Research Article CODEN: IJPAKY Impact Factor: 4.226 ISSN: 2319-507X
A Venkata Vishnu, IJPRET, 2017; Volume 6 (4): 1-15 IJPRET

INTERNATIONAL JOURNAL OF PURE AND APPLIED RESEARCH IN ENGINEERING AND TECHNOLOGY

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AN INVESTIGATION ON COMPARISON OF VEGETABLE OIL AND NANO FLUIDS COOLANTS IN TURNING OF EN 19 ALLOY STEEL

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Accepted Date: 05/11/2017; Published Date: 01/12/2017

Abstract: - Almost all machining process produces heat and friction which will potentially damage the cutting tools as well as the machined work piece. To reduce the friction, heat transfer and to remove metal particles away from the cutting zone normally cutting fluids are used in machining operation. In the present paper an attempt is made to reduce the friction at the cutting zone by using Nano fluid and vegetable oil based coconut oil under flooded condition. By using Taguchi Robust Design methodology the experiments are carried out using L_9 (3^4) orthogonal array and the work material used is EN 19 Alloy Steel. The selected process parameters are Cutting Speed, Feed rate, Depth of cut and Type of tool. Taguchi orthogonal array is designed with three levels, four factors and nine experiments using L_9 (3^4) orthogonal array. The nine experiments are performed using nano fluid and vegetable oil individually and MRR is calculated. Results obtained by Taguchi Method, show that the factors affecting the MRR are Significant for both the coolants and compared their effect, where Vegetable oil showed better performance than nano fluid.

Keywords: Taguchi Method, EN-19 Alloy, Turning, MRR (Material removal rate), Vegetable oil, Nano Fluid etc.

PAPER-QR CODE

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How to Cite This Article:

A Venkata Vishnu, IJPRET, 2017; Volume 6 (4): 1-15

INTRODUCTION

The growing demand for higher productivity, product quality and overall economy in manufacturing by machining, insists high material removal rate and high stability and long life of the cutting tools. But machining with high cutting velocity, feed rate and depth of cut is inherently associated with generation of large amount of heat and high cutting temperature. Such high cutting temperature not only reduces dimensional accuracy and tool life but also impairs the surface integrity of the product by inducing tensile residual stresses, surface and subsurface micro-cracks in addition to rapid oxidation and corrosion. Machining experiences high temperatures due to friction between the tool and work piece, thus influencing the work piece dimensional accuracy and surface quality. Machining temperatures can be controlled by reducing the friction between tool–work-piece and tool–chip interface with the help of effective lubrication. Cutting fluids are the conventional choice to act as both lubricants and coolants. But, their application has several adverse effects such as environmental pollution, dermatitis to operators, water pollution and soil contamination during disposal [1, 2]. Further, the cutting fluids also incur a major portion of the total manufacturing cost.

Application of Nano fluid lubrication in cutting has proved to be feasible alternative to cutting fluids, if it can be applied properly. If the friction at the machining zone can be minimized by providing effective lubrication, the heat generated can be reduced to some extent. If a suitable lubricant can be successfully applied in the machining zone, it leads to process improvement. Several studies related to the lubrication properties of Nano fluids are carried out over the past several decades. It has been found by M. M. A. Khan (2009), that Nanofluids have much higher and strongly temperature dependent thermal conductivity at very low particle concentration, which is considered to be a key parameter for enhanced performance for many of the applications.

It was found that Vegetable oil(Coconut oil) to be most suitable as it increases wet ability, reduces cutting forces, and shows enhanced tribological effects along with minimum toxic nature. The objective of the present work is to find out the set of optimum conditions for the selected control parameters and to compare the performance characteristics of Nano Fluids and Vegetable oil in order to measure Material Removal rate. Taguchi Robust Design methodology is used to determine the optimum parameters for the selected control factors viz. Cutting speed, feed rate, depth of cut and type of tool at three different levels where the experiments are carried out using L_9 (3^4) orthogonal array[15-17].

1. MATERIALS AND METHOD

The Literature survey helped in proper selection of the material and suitable method. Taguchi Robust Design Methodology is used to determine the optimum conditions for the selected process parameters. Orthogonal Array, Signal to Noise Ratio and Analysis of Variance are employed to study the performance characteristics for the selected process parameters. The turning operations (facing) are carried out on CNC machine at BRD Rock Drills, Cherlapaly, Hyderabad and the machine used is WASINO LJ-63m CNC Turning Machine shown in fig.no.1.

The work piece material used is EN19 steel in the form of round bars of 30 mm diameter and length of 120 mm as shown in fig.no.2. EN19 is widely used for Machining components in various industries. This material has significant application in automotive industry. Typical applications of this material are crown wheel, crown pinion, bevel pinion, bevel wheel, timing gears, king pin, pinion shaft, differential turning etc.

Fig. No. 1: CNC Lathe

Fig. No. 2: EN19 Alloy Steel

The cutting inserts used for machining are CNMG carbide tools of KORLEY Company, which are Gold coated, silver coated and uncoated Carbide tools as shown in the fig.no.3.

Selection of cutting fluid is important in order to maintain better tool life, less cutting forces, lower power consumption, high machining accuracy and better surface integrity etc. Here Nano

fluid and Vegetable Oil (coconut oil) is used as cutting fluid. Coconut oil is an environmentally acceptable vegetables oil based lubricant. In the present work alumina (Al_2O_3) Nano particles are mixed with water, as a base fluid used is water, to make Al_2O_3Nanofluid. Five grams of Al_2O_3 Nano particles and directly mix with 100 ml of water as a base fluid with a mixture of triethanol amine.

The mixture of vegetable oil (coconut oil), oleic acid and triethanol amine is used as lubricant, from these three chemicals, coconut oil and oleic acid will improve machining parameters. The solvent triethanol amine is used for proper mixing of coconut oil and oleic acid. It can also control the evaporation rate of water in coolant.

Composition of solution as follows:

1 Coconut Oil is taken 40%

2 Oleic Acid is taken 40% and

3 Triethanol Amine is 20%

40% of coconut oil is taken in a beaker and then 20% of triethanol amine is mixed in coconut oil and this mixture is stirred with mechanical stirrer for half an hour and then 40% of Oleic acid is added in the above solution slowly to dissolve or proper mixing and it is stirred for an half an hour to get a homogeneous mixture which is to be dissolve in water in all conditions.

Fig. No.3. Cutting tool Inserts

Fig. No. 4 Machining of EN 19 alloy steel

The four control factors speed (A), feed (B), Depth Of Cut(C)and type of tool (D) are selected with three levels and the corresponding orthogonal array L_9 (3^4) is chosen with respect to its degrees of freedom[1] and are tabulated in Table No.1. Steel bars of 30mm diaX120mm length are prepared for conducting the experiment. Using different levels of the process parameters as per the experimental design shown in table no.2, the specimens have been machined in CNC Lathe Machine accordingly, the MRR is measured precisely with the help of MRR Formula shown in Eq-1 for nano fluids and vegetable oil individually.

Table No. 1: Control Factors & Levels for Nano fluid & Vegetable oil

Factors /Levels	Speed (A) (rpm)	Feed (B) (mm/min)	Depth Of Cut (C) (mm)	Type of tools (D)
1	700	0.2	0.5	uncoated
2	1100	0.5	1.5	Gold
3	1500	0.8	2.5	silver

Table No. 2. Experimental Design for Nano fluid & Vegetable oil

EXPERIMENT NO.	SPEED	FEED	DEPTH OF CUT	TYPE OF tool
1	700	0.2	0.5	Uncoated
2	700	0.5	1.5	Gold
3	700	0.8	2.5	Silver
4	1100	0.2	1.5	Silver
5	1100	0.5	2.5	Uncoated
6	1100	0.8	0.5	Gold
7	1500	0.2	2.5	Gold
8	1500	0.5	0.5	Silver
9	1500	0.8	1.5	uncoated

2. RESULTS & DISCUSSIONS:

Material removal rate (MRR) has been calculated using equation (1), i.e., the difference of weight of work piece before and after experiment. The weight of the specimen is measured with the help of digital weighing machine before and after machining the work piece. The machining time is also noted during the machining process for each work piece

$$MRR = \frac{1000 \times W_w}{\rho_w \times t} \text{ mm}^3/\text{min} \quad \text{..... (1)}$$

The MRR is measured precisely with the help of a MRR formula and the experiments results are tabulated in table no. 3& 9 for Nano fluids and vegetable oils under Flooded Condition individually. For each experiment the corresponding S/N values at larger the better are also tabulated. Optimization of Material removal Rate is carried out using Taguchi methodology. Confirmatory tests have also been conducted to validate the optimal results.

Table No.3. Experimental Results of MRR for Nano fluids with the corresponding S/N Ratio's

EXP NO.	MRR with Nano fluid-flooded			S/N RATIO
	TRAIL1	TRAIL2	MEAN	
1	490.38	485.33	487.85	53.76
2	4609	4610.2	4609.6	73.27
3	10608.2	10605.1	10606.7	80.51
4	4109.4	4108.2	4108.8	72.67
5	8400.8	8409.87	8405.3	78.49
6	755.16	754.11	754.63	57.55
7	6689.2	6683.17	6686.18	76.50
8	939.96	936.5	938.23	59.44
9	7399.5	7293.14	7346.32	77.32

Table No 4: Summary of S/N Ratios (Nano fluid)

Factor	Level 1	Level 2	Level 3
Speed(A)	69.18	69.57	**71.08**
Feed(B)	61.32	70.4	**71.79**
Depth of Cut(C)	56.91	74.42	**78.5**
Type of tool(D)	69.85	**74.42**	70.87

The best condition for speed is level 3 (71.08), for feed is level 3 (71.79), for depth of cut is level 3 (78.5) and type of tool is level 2 (74.42). Thus, the optimum conditions chosen were: **A3-B3-C3-D2**. A confirmation test is performed with the obtained optimum cutting, the MRR is measured and the S/N ratio is calculated for this condition. The conformation test results are tabulated in the table no 6.

Table No 5: Optimum Set Of Control Factors for flooded

Factors /Levels	Speed (A) (rpm)	Feed (B) (mm/min)	Depth Of Cut (C) (mm)	Type of tool (D)
Optimum Value	1500	0.8	2.5	Gold coated carbide tip

From table no.4 the following the predicted value, calculations are done,

η predicted=[A3+B3+C3+D2]-3Y

= [71.08+71.79+78.50+74.42] – [3X (69.94)]

η predicted= 85.96.

Therefore, the predicted average for optimum condition of material removal rate under nano fluid is 85.96.A confirmation test is performed with the obtained optimum cutting parameters. The material removal rate values are taken for two trials and the S/N ratio is calculated for this condition. The conformation test and the predicted values are tabulated in the table no 7.

Table No 6. Conformation results for Nano fluid

Material removal rate			
1	2	Average	**S/N RATIO**
16,707.9	16,530.9	16,619.4	84.41

Table No 7. Comparison of S/N ratios for Nano fluid

η predicted	**85.96**
η conformation	84.41

Table No. 8: Analysis Of Variance for Nano fluid

FACTOR	S.S	D.O.F	M.S.S	F-RATIO (DATA)	SS1	ρ %
SPEED	2081194	2	1040597	1450.039	2079759	0.971101
FEED	18858326.8	2	9429163	13139.24	18856892	8.804845
DEPTH OF CUT	186364282	2	93182141	129846.4	186362846859710	87.01837
TYPE OF TOOL	6861145.43	2	3430573	4780.394		3.203003
ERROR	5741.071	9	717.6339			0.002681
St						
MEAN		1				
ST		18			21416494	100%

Table No.9. Experimental Results of MRR for Vegetable oil with the corresponding S/N Ratio's

EXP NO.	MRR (vegetable oil)			S/N RATIO
	TRAIL1	TRAIL2	MEAN	
1	416.4	415.1	415.75	52.37
2	3889.67	3889.3	3889.48	71.79
3	12711.86	12714.7	12713.28	82.08
4	3998.47	3994.5	3996.48	72.03
5	9055.78	9048.2	9051.9	79.13
6	768.18	752.2	760.19	57.62

7	7278.7	7268.8	7273.75	77.23
8	464.1	462.8	463.45	53.32
9	7425.74	7428.2	7426.97	77.42

Table No 10: Summary of S/N Ratios (Vegetable oil)

Factor	Level 1	Level 2	Level 3
Speed(A)	68.74	**69.59**	69.32
Feed(B)	67.21	68.08	**72.37**
Depth of cut(C)	54.44	73.74	**79.48**
Type of tool(D)	**69.64**	68.88	69.14

From table no. 10 the speed level at level 2, feed at level 3, depth of cut at level 3 and type of tool at level 1 are higher values. Thus, the optimum conditions chosen were: **A2-B3-C3-D1**. A confirmation test is performed with the obtained optimum cutting, the MRR is measured and the S/N ratio is calculated for this condition. The conformation test and the predicted values are tabulated in the table no 12 & 13.

Table No 11: Optimum Set of Control Factors for s/n ratio for Flooded

Factors /Levels	Speed (A) (rpm)	Feed (B) (mm/min)	Depth Of Cut (C) (mm)	Type of tool (D)
Optimum Value	**1100**	0.5	2.5	uncoated

Table No 12. Conformation results for vegetable oil

Cutting Temperature			
1	2	Average	S/N RATIO
14320.1	14021.2	14170.65	83.02

Table No 13. Comparison of S/N ratios for vegetable oil

η predicted	83.42
η conformation	83.02

The ANOVA calculation is performed for the results obtained i.e. MRR values using nano fluids and vegetable oil. The calculations are done manually and compared with the Minitab Statistical Software version 18 and it is verified. The model was checked at 95% confidence level for the adequacy. From the ANOVA it is observed that all the factors selected (Cutting speed, Feed rate, Depth of cut and type of tool conditions) are significant shown in Table No.8 & 14.

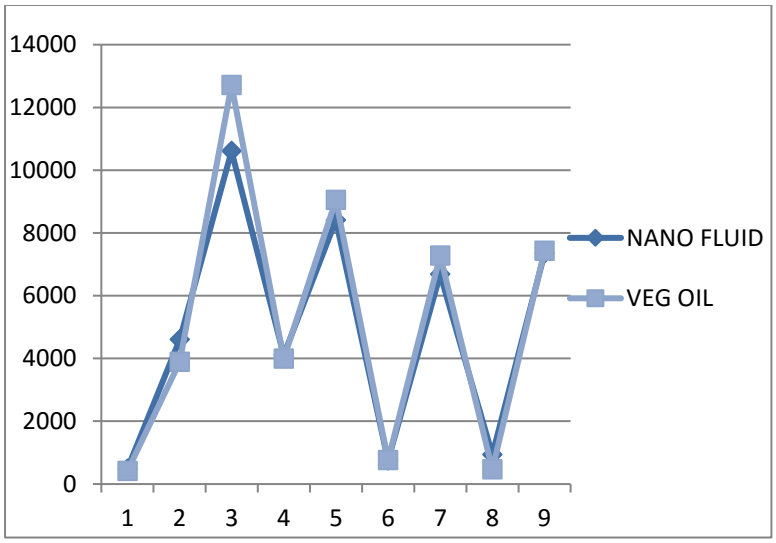
Table No. 14: Analysis Of Variance for vegetable oil

FACTOR	S.S	D.O.F	M.S.S	F-RATIO (DATA)	SS1	ρ %
SPEED	3462028	2	1731014	62347.74	3461973	1.164266
FEED	32009707	2	16004853	576463.5	32009651	10.76489
DEPTH OF CUT	250246881	2	125123440.6	4506701	250246825	84.15836
TYPE OF TOOL	11633674	2	5816837	209511.1	11633619	3.912403
ERROR		9				0.000074
St						

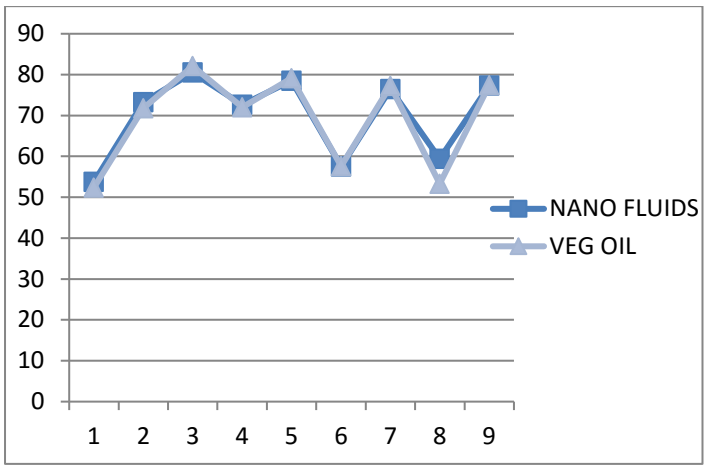
MEAN	1	
ST	18	100%

3.1. Comparison of Nano fluid and Vegetable oil:

Comparison of Nano fluid and Vegetable oil mean MRR results are plotted in Graph No. 1 in the terms of MRR, the graph shows nine experiment results for both Coolants i.e. Vegetable oil and Nano fluids in machining of En 19 steel alloy under Flooded conditions and it is observed that Vegetable based coconut oil shows better material removal than machining with nano fluid. Similarly the S/N ratios are plotted in Graph No. 2, which shows Vegetable oil has low noise factor, hence vegetable oil based coconut oil shows better performance than Al_2O_3 nano fluid particles



Graph no.1. Mean Effect of Nano Fluid vs Vegetable oil



Graph No.2. S/N ratio effect of Nano Fluid vs Vegetable oil

3. CONCLUSIONS:

The objective of the paper is to find out the set of optimum conditions in order to improve MRR, using Taguchi's techniques considering the Turning parameters for the EN 19 Steel Alloy material using Nano Fluids and Vegetable oil. Based on the results of the present experimentation the following conclusions are drawn:

- By using nano fluids under flooded conditions, the optimum speed obtained using Taguchi Robust Design Methodology is 1500 rpm. Similarly the results obtained for feed and depth of cut are 0.8mm/min and 2.5mm respectively. The corresponding Type of tool is gold coated carbide tip.

- By using Vegetables oils under flooded conditions the optimum speed obtained using Taguchi Robust Design Methodology is 1100 rpm. Similarly the results obtained for feed and depth of cut are 0.8mm/min and 2.5mm respectively. The corresponding Type of tool is uncoated carbide tip.

- For Nano fluid and vegetable oil, the S/N ratio of predicted value and verification test values are valid when compared with the optimum values individually. It is found that S/N ratio value of verification test is within the limits of the predicted value and the objective of the work is full filled.

- Using ANOVA, the individual factor effects are found to be significant factors for both nano fluids and vegetable oil and concluded that the effect depth of cut is more followed by feedrate, type of tool and cutting speed for Material Removal rate.

- It is observed that in machining of EN 19 steel alloy under Flooded conditions, an attempt is made in comparison of Nano fluid and Vegetable oil and it is concluded that Vegetable based coconut oil shows better performance than machining with nano fluid.

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