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An Investigation Of Multi Walled Carbon Nanotubes Based Nano Cutting Fluids In Turning Of Martensitic Stainless Steel By Using Taguchi And Anova Analysis

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***ABSTRACT**: In this paper focus on recent development of the study of nanoparticle based metal working fluids as used in the machining process. In the last 175 years the cutting fluids are widely used in the metal cutting operations to cool and lubricate between the tool and workpiece. In this work to investigate the machining of martensitic stainless steel 420 grade by the utility of multi walled carbon nano tubes dispersed with coconut oil as a metal working nano cutting fluids. In the asset of metal working nano cutting fluid and its behavior with respect to cutting temperature, surface finish have been analyzed. The results shows that carbon nano tubes based coconut oil has better surface finish and reduction of cutting temperature when compared to conventional cutting fluids is used as a coconut oil and dry condition. By using of Taguchi's L9 orthogonal array method to carried out for turning operations. And the analysis of variance is used to investigate the cutting parameters that affect the cutting performance in the operations.*

***Keywords** – Anova, Cutting fluids, Machining, Nanoparticle, Taguchi.*

I. INTRODUCTION

Nanofluids are made up of dispersion of nanoparticle (1-100nm) with the base fluid. The common base fluids comprise of water, oils, ethylene glycols, lubricants and other common liquids. The following materials are generally used as nanoparticles include metals (e.g. copper, gold), metal oxides (e.g. silica, alumina, Zirconia), oxide ceramics (e.g. CuO, Al_2O_3), metal nitrides (e.g. SiN, AIN), metal carbides (e.g. Sic) and carbon forms (e.g. diamond, fullerene, graphite, carbon nanotubes). Solids have high thermal conductivity when compared to conventional fluids as shown in table 1. By the dispersion of nanoparticle with the base fluid the thermal property of the fluids can be significantly improved. The thermal conductivities of various solid and liquids as shown in the table 1. In the multi walled carbon nano tubes has high thermal conductivity compared to other particles [1].The role of nanoparticle in the nano oil lubrication is direct effect (e.g. Sliding / rolling / filming) and surface enhancement effect (e.g. Polishing/mending). By the addition of nanoparticle in the lubricating oil it reduces the coefficient of friction and increase the load bearing capacity between the friction parts in the system. The various mechanisms have been suggested to reveal the lubrication enhancement of nanofluids including the ball bearing effect, polishing effect, mending effect. This mechanism can be divided into two groups as shown in the fig.1[2]

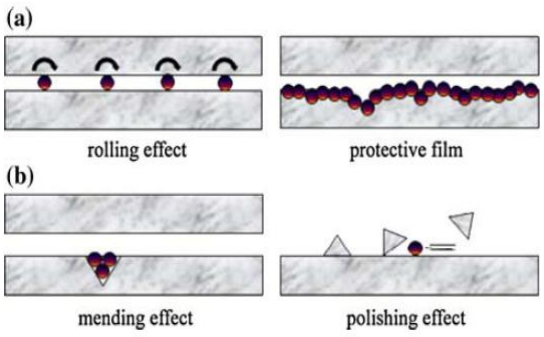

Fig. 1 Possible lubrication mechanisms by the application of nano oil between the frictional surfaces

Table1. Thermal conductivities of various solids and liquids at room temperature [1]

Material	**Form**	**Thermal Conductivity (W/mK)**
Carbon	Nanotubes Diamond Graphite Fullerenes film	1800-6600 2300 110-190 0.4
Metallic solids (pure)	Silver Copper Nickel	429 401 237
Non-metallic solids	Silicon	148
Metallic liquids	Aluminum Sodium at 644 K	40 72.3
Others	Water Ethylene Glycol Engine Oil R134a	0.613 0.253 0.145 0.0811

II. LITERATURE REVIEW

Assael et al [3] analyzed the thermal conductivity of nanofluids with the help of transient hot-wire method. Multi walled carbon nano tubes dispersed with Ethylene glycol and water by the addition of surfactant for stable and homogenous suspension. The result shows that thermal conductivity of fluids can be increased. Prabhu and Vinayagam [4] investigated the surface characteristics of AISI D2 tool steel in grinding operation by using Multiwalled carbon nano tube based lubricant. The result shows that surface characteristics were improved from micro level to nano level. Vamsi Krishna et al [5] analyzed that turning of AISI 1040 steel by the application of nano boric acid (50 nm) dispersed with coconut oil and SAE 40 oil. The experimental results show that coconut oil based cutting fluids has better performance in the case of surface finish, cutting temperature, tool flank wear when compared to SAE 40 oil. Xavior et al [6] estimated the tool wear & surface roughness in turning of AISI 304 steel with the influence of three cutting fluids are coconut oil, emulsion, neat cutting oil. It shows that coconut oil shows better performance because of good lubricating properties. Khandekar et al [7] proposed that adding of 1% of Al_2O_3 nanoparticles in conventional cutting fluid. It shows that wettability characteristics are improved and reduction of tool wear, cutting force and surface roughness compared to dry and conventional cutting fluid. Narayana Rao et al [8] investigated the machining of AISI 1040 steel by using HSS and carbide cutting tools. Nodal temperature and tool flank wear has decreases with the CNT content, but the change is less beyond 2% CNT inclusion. Prabhu and Vinayagam [9] analyzed the grinding process multi walled carbon nano tubes dispersed with SAE 20W40 oil. The result indicates that the surface finish of the workpiece gives micro level to nano level. Rajasekaran et al [10] analyzed the turning parameter for surface roughness using taguchi approach to find out the number of experiments to carried out for the turning operations.

III. EXPERIMENTATION

Coconut oil has widely used in food processing industries. It has good lubricating properties which has high flash and fire point and pour point compared to mineral oils. Coconut oil has better thermal and oxidation stabilities when compared other vegetable oils like sunflower oil, sesame oil because of high percentage of unsaturated fatty acid content in coconut oil. Multi walled carbon nano tubes were purchased in Ad-nano Technologies, Bangalore. The specification of multi walled carbon nano tubes as shown in the table2. The 0.1 wt % of MWCNT was dispersed with coconut oil with the help of ultra sonicator in l hour. By using sodium do

decyl sulphate was added during the sonication for proper stable and homogenous dispersion. The mixed lubricant has to be tested for various test like flash point, fire point & viscosity as shown in table 3

Table 2. Specification of Multi walled carbon nano tubes

Outer Diameter:	12nm
Inside Diameter:	6 nm
Length	20 μm
Nanotubes purity	>95%
Thermal Conductivity	3070 W/mk
Specific Surface area	50-220 m2/g
Bulk density	0.20 g/cm3

Stainless steel is one of the difficult to cut the material which is widely used in aerospace, chemical, automotive, food processing industries. It has low thermal conductivity together with high strength is made as difficult to machine material. The attributes of stainless steel are low thermal conductivity, poor chip breakability, work hardening which characterizes the machining of stainless steel together with shorter tool life and poor surface finish.

Table 3. Properties of Lubricant

Properties	Coconut oil	Coconut oil + MWCNT
Kinematic Viscosity	22.89 cst	42.659 cst
Flash Point	310 deg	199 deg
Fire Point	330 deg	232 deg

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Table 4. Chemical composition of martensitic stainless steel 420 grade

Elements	Wt. %
C	0.2
Si	0.508
Mn	0.653
P	0.0253
S	0.0082
Cr	12.8
Ni	0.060
Cu	0.0905
Nb	0.0214
V	0.0574
Fe	Balance

The dimensions of the workpiece are diameter 50 mm, length 210 mm, the constant turning length is taken as 140 mm. The application of the stainless steel 420 grade are Machine parts, Bolt, Screws, nuts, Pump shafts, Valves & Bushing, Steam and gas turbine parts. The chemical composition of workpiece was measured by spectro analysis. The table 4 lists the chemical composition (wt %) of material stainless steel 420 grade. The hardness of the specimen is 255 BHN was measured by Brinell hardness.

Turning process was chosen as machining process and the plain turning was performed on the workpiece. The operation was performed on three samples. First sample was dry condition, Second sample with coconut oil, Third sample with coconut oil + Multi walled carbon nano tubes. The method of application of

lubricant in minimum quantity lubrication in 250ml/min The surface roughness was obtained by surface roughness tester, cutting temperature was measured by K- type thermocouple.

Table 5. Machining parameters

Levels	Speed (rpm)	Feed (mm/rev)	Depth of cut (mm)
1	230	0.12	0.4
2	400	0.206	0.6
3	560	0.32	1

IV. RESULTS AND DISCUSSION.

In this work three parameters are taken, namely cutting speed, feed, and depth of cut. The design of experiment is taken as L9 orthogonal array for reduce the number of experiments. The carbide tool insert were used to machine the stainless steel workpiece. The cutting speed is various between 30 m/min to 85 m/min. The surface roughness was measured at three areas of specimen and its average value was calculated.

Table 6. The results of experiment in dry machining

Tests	Rpm	Feed	Doc	RA (µm)	CT (^{o}c)
1	280	0.12	0.4	1.63	65
2	280	0.206	0.6	2.95	83
3	280	0.329	1	5.00	127
4	400	0.12	0.6	1.31	87
5	400	0.206	1	2.6	106
6	400	0.329	0.4	4.73	66
7	560	0.12	1	1.19	105
8	560	0.206	0.4	2.23	75
9	560	0.329	0.6	4.57	105

Table 7. The results of experiment in coconut oil Condition

Tests	Rpm	Feed	Doc	RA (µm)	CT (^{o}c)
1	280	0.12	0.4	1.55	42
2	280	0.206	0.6	2.65	54
3	280	0.329	1	3.51	68
4	400	0.12	0.6	1.05	55
5	400	0.206	1	1.95	64
6	400	0.329	0.4	3.22	54
7	560	0.12	1	0.97	78
8	560	0.206	0.4	1.89	60
9	560	0.329	0.6	3.56	62

Table 8. The results of experiment in nano cutting oil condition

Tests	Rpm	Feed	Doc	RA (µm)	CT (^{o}c)
1	280	0.12	0.4	1.41	40
2	280	0.206	0.6	2.43	48
3	280	0.329	1	3.2	62
4	400	0.12	0.6	0.84	48
5	400	0.206	1	1.75	52

6	400	0.329	0.4	2.86	52
7	560	0.12	1	0.77	57
8	560	0.206	0.4	1.63	61
9	560	0.329	0.6	3.25	60

Fig 2. Experimental set up in machining

The experiment setup is shown in the figure 2. The average surface roughness of the dry condition is 2.91 µm, coconut oil has 2.26 µm and MWCNT + coconut oil has 2.01 µm as shown in the figure 3. The cutting tool temperature was reduced with application of coconut oil, nano cutting fluid when compared to dry condition, but there is change is less between the coconut oil and nano cutting oil.

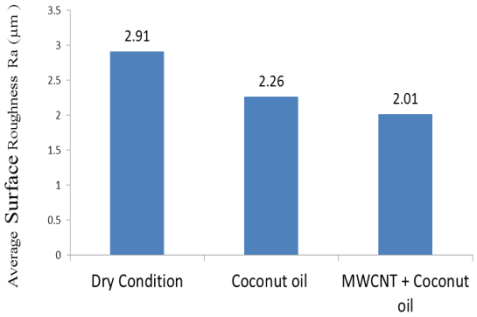


Fig 3. Variation of average surface roughness of dry condition, coconut oil, MWCNT + coconut oil

The variation of cutting temperature is shown in the figure 4. It shows that nano based cutting fluid has better reduction of cutting temperature when compared to coconut oil, dry cutting condition.

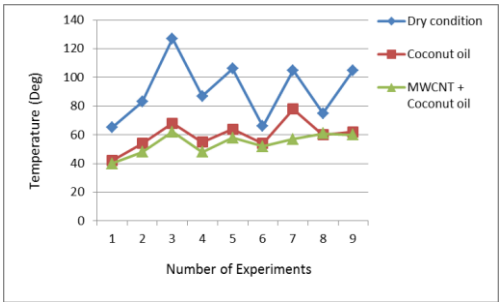
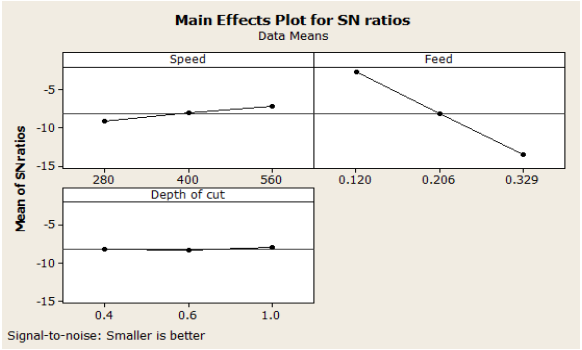


Fig 4. Variation of cutting temperature with dry, coconut oil, MWCNT+ coconut oil condition

V. ANALYSIS BY TAGUCHI METHOD

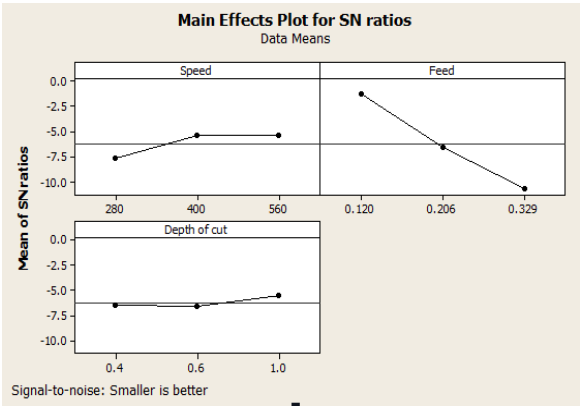
The main advantage of using taguchi method to decrease the number of experiment and find out the significant factor in the shorter time period. It is an important tool for robust design. In dry machining condition analysis of surface roughness by using Taguchi, RA versus speed (A), Feed (B), Depth of cut (C). For smaller is better the following S/N ratio formula is used.



Graph 1. Main Effect Diagram (Dry condition)

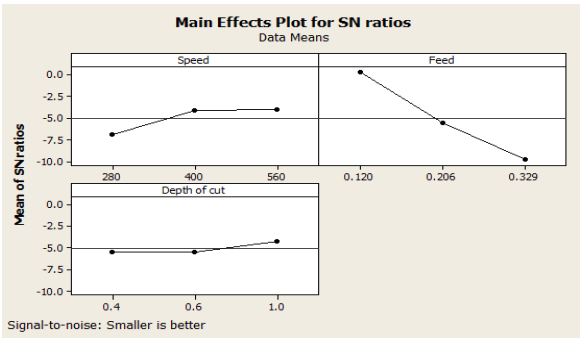
S/N Ratio (η) = -10 log $_{10}$ $\frac{n}{i=1}$ y^2

n = no.of experiments, y = response value. S/N Ratio is -1.5109 corresponding actual surface roughness with dry machining condition Ra (y) = 1.19 µm. By using coconut oil machining condition analysis of surface roughness by using Taguchi, RA versus speed (A), Feed (B), Depth of cut (C)



Graph 2. Main Effect Diagram (with coconut oil condition)

The S/N Ratio is 0.264 corresponding for the actual surface roughness with coconut oil machining condition Ra (y) is 0.97 µm. By using nano oil machining condition analysis of surface roughness by using Taguchi, RA versus speed (A), Feed (B), Depth of cut (C). The S/N Ratio is 2.27 corresponding for the actual surface roughness with coconut oil + MWCNT machining condition Ra (y) is 0.77 µm. The results clearly show that three control factors are actually affecting the machining of the material. The optimum cutting conditions, which were the cutting speed of 560 rpm, the feed rate of 0.12 mm/rev and the depth of cut of 1 mm were obtained for the best Ra Values



Graph 3. Main Effect Diagram (with nano oil condition)

ANOVA ANALYSIS

The purpose of anova analysis is to find the significant factors affecting the machining process to improve the surface characteristics of stainless steel 420 grades in turning process. The results show that how the process parameter affect the response and
the level of significance of the factor considered. At 5% significance level, $F_{0.05,\ 2,\ 2}$ = 19.00. So the main effect feed alone are significant. That is feed influence the surface finish. The main study of anova study is arranged in table 9 and table 10. The anova analysis for coconut oil reveals that speed, feed, depth of cut has 4.5 %, 91.62 %, 0.71 % contribution, nano cutting oil reveals that speed, feed, depth of cut has 5.573 %, 89.08 %, 0.35 % contribution, respectively in surface roughness.

Table 9. The anova table for surface roughness of coconut oil condition

Machining Parameter	Dof	Sum of squares (Ssa)	Variance (Va)	F	P	Contribution (%)
A	2	0.5	0.25	5.47	0.154	5.573
B	2	6.622	3.311	72.49	0.014	89.08
C	2	0.1174	0.0587	1.29	0.438	0.35
Error	2	0.0914	0.0457			5.01
Total	8	7.3308				100

Table 10. The anova table for surface roughness of coconut oil + MWCNT condition

Machi-ning Parameter	DOF	Sum of square (Ssa)	Varian-ce (Va)	F-test	P	Contribution (%)
A	2	0.4360	0.2180	6.85	0.127	4.5
B	2	7.5694	3.7847	118.97	0.008	91.62
C	2	0.1224	0.0612	1.92	0.342	0.71
Error	2	0.0636	0.0318			3.17
Total	8	8.1915				100

VI. CONCLUSION

The surface characteristics of stainless steel 420 grade were analyzed with dry, coconut oil, coconut + MWCNT oil condition in turning process. The result showed that multi walled carbon nano tubes based cutting fluid has better surface characteristics when compared dry and coconut oil condition. By using taguchi's L9 orthogonal array it was found better surface finish achieved by with the application of nano cutting fluid Ra is 0.77µm when compared to coconut oil Ra is 0.97µm and dry condition 1.19 µm with the optimum cutting conditions, which were the cutting speed of 560 rpm, the feed rate of 0.12 mm/rev and the depth of cut of 1 mm. In the anova analysis for nano cutting fluid reveals that speed, feed, depth of cut has 5.573 %, 89.08 %, 0.35 % contribution, respectively in surface roughness and p value shows that feed is most significant factor for surface roughness in nano cutting fluid.

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