The Taguchi technique was used and signal to noise ratio of the smaller the better was likewise used to obtain results on the optimum Surface roughness of each cutting fluid as shown in the Figure 2. It was observed that for the three-machining condition the increase in the spindle speed decreases the value of the surface roughness. When the Depth of cut was increased the surface roughness also increases and thereby decreases the surface quality of the workpiece. From the result obtained the optimum surface roughness was obtained by tamarind seed oil-based cutting fluid at spindle speed of 1700 rpm, feed rate 0.2 mm/min and a depth of cut 0.5 mm.

B. ANOVA and mean effect plot of the cutting fluids

The analysis of variance (ANOVA) was applied to the data obtained and the design parameter. The ANOVA was used to identify the contribution of the three parameters on the surface quality of the workpiece and the interaction of the relative parameters on machining performance (Table 8, 9 and 10). The result of the Taguchi S/N Ratio was used for the ANOVA analysis and the P-Value (Significant Factor) Test. The P-Value was selected at a most significant factor of 0.05. The main effect plot of the data means showed that the best surface quality was obtained from the spindle speed of 1700 rpm, feed rate 0.2 mm/min and depth of cut 0.5 mm for the three cutting fluids. The contributions of the parameters to the values of the surface roughness were: cutting speed (36.9%), feed rate (20.4%), and depth of cut (18.0%) for Tamarind cutting fluid applied cutting condition; cutting speed (48.3%), feed (58.3%), and depth of cut (37.7%) for Neem cutting fluid applied cutting condition and cutting speed (37.3%), feed (11.9%), and depth of cut (13.3%) for Conventional Mineral cutting fluid applied cutting condition. The result obtained confirmed the works of [13]; whose results showed that Feed rate has the greatest effect on the value of surface roughness, the second is the depth of cut and the least effect on surface roughness was obtained by the Cutting speed. Then main effect plot of the of Mean and Signal to noise ratio of the cutting fluid are shown as flows;

The main effect plot of the Mean of Tamarind based cutting fluid Table 8, Neem based cutting fluid Table 9 and Mineral oil-based cutting fluid Table 10 indicate the optimum parameter which was Spindle speed 1700rpm, Feed rate 0.2 and Depth of cut 0.5. The main effect graph (Figure 2 and 8) gave the optimum surface roughness of Tamarind cutting fluid as 3.314Ra (µm), Neem seed cutting fluid of 3.847Ra (µm) (Figure 4 and 10) and Mineral oil cutting fluid of 4.640Ra (µm) (Figure 6 and 12). Graphically the relationships of the various parameters were seen in the Main effect plot of the Mean and Signal to noise ratio. It indicated the maximum effect for the three cutting fluid was observed by that of Depth of cut and Spindle speed.

C. Analysis of variance and Main effect plots of Tamarind seed cutting oil

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Spindle speed	2	1.7057	1.7057	0.8528	1.71	0.369
Feed rate	2	3.9013	3.9013	1.9507	3.91	0.204
Depth of cut	2	4.5484	4.5484	2.2742	4.55	0.180
Error	2	0.9987	0.9987	0.4994		
Total	8	11.1542				

Table 2: Tamarind oil cutting fluid Analysis of Variance for Surface roughness, using Adjusted SS for Tests

S = 0.706652 R-Sq = 91.05% R-Sq (adj) = 64.19%

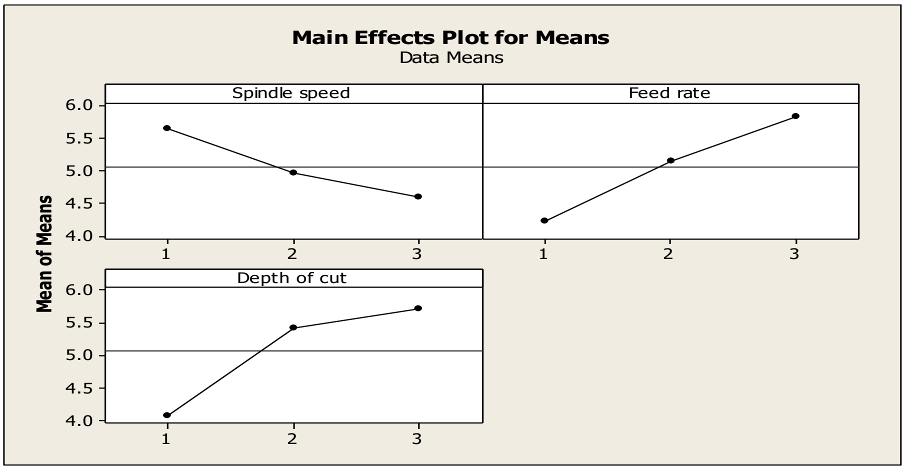

Fig. 2: Main effect plots for Mean ratio of Tamarind seed oil cutting fluid.

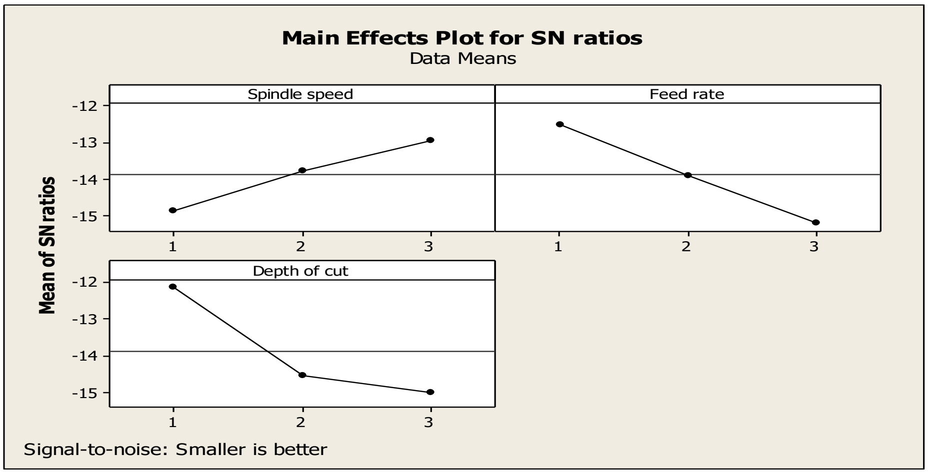

Fig. 3: Main effects plot for S/N of Tamarind seed oil cutting fluid

D. Analysis of variance and main effect plots of Neem oil-based cutting fluid

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Spindle speed	2	2.609	2.609	1.305	1.07	0.483
Feed rate	2	1.738	1.738	0.869	0.71	0.583
Depth of cut	2	4.029	4.029	2.015	1.66	0.377
Error	2	2.435	2.435	1.217		
Total	8	10.812				

Table 3: Neem oil cutting fluid Analysis of Variance for Surface roughness, using Adjusted SS for Tests

S = 1.10331 R-Sq = 77.48% R-Sq(adj) = 9.93%

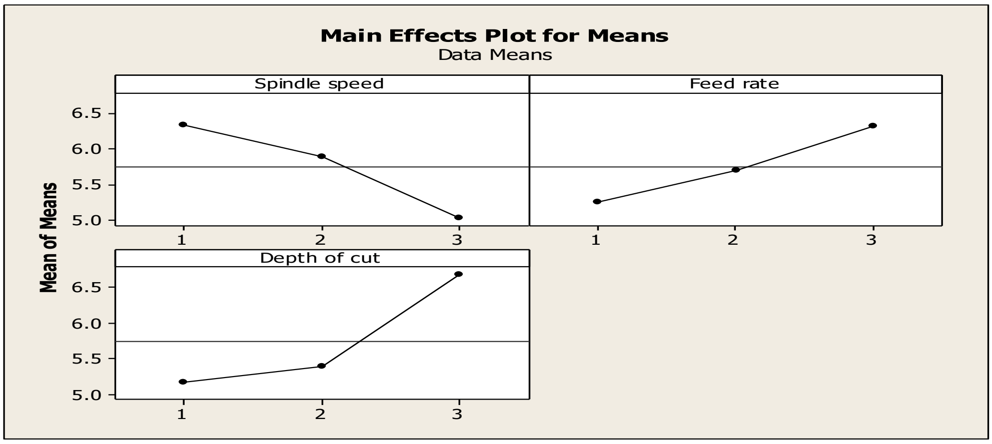

Fig. 4: Main effect plot for Mean ratio of Neem seed oil cutting fluid

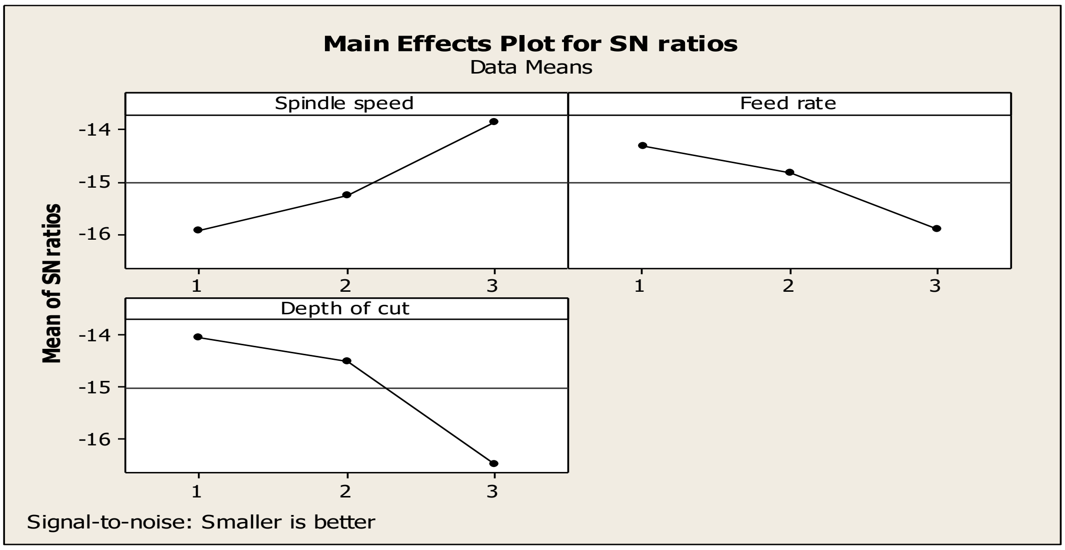

Fig. 5: Main effect plot for S/N of Neem seed oil cutting fluid

E. Analysis of variance and main effect plots of mineral oil-based cutting fluid

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Spindle speed	2	1.9283	1.9283	0.9641	1.68	0.373
Feed rate	2	8.4575	8.4575	4.2288	7.38	0.119
Depth of cut	2	7.4983	7.4983	3.7491	6.54	0.133
Error	2	1.1461	1.1461	0.5731		
Total	8	19.0302				

Table 4: Mineral oil cutting Analysis of Variance for Surface roughness, using Adjusted SS for Tests

S = 0.757002 R-Sq = 93.98% R-Sq (adj) = 75.91%

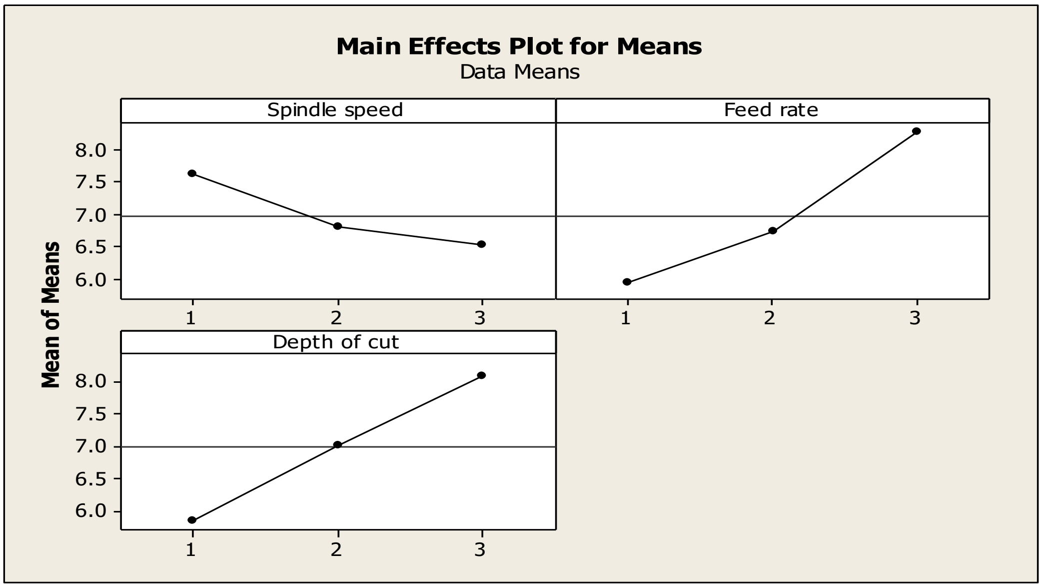

Fig. 6: Main effect plot for Mean ratios of Mineral oil-based cutting fluid.

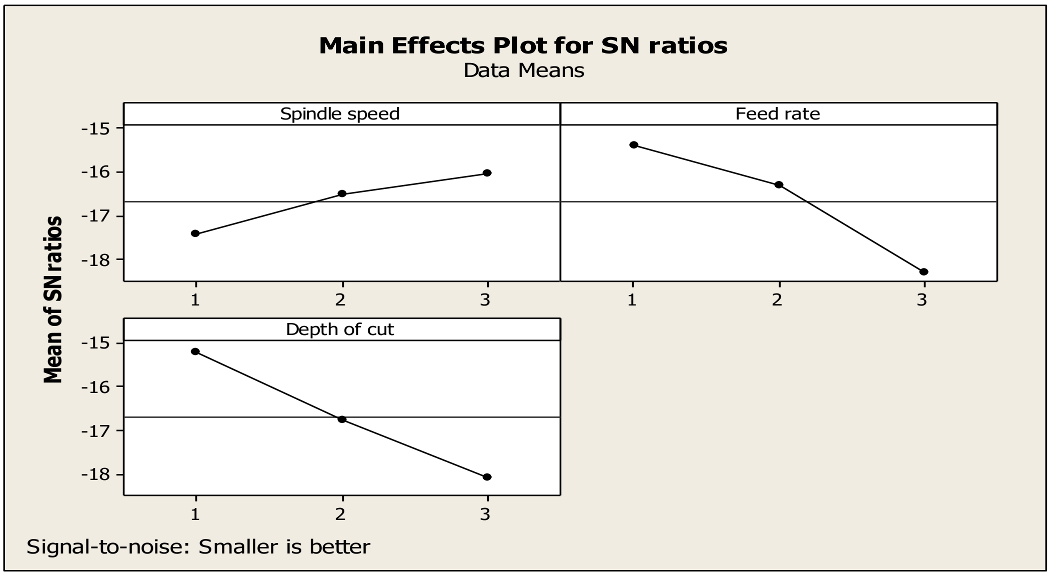

Fig. 7: Main effect plot for S/Nof Mineral oil-based cutting fluid.

F. Contour plot surface roughness of the cutting fluid

The regression analysis of the result shows that when the Spindle speed increases it effect on the Surface roughness is very little. The process parameters for the Contour plot of the surface roughness are on the y-axis and x-axis, while the surface roughness is shown as the contour on the graph of the plot (Figure 8-16).

The Spindle speed affects the surface roughness more than the Feed rate and the effect is far greater than that of the depth of cut. The Figure 10, 13 and 16 show the Contour plot of surface roughness vs Feed rate, Depth of cut of Tamarind cutting fluid, Neem cutting fluid and Mineral based cutting fluid respectively. It was observed that for higher Feed rate at Level 1, 2 and 3 Surface roughness increases. Depth of cut increases the surface roughness from lower to a higher value till level 2 and the start slightly dropping to a lower Surface Roughness value. The Figures 13, 14 are contour surface roughness values for tamarind oil cutting fluid. In the plot of surface roughness vs spindle speed, depth of cut Figure 8, the increase in spindle speed from level 1, level 2 and level 3 reduces surface roughness and an increase in depth of cut level from level 1, level 2 to 3 increases surface roughness. The combined effect of these parameters is the least on surface roughness of the mild steel. The Figures 12 and 15 are the Contour plot of surface roughness vs Spindle speed, Feed rate of Neem cutting fluid and Mineral based cutting respectively, it was observed that high spindle speed recorded a reduction of surface roughness at high level of 2 and 3 of their parameters. It could be deduced that as Spindle speed increase the surface roughness reduces and it increases with increase in Feed rate and Depth of cut, due to the greater effect of the Feed rate till it gets to a higher value at parameter level 3 for all the cutting fluids. The optimum parameter on the graph for the three cutting fluid is Spindle speed 1700 rpm, Feed rate 0.2 mm/rev and depth of cut 0.5 mm. The optimum surface roughness from the graph is 3.314 Ra (µm), 3.847 Ra (µm) and 4.640 Ra (µm) for Tamarind cutting fluid, Neem seed cutting fluid and Mineral oil cutting fluid respectively.

G. Contour plot of Surface roughness of Tamarind oil-based cutting fluid

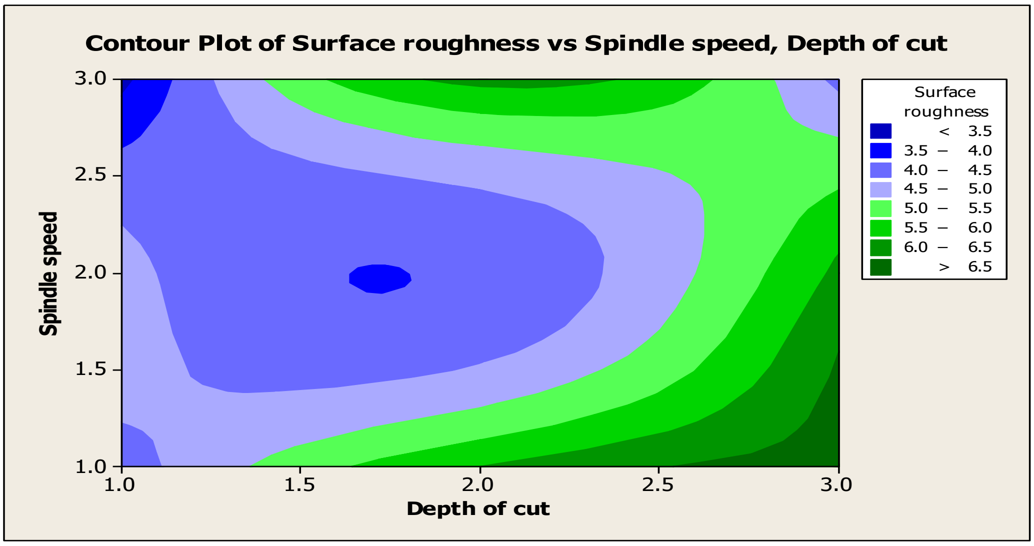

Fig. 8: Contour roughness plot of Tamarind seed oil cutting fluid surface roughness vsspindle speed, depth of cut.

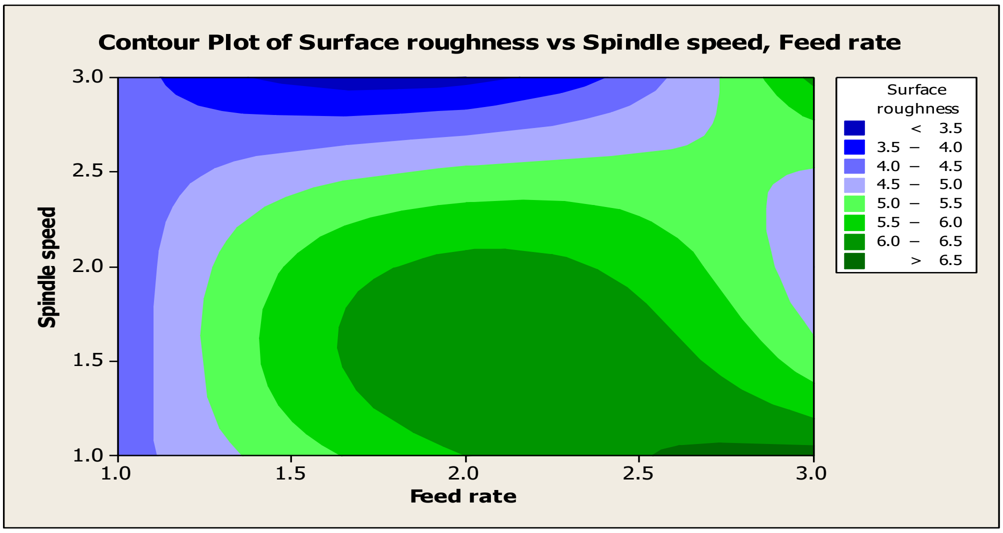

Fig. 9: Contour plot of surface roughnessvs spindle speed, feed rate of Tamarindseed oil cutting fluid.

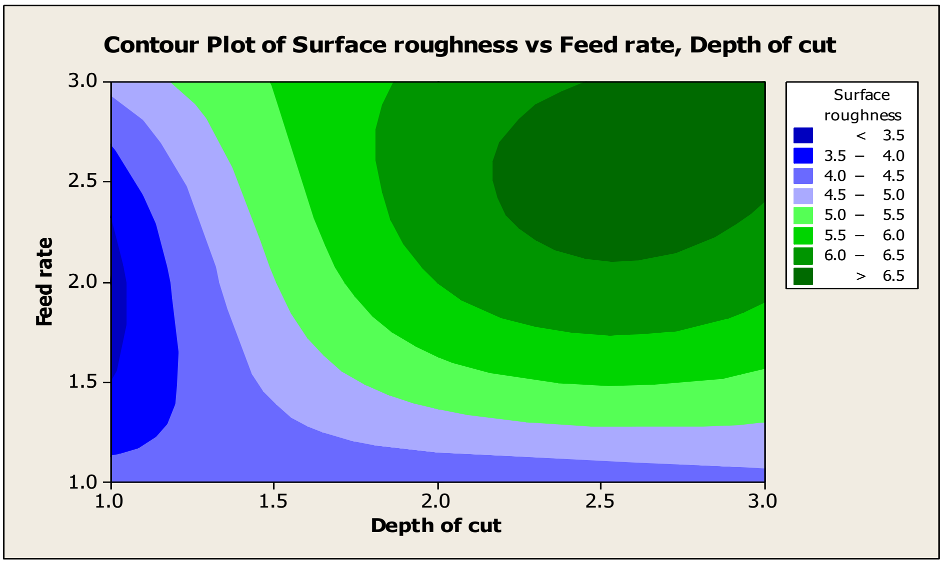

Fig. 10: Contour plot of surface roughness vs depth of cut, feed rate of Tamarind seed oil cutting fluid.

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H. Contour plot of surface roughness of Neem seed oil-based cutting fluid.

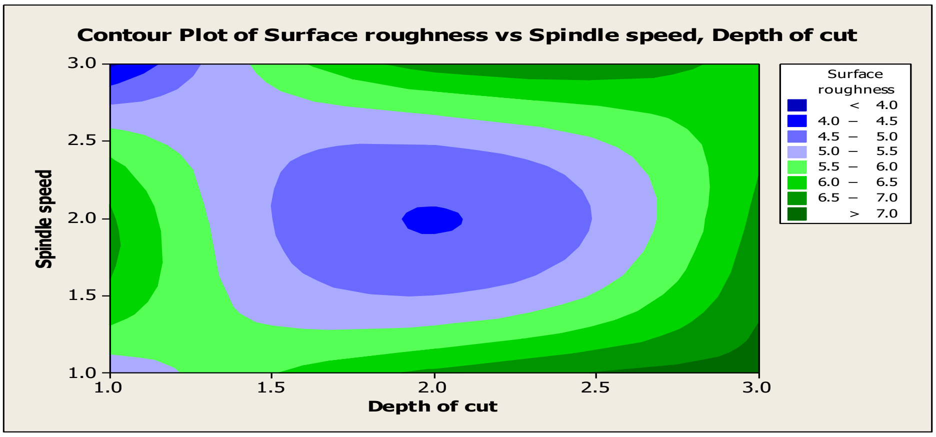

Fig. 11: Contour plot of Neem seed oil cutting fluid surface roughness vs spindlespeed, depth of cut.

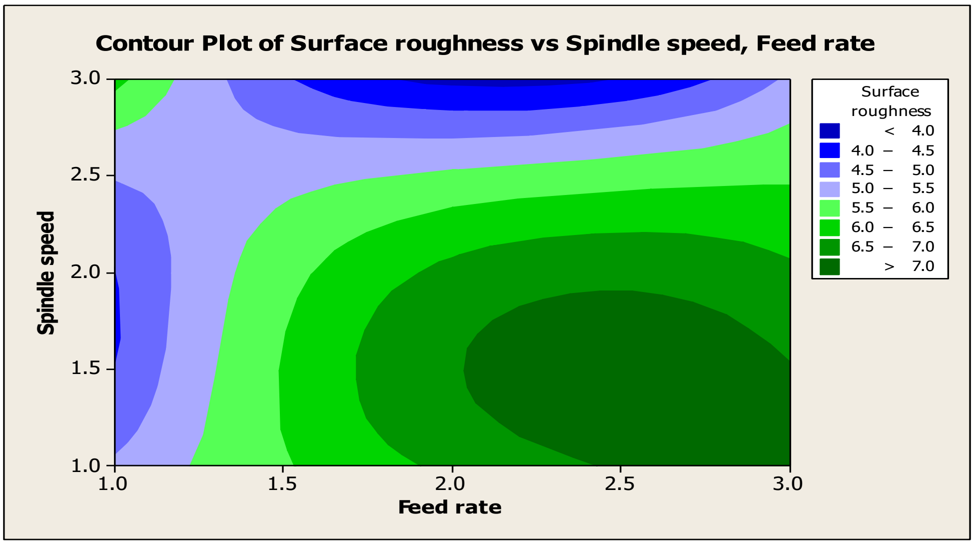

Fig. 12: Contour plot of Neem seed oil cutting fluid surface roughness vs spindlespeed, feedrate.

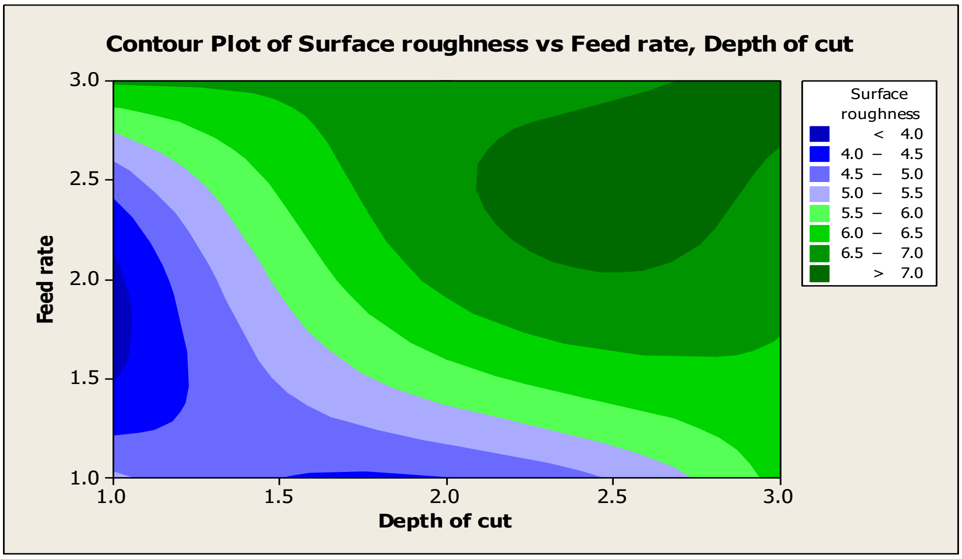

Fig. 13: Contour plot of Neem seed oil cutting fluid surface roughness vs feed rate, depth of cut.

I. Contour plot of Surface roughness of Mineral oil-based Cutting fluid

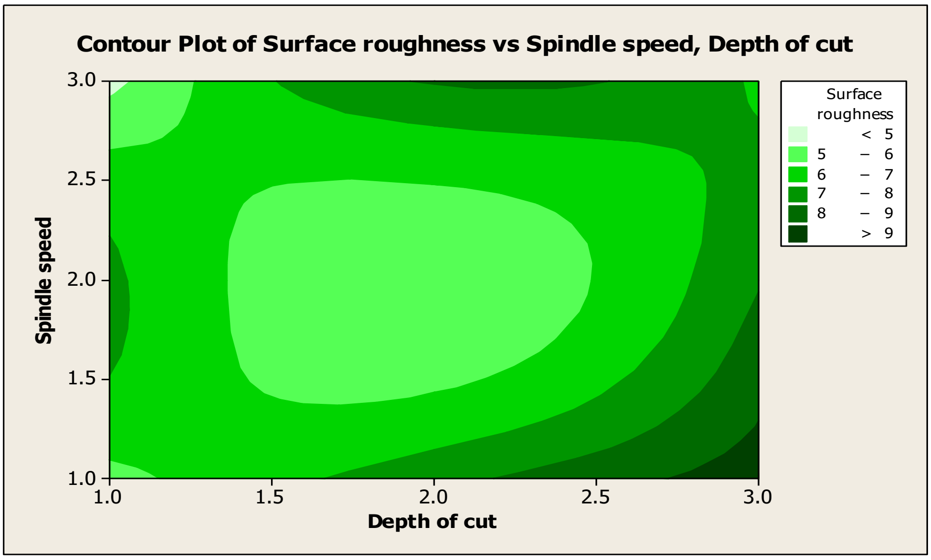

Fig. 14: Contour plot of roughness vsspindle speed, depth of cut of mineraloil-based cutting fluid

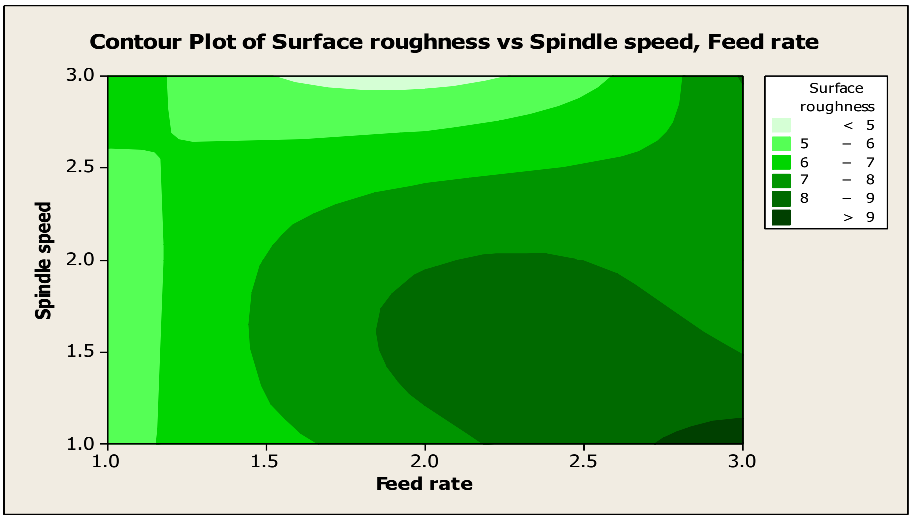

Fig. 15: Contour plot of Surfaceroughness vs spindle speed, feedrate of Mineral oil-based cutting fluid

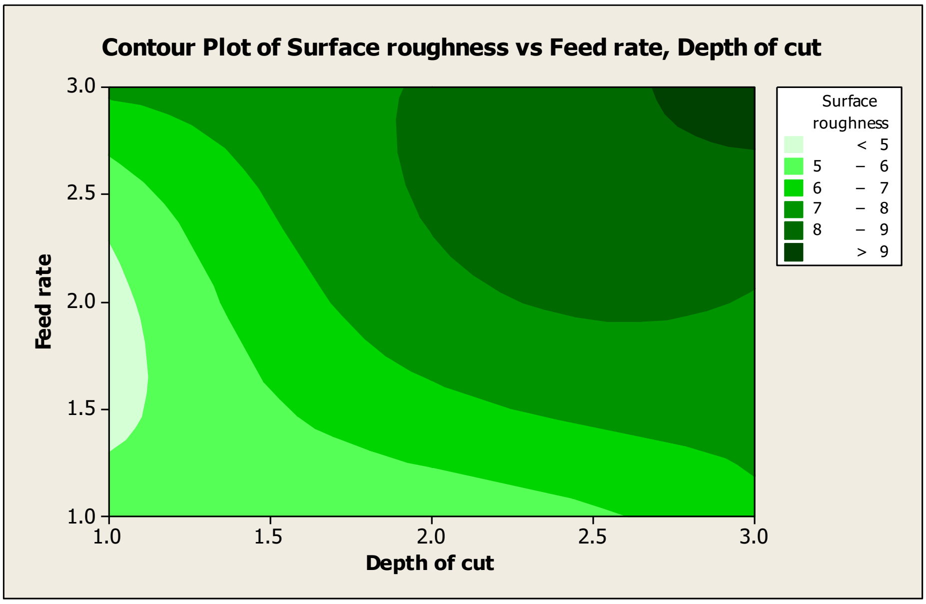

Fig. 16: Contour plot of roughness vs depth of cut, feed rate of mineral oil-based cutting fluid

J. Cutting zone temperature and cooling curve of the cutting fluids

The temperature measurement of the cutting zone reveals that for experiment run 4, Tamarind had a cutting zone temperature of 36ºC, Neem cutting fluid had 39ºC, Mineral cutting fluid had 39ºC and Dry machining temperature was 49ºC. Tamarind cutting oil had percentage temperature reduction for the fourth experiment run of 26.53%, Neem cutting fluid and Mineral cutting fluid had the same percentage temperature reduction of 20.41% (Figure 17). Similar pattern was noticed for experiment run 8 where Tamarind had cutting zone temperature of 31ºC, Neem cutting fluid 33ºC, Mineral oil had cutting zone temperature of 33ºC and Dry machining cutting zone temperature was at 40ºC (Figure 18). Consequently, the percentage temperature reduction rate was 22.5% for Tamarind cutting fluid, 17.5% for Neem and Mineral oil cutting fluid each. Tamarind cutting fluid also had the best temperature reduction for the two experiment runs 4 and 8. Tamarind had the best reduction rate and outperforms Neem and Mineral oil cutting fluid as a result of its superior fluidity and better lubrication characteristics [14]. This led to improved lubricating action which reduced the frictional forces between the workpiece and the tool and thus reducing the temperatures developed and eventually preventing tool wear, thereforeincreasing the tool life, resulting into reduced surface roughness and improved surface quality of the workpiece.

It was observed that the parameters of the machining, affect the rate of cooling of each cutting fluid as can be observed in (Figure 19). This result is similar to the report of [15]; where it was found that cutting zone temperature is related to surface roughness of machined surface. Therefore, the rougher the surface the more temperature is generated at the cutting zone during turning operation.

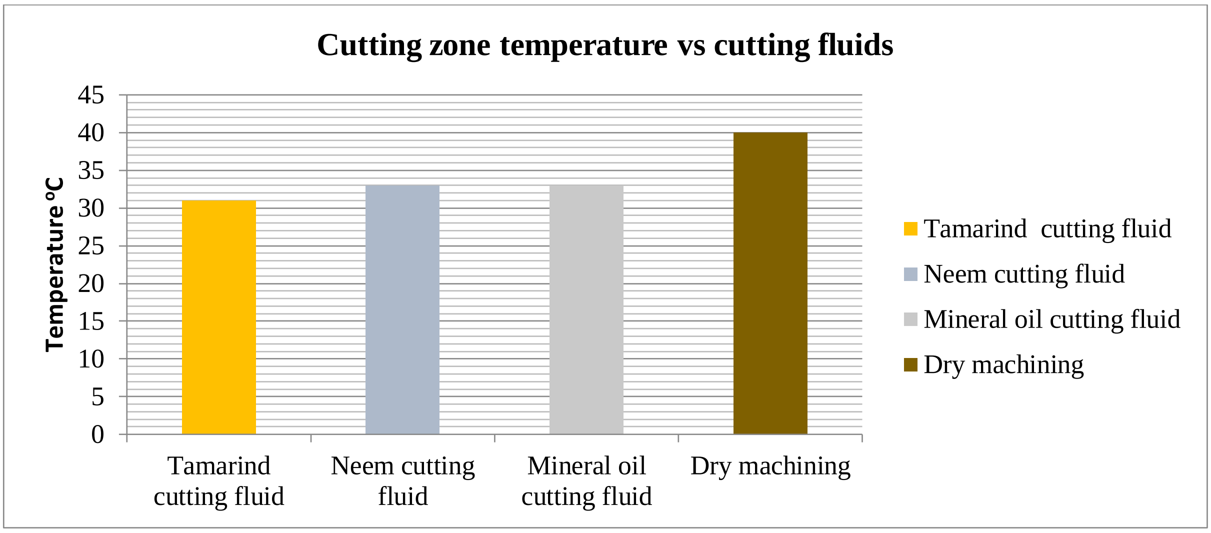

Fig. 17: Cutting zone temperature of cutting fluids for experiment run 4.

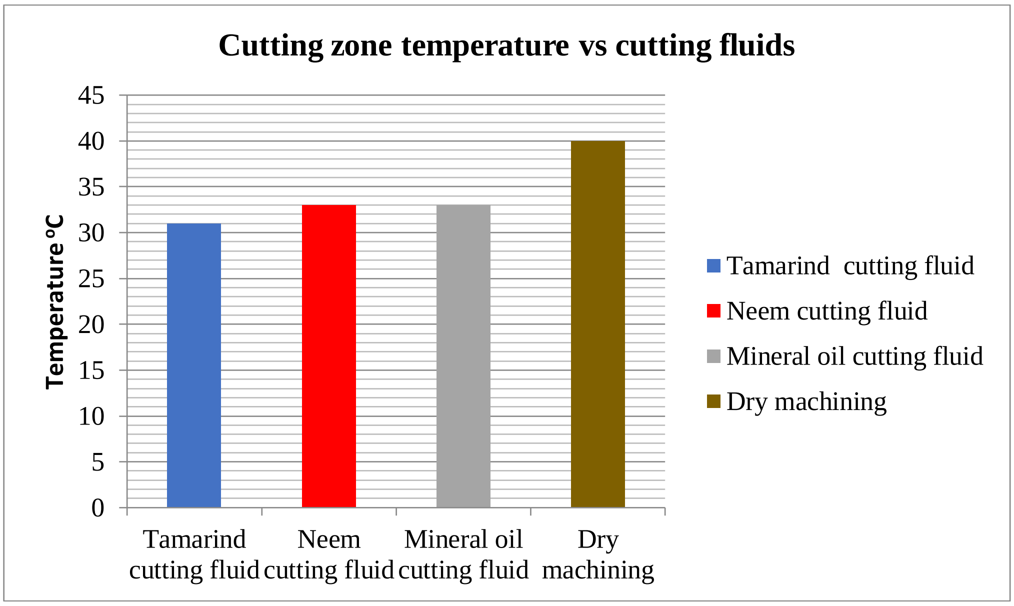

Fig. 18: Cutting zone temperature of cutting fluids for experiment run 8.

The cooling curve presented in Figure 19 revealed that the tamarind cutting fluid cools faster than Neem and Mineral cutting fluid. This result showed that the Tamarind cutting fluid dissipate heat faster than the other cutting fluids due to its high lubricating property. The fundamental composition of Tamarind formulated cutting fluid molecules along with the chemical structure is responsible for the impressive superior cooling ability during turning operation the mild steel.

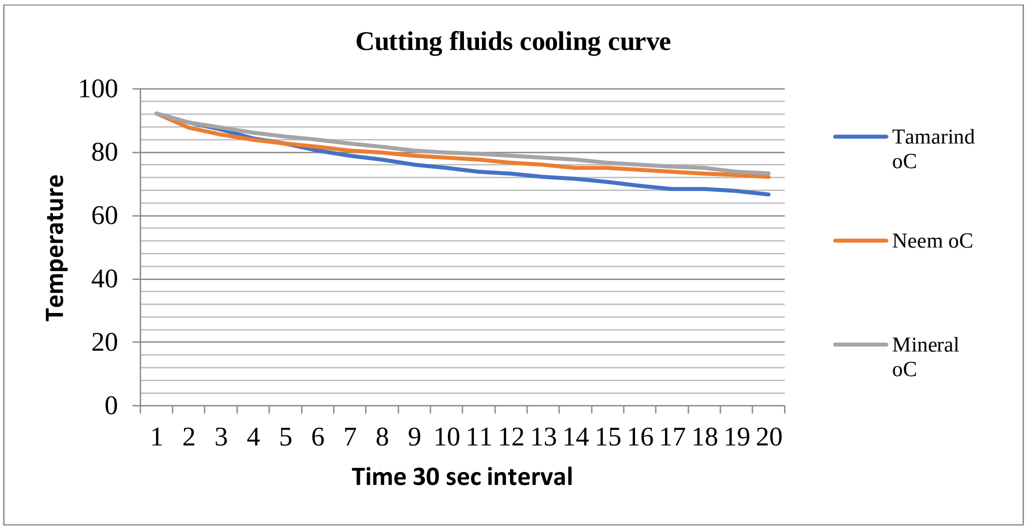

Fig. 19: Cooling cure of cutting fluids for 30 sec intervals

IV. CONCLUSION

The following conclusions can be drawn from the present study conducted:

- Tamarind oil cutting fluid produced the best result of surface finish at experiment run eight (8). The Neem seed was next followed by the Mineral based cutting fluid.
  - ➢ The investigation deduced that better surface roughness was produced by Tamarind oil-based cutting fluid with a least surface roughness of 3.142 Ra (μm).
  - ➢ The optimum turning condition for the three cutting fluid was obtained at a machining parameters Spindle speed of 1700 rpm, Feed rate of 0.2 mm/min and Depth of cut of 0.5 mm.
  - ➢ The investigation reveals that an increase in the spindle speed increase the surface roughness of the turned milled steel from level 1, level 2 to level 3.
  - ➢ The Taguchi and ANOVA analysis showed that the Spindle speed had the most statistically significant effect on the Surface quality of the mild steel followed by the Depth of cut and finally the Spindle speed.
  - ➢ The Tamarind oil-based cutting improves the surface quality by 37.32% and Neem oil cutting fluid improve surface finish by 27.25% when their least value was compared to that of Mineral based cutting fluid.
- Tamarind cutting fluid recorded the best percentage temperature reduction rate while the duo of Neem cutting fluid and Mineral oil cutting fluid had similar percentage temperature reduction rate. The cooling curved show that the Tamarind oil had a much stipe curve compared to the Neem oil and Mineral oil cutting fluids. Thus, for improve thermal performance in terms of temperature removal tamarind tends to exhibit a superior performance.

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