Optimization of Bio Degradable Nano Cutting Fluid Parameters during Machining of Titanium Alloy

C. Venkatesh, Mengistu Gelaw, Soloman Dufera

Abstract*: Varieties of cutting fluids are available in market to facilitate good machining objectives for metal removing Industries. Eventually, majority of the cutting fluids are synthetic and semi synthetic in nature, despite they are helping to the industries but they are harmful to health of the operators and environment. Though they are having good properties needed for machining, nature of non-biodegradability and non-friendliness to the environment are the key barriers associated with these fluids. Various researches have been carried out to prepare a vegetable based bio degradable effective cutting fluid to nullify above said constraints. In this research work, a unique castor oil based cutting fluid infused with nano molybdenum di sulfide (MoS2) particles has been prepared and its performance during machining has been investigated. In this study, much attention has been applied to achieve the optimized parameters of the biodegradable nano cutting fluid. Taguchi's method equipped with gray relational analysis was utilized by considering the size of the nano particles, nano particle inclusion (npi) and flow rate as the chief fluid parameters. The surface roughness and tool wear were treated as responses. As per L9 orthogonal array, totally nine experiments were conducted. Additionally, the most significant parameter which affects the machining responses was identified with the help of grey grade, ANOVA and MRPI ranking. Confirmation test were carried out followed by prediction of grey grade so as to improve the degree of validation. It has been observed that there was significant improvement in gray grade for the optimal parameters.

***Keywords* : Molybdenum disulfide, Sulfanated castor oil, Tool wear, Surface roughness, Grey grade.**

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I. INTRODUCTION

Whenever the manufacturing process is considered, metal cutting operation is a most important and unavoidable process. Major challenge in the metal cutting operation is the development of heat due to the contact between metals. This heat becomes another barrier, which strongly influences the main objectives of machining like surface finish, tool life in unsatisfactory level. There are various types of cutting fluids introduced in the cutting zone to eliminate this heat. Most of the cutting fluids used in machining center are made up of petroleum based synthetic fluid, which are not degradable in nature and also affects the health of the operator. To advocate the green environment concept, the development of cutting fluids in the capacity of degradability and friendly to the environment and operators are highly preferred.

Recent researches proved that the cutting fluid developed through vegetable oil possesses improved performance in terms of improving surface finish, minimizing the tool wear and cutting forces [1-3]. Now a day, vegetable based cutting fluid (VBFC) becomes a good substitution for the existing petroleum based cutting fluids [4]. Variety of vegetable oils like coconut oil, palm oil, castor oil, sesame oil and contra oil etc. are used as cutting fluid. Modern manufacturing environment encourages the dry machining and Minimum Quantity Lubrication (MQL) in order to minimize the use of cutting fluid [5]. Recently extensive nano particles have been added to the base fluid so as to construct nano fluid. These nano fluids were found highly beneficial to improve the industrial requirements. Specific application of these nano fluid extends to cutting fluid, engine cooling, cooling of electronics, cooling of heat exchanging devices, solar water heating, cooling of transformer oil, domestic refrigerator-freezers, improving heat transfer efficiency of chillies, and cooling in machining [6-9].

Recent research finding explores that the nano Molybdenum di sulphide (MoS_2) have been infused to the vegetable oil to form a biodegradable nano cutting fluid, since Molybdenum di sulphide is a known solid lubricant. In earlier investigation, it has been revealed that the increase in nano particle inclusions (npi) of MoS_2 in the vegetable base cutting fluid, significantly improves the machining objectives [10-11].

Considerable reductions in cutting forces, tool wear, surface roughness and cutting temperature have also been recorded. Size of the nano particle, percentage of inclusion of nano particle in the base fluid and flow rate also affects performance characteristics of the nano cutting fluid.

Previous study related to the development of hybrid nano cutting fluid composed with MoS_2 and Carbon Nano Tubes (CNT), also acknowledges the fact that the hybrid nano cutting fluid exhibited better performance characteristics over the single nano particle [12].

Cutting temperature, flank wear and surface roughness were found decrease with the increment of percentage of inclusion of nano boric acid with the base fluid coconut oil [13]. Inclusion of Al_2O_3 and CuO nano particles in the water as nano cutting fluid, was employed in grinding of Ti-6Al-4V alloy to evaluate the chip formation and coefficient of friction[14]. It has been reported that the implementation of nano fluid composed of Al_2O_3, CuO nanoparticles significantly reduces the coefficient of friction and temperature gradient between upper and lower side of the chip which leads to severe curling.

The present work explores the development of unique biodegradable nano cutting fluid by adding nano molybdenum disulfide particle with sulfanated castor oil base fluid. The performance of purposely developed bio degradable cutting fluid was optimized by considering size of the nano particle, nano particle inclusion and flow rate as chief fluid parameters, towards to achieve the objective of good surface finish and less tool wear.

II. EXPERIMENTAL DETAILS

A. Cutting tool and workpiece

Industrially preferred titanium material of commercial Grade 5 was chosen as the work material. The mechanical properties and chemical composition of titanium Grade 5 alloy has shown in Tab.1 and Tab.2 respectively

Table 1 Mechanical properties of Titanium alloy Grade 5

Hardness	RC36
Tensile strength(MPa)	895
Yield strength(MPa)	825
Reduction of area in %	25
Elongation in %	10

Table 2 Chemical composition of Titanium alloy Grade 5

Chemicals	Percentage
O	0.2
Vi	3.5-4.5
N	0.05
H	0.0125
Al	5.5-6.75
Fe	0.4
C	0.1
Ti	Balance

Tungsten carbide inserts with grade DRT3Z69 supplied by KORLOY Inc was mounted on DCBNL 2525 M12 V_{04-16} tool holder has been selected as cutting tool to conduct an experiment. The experimental set up employed for the present work has shown in Fig.1.

Fig.1 Experimental set up

B. Base fluid sulfanated castor oil, nano cutting fluid preparation

Castor oil of premeasured quantity was taken in beaker and concentrated sulphuric acid was mixed within that in a control rate. Constant cooling was maintained so as to achieve agitation of reaction mass. After the completion of acid addition, alkali solution was used to wash the reaction mass and bring it to neutral state. The product derived in such a way is known as sulphated or sulfonated castor oil whose chemical properties are given in Table 3

Table 3. Chemical characteristics of Sulfonated castor oil

Appearance	Brownish Yellow
PH	7-8
Specific Gravity	0.98
Solubility	Miscible in water giving milky emulsion
Chemical character	Anionic
Boiling point	<150^0
Sulfanation degree	Min 4
CAS Number	8002-33-3

The planetary ball mill was employed to pulverize the crystalline molybdenum sulfides (MoS_2) particles into nano level. Three different sizes 30 -40 nm, 70-80nm and 100 -120 nm of molybdenum sulphides were made ready for the purpose of inclusion.

Premeasured quantities of $nMoS_2$ like 1%, 1.5% and 2% pulverized from planetary ball mill were taken in a beaker and the corresponding quantity of sulfonated castor oil was slowly poured by mixing both to achieve uniform suspension. The developed nano suspension was pressed into the sonication process using magnetic sonicator Sera-Meg™, up to an hour as represents in Fig.2. After the completion of sonication process, it was noticed that the infused nano MoS_2 granules were homogeneously distributed within the fluid without any considerable agglomeration.

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A contamination test was carried out by employing Fouriet Transform Infra Red (FTIR) analysis to validate the distribution of $nMoS_2$ particles within the sulfanated castor oil. The The FTIR image given in Fig.2 acknowledges the presence of nano molybdenum disulfide particles with the help of hydrocarbon molecules in similar orientation.

The frequency range 2900- 3000 confirms the presence of C-H molecules.

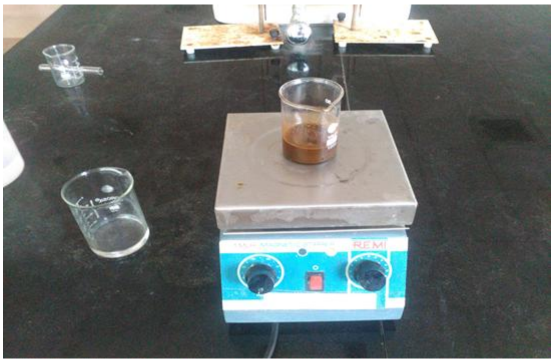

Fig.2 Preparation of nano Bio-Degradable cutting fluid

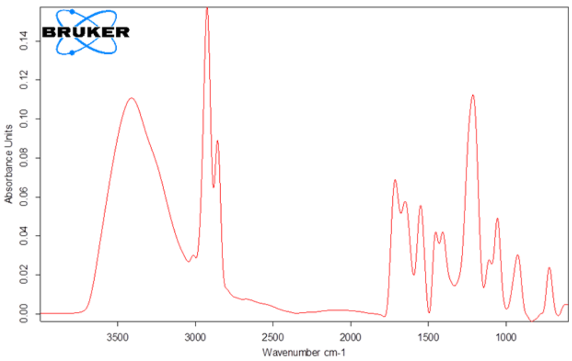

Fig. 3 FTIR image of CF II

III. DESIGN OF EXPERIMENT

Now a day many more complex engineering and Industrial problems can be solved by Taguch's design of experiment method. The number experiment to be conducted can be .drastically minimized with the implementation of orthogonal array (OA). Each column of OA represents the significant parameters which influences the objectives. The degree of freedom and number of trials was decided by the number of parameters and their levels.

For the present case of optimizing the nano cutting fluid parameters, three important parameters for the development of nano cutting fluid at three different levels as shown in Table 4 were considered by implementing L9 OA.

Table 4 Process parameters and their levels

Symbol	Process parameters	unit	Level 1	Level 2	Level 3
A	Particle size	nm	30-40	70-80	100-120
B	Nano particle inclusion (npi)	%	1	1.5	2
C	Flow rate	ml/hr	90	125	150

Whenever the machining operation is considered using lathe, surface roughness of the work piece and the wear of the tool are dominant factor in terms of objectives of the machining. Hence it is most important to know the degree of influence of the cutting fluid parameters over these objectives with optimized way. However, inclusion of two responses changes the problem into multivariable approach. As per the Taguchi's robust design of experiment approach, there shall be nine experiments to be conducted based on L9 OA. For each experiment trial, the specimen was made into observation of surface roughness using Mitutoyo Surftest SJ 400 surface profilometer and the tool wear using AFM. Table 5 shows the recorded value of both the responses (surface roughness and tool wear) for each experiment.

A.Grey Relational analysis

Grey Relational Analysis (GRA) is an important statistical tool to solve the complex problem having with limited data. GRA can be applicable to evaluate the problem with more than one objective. The multi response optimization can be changed in to single objective problem. The data observed through experiments were analyzed and normalized between zero to one so as to generate the grey relational coefficients.

Initially the response data recorded in experiment trials were transformed into S/N ratio. The effect of response in terms of larger or smaller was arrived. For the present study, both the objective surface roughness and tool wear to be as lower as possible are preferred. S/N ratio were calculated as per smaller the better type approach as follows,

$$\frac{S}{N} ratio = -10 \log\left[\frac{1}{n}\sum_{i=1}^{n} y_{ij}^2\right] \quad (1)$$

Computed S/N ratio for the recorded response value as shown in Table 6

The purpose of normalization is to express the analyzed data in to single decimal ranging from 0 to 1. The following relation was employed to execute the normalization under smaller the better type approach.

Z_{ij} = normalized value for the *i* th experiment/trial for the *j* th response

$$Z_{ij} = \frac{max(Y_{ij}, i = 1,2, \ldots., n) - Y_{ij}}{max(Y_{ij}, i = 1,2, \ldots., n) - min(Y_{ij}, i = 1,2, \ldots., n)} \quad (2)$$

Calculated normalized ratio has been presented in Table 7

Table 5 Experimental observations using L9 orthogonal arrays

Trial No.	Biodegradable nano cutting fluid parameters: Particle size (A) Level	Particle size (A) Value (nm)	Nano particle inclusion (npi) (B) Level	Nano particle inclusion (npi) (B) Value (%)	Flow rate (C) Level	Flow rate (C) Value (ml/hr)	Surface roughness (µm)	Tool wear (µm)
1	1	30-40	1	1	1	90	1.897	243
2	1	30-40	2	1.5	2	125	1.714	256
3	1	30-40	3	2	3	150	1.586	118
4	2	70-80	1	1	2	125	1.984	184
5	2	70-80	2	1.5	3	150	2.307	197
6	2	70-80	3	2	1	90	1.903	171
7	3	100-120	1	1	3	150	2.946	134
8	3	100-120	2	1.5	1	90	2.147	123
9	3	100-120	3	2	2	125	2.084	156

Table 6 S/N ratio

Trial No	Surface roughness (µm)	Tool wear (µm)	S/N ratio: Surface roughness	S/N ratio: Tool wear
1	1.897	243	-5.56	-47.71
2	1.714	256	-4.68	-48.16
3	1.586	118	-4.00	-41.13
4	1.984	184	-5.95	-45.26
5	2.307	197	-7.26	-45.88
6	1.903	171	-5.58	-44.66
7	2.946	134	-9.38	-42.56
8	2.147	123	-6.05	-41.80
9	2.084	156	-6.37	-43.86

Table 7 Normalized S/N ratio

Trial No	S/N ratio: Surface roughness	S/N ratio: Tool wear	Normalized S/N ratio: Surface roughness	Normalized S/N ratio: Tool wear
1	-5.56	-47.71	0.289	0.933
2	-4.68	-48.16	0.126	1.000
3	-4.00	-41.13	0.000	0.000
4	-5.95	-45.26	0.362	0.569
5	-7.26	-45.88	0.605	0.661
6	-5.58	-44.66	0.293	0.479
7	-9.38	-42.56	1.000	0.167
8	-6.05	-41.80	0.181	0.550
9	-6.37	-43.86	0.440	0.361

Table 8 Grey Relational Coefficients and Grey relational Grade

Trial No	Normalized S/N ratio: Surface roughness	Normalized S/N ratio: Tool wear	Quality loss: $\Delta_{\text{Surface roughness}}$	Quality loss: $\Delta_{\text{Tool wear}}$	Grey relational Coefficient: $GC_{\text{Surface roughness}}$	Grey relational Coefficient: $GC_{\text{Tool wear}}$	Grey Grade: G
1	0.289	0.933	0.711	0.067	0.584	0.937	0.760
2	0.126	1.000	0.873	0.000	0.533	1.000	0.766

3	0.000	0.000	1.000	0.250	0.500	0.799	0.649
4	0.362	0.569	0.637	0.456	0.610	0.686	0.648
5	0.605	0.661	0.394	0.358	0.717	0.736	0.726
6	0.293	0.479	0.706	0.550	0.585	0.645	0.615
7	1.000	0.167	0.000	0.880	1.000	0.531	0.765
8	0.181	0.550	0.619	0.450	0.617	0.500	0.558
9	0.440	0.361	0.559	0.676	0.641	0.596	0.618

*Optimized level of parameters

From the normalized S/N ratio, the grey relational coefficient can be manipulated by using the following relation,

$$GC_{ij} = \frac{\Delta_{min} + \lambda\Delta_{max}}{\Delta_{ij} + \lambda\Delta_{max}} \begin{cases} i = 1,2,\ldots,n - experiments \\ j = 1,2,\ldots,m - responses \end{cases} \quad (3)$$

Where GC_{ij} = Grey Relational Coefficients for the *i* th experiment/trial for the *j* th response

Δ = Absolute difference between Y_{oj} and Y_{ij} which is a deviation from the target value and can be treated as quality loss

Y_{oj} = Ideal normalized value of the *j* th response

Y_{ij} = the *i* th normalized value of the *j* th response

Δ_{min} = Minimum value of Δ

Δ_{max} = Maximun value of Δ

λ = Distinguishing coefficient defined in the range $0 \leq \lambda \geq 1$

The Grey Relational Grade (G_i) can be determined with the help of following relation,

$$G_i = \frac{1}{m}\sum GC_{ij} \quad (4)$$

The manipulated value of the Grey Relational Coefficients (GRC) and Grey relational Grade (G) has shown in Table 8

The manipulated Grey Relational grade now can be equated with Multi Response Performance Index (MRPI), so as to convert the multi objective problem into single objective. The optimal parameters required to develop unique nano cutting fluid can be earned through MRPI data, the effects of MRPI are tabulated in Table 9.

Table 9 Mean MRPI and the ranking of factors effect

Factors	Particle size (A)	Nano particle inclusion (npi) (B)	Flow rate (C)
Level 1	0.675	0.582	**0.682***
Level 2	0.679	0.717	0.678
Level 3	**0.684***	**0.782***	0.668
Max-Min	0.005	0.2	0.014
Rank	3	1	2

It is quite clear from the MRPI analysis that the effect of nano particle inclusion is more significant than other two parameters followed by the effect of particle size. The higher the values of MRPI are taken into consideration for arriving the optimal parameters. It is quiet clear from the grey grade graph presented in Fig.4 which confirms the optimal level of parameters for the development of Bio-degradable nano cutting fluid as $A_3B_3C_1$.

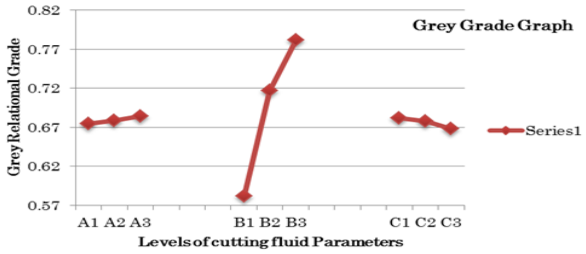

Fig.4 Grey grade grapgh

IV. RESULTS AND DISCUSSION

A. Analysis of variance

The main objective of constructing ANOVA table as shown in Table 10 is to evaluate the degree of significance of each parameter over the responses. The rank and percentage of contribution of each parameter can be known through ANOVA. From Table 10, it is very much clear that the nano particle inclusion in nano cutting fluid has got the most influencing characteristic over the responses by achieving highest contribution of 57.15 % followed by the parameter flow rate. It is evident that the particle size becomes the least significant parameter in the study as shown in Fig 5. The physical reason behind this influence has observed that the volume of nano molybdenum di sulfide particle acts solid lubricant between tool and workpiece interface to minimize the wear and surface roughness, when it was in more inclusion percentage. Flow rate becomes the second influencing

Table 10. ANOVA table.

Source of Variation	DOF	Sum of squares	Mean squares	F value	% Contribution	Rank
Particle size (A)	2	0.002	0.001	0.55	2.02	3

Nano particle Inclusion (B)	2	0.056	0.028	15.55	57.15	1
Flow rate (C)	2	0.04	0.02	11.11	40.83	2
Error	8	0.0144	0.0072			
Total	14	0.1124		27.21	100	

parameter which reveals that at low flow rate, time with which nano particles contact with tool- workpiece interface also increases which minimize the responses effect considerably.

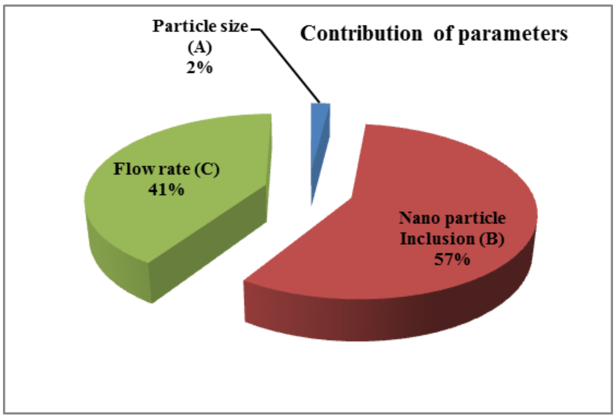

Fig.5 Contribution percentage over the response

B. Verification of optimal parameter through confirmation experiment

Confirmation experiment was carried out by following the optimized fluid parameters. The sample cutting fluid was developed by following the parameter level of A3B3C1 like 100-120 nm particle size, 2 % nano particle inclusion and 90 ml /hr. The tool wear observed for the specimen machined by implementing optimal cutting fluid is as shown in Fig.5. The surface roughness recorded for the same specimen is also shown in Fig. The value of tool wear is 143µm and surface roughness is 1.637µm and the corresponding grey grade for these observed results is 0.537.

The predicted grey relation $\alpha_{predicted}$ of the bio degradable nano cutting fluid can be expressed as

$$\alpha_{Predicted} = \alpha_m + \sum_{i=1}^{n} (\alpha_o - \alpha_m) \quad (5)$$

Where $\alpha_{predicted}$ is the grey relation grade for the predicted parametrrs. α_m is the mean average of the grey relational grades. α_o is the average grey relational grade of the optimal level of the fluid parameters ($A_3B_3C_1$) and '*n*' is the number of significant factors considered from the response table. The computed predicted grey relational grade was 0.562,

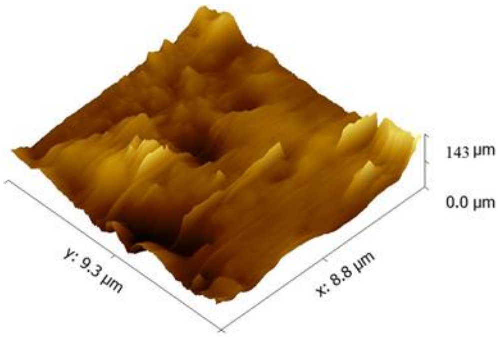

Fig.5 AFM Image of tool wear with optimized fluid parameter

Table 11 Comparative table of the grey grade for the random and optimal process parameters

Response Value	Raw Experiment $A_1B_3C_1$	Optimal process parameters	
		Predicted $A_3B_3C_1$	Confirmation Experiment $A_3B_3C_1$
Surface roughness (µm)	1.784		1.637
Tool wear (µm)	148		143
Grey Relational Grade	0.547	0.562	0.537

Table 11 confirms that the difference between predicted experiment and confirmation experiment is within the allowable value confident interval. From table 8, multi response performance index assures the fact that the nano fluid parameters, nano particle inclusion and flow rate are playing pivotal role over the machining objectives surface roughness and tool wear. More than half of the impact was through nano particle inclusion because of the infused nano particle in the nano fluid offers the ball bearing effect in the tool-workpiece interface, thereby minimizing the surface roughness and tool wear to the satisfactory extent.

V. CONCLUSION

Vegetable based castor oil was utilized to form a sulfanated castor oil as base fluid and nano molybdenum di sulfide were infused to construct a bio degradable nano cutting fluid. The important fluid parameters like nano particle inclusion percentage, flow arte and particle size were identified as the influencing contributors over the machining responses.

Following conclusion were arrived after performing Taguchi's design of experiment followed by grey relational analysis to investigate the degree of influence of each parameter over the machining objectives.

1. Considerable contamination of nano MoS2 particle were confirmed through contamination test conducted using FTIR.
2. After implementing the Taguchi's design of experiment, it is evidently proved that optimum level of the fluid parameters to minimize the surface finish and tool wear are A3B3C1.
3. Computation of grey grade through S/N ratio and Normalized S/N ration acknowledges the fact that the nano particle inclusion weightage and flow rate of the cutting fluid are the predominant factors in deciding the effectiveness of machining parameters. Nearly 57 % of contribution in minimizing effect of machining objectives has been recorded and the flow rate becomes another significant cutting fluid parameter by securing second rank with 41% contribution.
4. Effect of size of the nano particle becomes nullified comparatively.
5. Results of predicted experiment and confirmation experiment shows the good agreement in terms of confident interval.

REFERENCES

1. Babur Ozcelik, Emel Kuram, M. Huseyin Cetin, Erhan Demirbas. Experimental investigations of vegetable based cutting fluids with extreme pressure during turning of AISI 304L. Tribology International 44 1864–1871. **(2011)**
2. Khan MMA, Mithu MAH, Dhar NR. Effects of minimum quantity lubrication on turning AISI9310 alloy steel using vegetable oil-based cutting fluid. JMater ProcessTechnol209:5573–83**. (2009)**
3. Pervaiz.S,Deiab.L,Rashid.A,Nicolescu.M. Minimal quantity cooling lubrication in turning of Ti6Al4V: Influence on surface roughness, cutting force and tool Wear. JEngManuf **(2015)**
4. Shashidhara .Y.M, Jayaram.S.R. Vegetable oils as a potential cutting fluid—an evolution. Tribol Int ;43:1073–81.**(2010)**
5. N.R. Dhar , M. Kamruzzaman, Mahiuddin Ahmed. Effect of minimum quantity lubrication (MQL) on tool wear and surface roughness in turning AISI-4340 steel. JMater ProcessTechnol ; 172 (2006) 299–304
6. R. Saidura,, K.Y. Leongb, H.A. Mohammad. A review on applications and challenges of nanofluids. Renewable and Sustainable Energy Reviews 15 (2011) 1646–1668
7. Lee S, Choi SUS,Li S,Eastman JA. Measuring thermal conductivity of fluids containing oxide nano particles. J Heat Transf ;121:280–9.**(1999)**
8. Beck M,Yuan Y,Warrier P,Teja A. The effect of particle size on the thermal conductivity of alumina nano fluids. J Nano part Res.;11:1129–36. **(2009)**
9. Salehi JM, Heyhat MM, Rajabpour A. Enhancement of thermal conductivity of silver nano fluid synthesized by a one-step method with the effect of poly- vinyl pyrrolidone on thermal behavior. Appl Phys Lett ;102:231907.**(2013)**
10. Padmini R,VamsiKrishna P, KrishnaMohana Rao G. Effectiveness of vegetable oil based nano fluids as potential cutting fluids in turning AISI1040steel. Tribol Int ;94:490–501.**(2016)**
11. R Padmini, P Vamsi Krishna, G Krishna Mohana Rao. Experimental evaluation of nano-molybdenum disulphide and nano-boric acid suspensions in vegetable oils as prospective cutting fluids during turning of AISI 1040 steel. J Engineering Tribology 0 (0) 1–13.
12. YanbinZhang, ChangheLin, DongzhouJia, DongkunZhang, XiaoweiZhang Experimental evaluation of the lubrication performance of MoS2/CNT nanofluid for minimal quantity lubricationin Ni-based alloy grinding. International Journal of Machine Tools & Manufacture 99(2015)19–33.
13. Vamsi Krishna P, Srikant RR, NageswaraRao D. Experimental investigation on the performance of nanoboric acid suspensions in SAE-40 and coconut oil during turning of AISI1040 steel. Int J Mach Tools Manuf ;50:911–6.**(2010)**
14. DineshSetti nojKumarSinha,SudarsanGhosh,P.VenkateswaraRao. Performance evaluation of Ti–6Al–4V grinding using chip formation and coefficient of friction under the influence of nano fluids. International Journal of MachineTools & Manufacture 88 (2015)237–248.

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