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Experimental Investigation and Optimization of Process Parameters in Turning of AISI D2 Steel using Different Lubricant

J.B.Shaikh, J.S.Sidhu

Abstract-Vegetable oils have traditionally been applied in food uses but recent trend suggests that it has economic usefulness as an industrial fluids. Increasing crude oil prices and emphasis on the development of renewable, environment friendly fluids have brought vegetable oils to a place of prominence. As environment pollution and health problem are becoming more and more concerned, the use of environment friendly lubricants is strongly supported by manufacturers'. The objective of this work is to determine the influence of lubricant on surface roughness and material removal rate (MRR) by using CNC LATHE Machine with AISI D2 steel. Taguchi Method is used for determining and optimising operating parameters. The experimentation is proposed to identify the influence of cotton seed oil on AISI D2 steel. Further the usability of cotton seed oil will be checked in turning operation at low and high speeds. The performance of cotton seed oil is compared with servo cut oil and soybean oil. The above experimentation results may help practitioners to compare and increase MRR, Surface finish using more environment friendly oil as lubricant.

Keywords: Cotton seed oil, Servo cut and soya bean oil, AISI D2 steel ,CNMG carbide insert and Taguchi method .

I. INTRODUCTION

Cutting fluids which are also known as coolants or lubricants play an important role in material removal process and machining operation such as drilling, turning and milling. Traditionally, coolants have been used since long , a study was reported which achieved 40%increase in cutting speed while machining steel with high speed steel tool and water as a coolant [Taylor,1907][1]. The lubricants of the future have to be more environmental friendly and should have a higher level of performance and lower total life cycle cost than commonly used lubricants of today. Since we live on a planet with finite resources so we have to think about coming generations and work for a sustainable development in the field of tribology. Over the past decades the landscape of the lubrication has significantly changed because of a combination of environmental, health, economics, and performance challenges. To address these challenges it is essential to develop and use lubricants that come from natural resources. Environment friendly or "Green 'lubricants are renewable and usually made from vegetable oils e.g. rapeseed, canola, corn, soybean oil. When compared to mineral and synthetic oils, vegetable oils have a number of distinct advantages including significantly higher lubricity, viscosity, lower volatility and shear stability.

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With better biodegradability and low toxic properties than conventional petroleum based products, vegetable oils have a tremendous potential for use in the industrial sector. [2].Although metal working fluids are one of the most significant factors in machining; it also has many detrimental effects. Most of the fluids used in machining operation contain environmentally harmful or potentially damaging chemical constituents. Their application has several adverse effects such as environmental pollution, dermatitis to operators, water pollution and soil contamination during disposal. These fluids are difficult to dispose and expensive to recycle. Therefore, alternative has been sought to minimise the use of metal working fluid or use of biodegradable fluids in machining operations [3,4].All these factors have prompted investigations into the use of biodegradable coolants. therefore, and attempt has been made to investigate into the Material removal rate and surface roughness characteristics of AISI D2 Steel while using vegetable oil as a lubricant. Among various work tool steel AISI D2 is having well balanced toughness, wear resistance and red hardness properties .AISI D2 steel are very economical and offer excellent value. this grade is commonly used in deep drawing and forming dies, cold drawing punches, hobbing , blanking, lamination and stamping dies, shear blades, burnishing rolls, master tool sand gauges, slitting cutters, thread rolling & wire dies, extrusion dies etc [5,6,7]. Gurpreet Singh et al [8] compared the performance of vegetable and mineral oil in terms of surface roughness by using different cutting environment and different cutting inserts at different cutting parameters .The effect of nose radius on surface roughness in dry and MQL cutting environment has been presented. The surface roughness result obtained by using vegetable oil was within close proximity to that of mineral oil. It also shows that cutting speed increases the difference between surface roughness of vegetable oil and mineral oil. Kuram E.et al [9] has studied three different vegetable–based cutting fluid develop from raw and refined sun flower oil and two commercial type were used to determine the thrust force and surface roughness during drilling of AISI 304 austenitic stainless steel with HSSE tool. Experimentally it has observed that lower thrust force values were obtained with SCF-I and the least thrust force was achieved at spindle speed of 720 rpm .at feed rate of 0.12mm/rev. Dhar N.R. et al [10] has experimentally investigated the effect of MQL by vegetable oil based cutting fluid on machinability of steel the result obtained from this study using uncoated carbide tool. M.Venkata Ramana [11] has presented performance evaluation and selection of optimal parameters in turning of Ti-6AL-4V alloy under different cooling conditions and result was compared with dry, flooded, servo cut oil with water and flooded with synthetic oil coolant conditions. The cutting performance of Ti-6AL-4V alloy with synthetic oil

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is found to better when compared to dry and servo cut oil with water in reducing surface roughness. A through study of literature suggests the usage of vegetable based metal cutting fluid lubrication provides several benefits as compared to conventional metal fluid lubrication in machining. The present experimentation has been done to compare the performance of mineral oil and vegetable oil using flooded lubrication. The main aim of this study is to find out the effectiveness and suitability of vegetable oil as compared to mineral oil.

II. MATERIALS AND METHODS

Following materials are used for experimentations.

2.1Cutting Tool

A Sandivik make PVD (TiAIN) coated carbide insert having eight cutting edges designed with grade as CNMG 120408 Insert (0.8mm corner radius) rhombus shape with 80° angle was used for 27 trials under wet environment. For every experimental runs a new cutting edge was used [12,13,14].

2.2 Work Piece Material

The work piece material used is AISI D2 Steel of 40mm long and 25mm diameter in the form of bar .the composition of AISI-D2 steel is as shown in Table 1 in percentage.

Table 1 Chemical composition of AISI D2 Steel work piece in percentage by weight

C	Cr	Mn	Si	Mo	W	S	P
1.55	11.8	0.4	0.4	0.7	0.6	0.03	0.03

2.3 Cutting Fluids: Three types of cutting fluids are used such as cotton seed oil; servo cut oil and soybean oil, and Specification of cutting fluids are as below in table 2[16].

Table 2 Specification of Cutting Fluids

PROPERTIES	COTTON SEED OIL	SERVO CUT OIL	SOYABEAN OIL
Viscosity (cst at 40°c)	33.86	40	31.49
Flash point °c	252	180	230
density	0.917	1.206	0.92

2.4 Material Removal Rate

The material removal rate, MRR (mm3/min) is calculated using the formula.

$$MRR = \frac{Wi - Wf}{ds} \ mm^3/min$$

Where,

Wi = initial weight of work piece in gm,
Wf =Final weight of work piece in gm
t = Machining time in second ,
ds =Density of AISID2 steel ($7.7\times10^{-3} g/mm^3$)

III. EXPERIMENTAL DETAILS

3.1 Methodology

Figure No.1 Experimental Set Up

In this work, Taguchi robust design methodology [16] is used to obtain the optimum conditions for lower surface roughness and high material removal rate in turning of AISI D2 Steel under flooded cotton seed oil, servo cut oil and soybean oil. Statistical software Minitab-15 is used to obtain results for analysis of mean (ANOM) and Analysis of variance (ANOVA). The experiments are carried out on a JYOTI CNC DX 150 lathe at different cutting velocities, feed and depth of cut under wet (flooded) conditions. The ranges of cutting parameters have selected based on the tool manufacturer recommendation mentioned in the table 3 as per industrial expert advices. the surface roughness has been measured by HOMMEL TESTER T500 surface roughness tester during different machining condition and different cutting fluids for the comparison purpose. The experimentations have been conducted in three different phases in first phase surface roughness and material removal rate performance conducted by cotton seed oil at variable cutting velocity ,feed and depth of cut has been compared with the Surface roughness and Material removal rate obtained during vegetable oils at same cutting conditions at second and third phase for servo cut and soya bean oil .

3.2 Surface Roughness Tester

Roughness is measured using stylus type surface roughness tester HOMMEL TESTER T500 .the cut off length was chosen as 10 cm for each roughness measurement in µm.

Figure No.2 Surface Roughness Tester

3.3 Control Parameters and Levels

A total three process parameters with three levels are chosen as the control parameters such that levels are sufficiently far apart

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so that they cover wide range. The process parameters and their ranges are finalized based on literature, machine operator experience. The three control parameters selected spindle speed, feed and depth of cut.

Table 3 Control Parameters and Levels

Parameter s /Levels	CUTTING SPEED (m/min)	FEED RATE (mm/rev)	DEPTH OF CUT (mm)	Environmental condition
01	1700	0.15	0.5	Wet
02	1800	0.2	0.2	Wet
03	1900	0.25	0.25	wet

3.4 Analysis of s/n Ratio for Material Removal Rate and Surface Roughness

Taguchi method stresses the importance of studying response variations using single to noise (S/N) ratio, resulting in minimization of quality characteristic variation due to uncontrollable parameter. The S/N Ratio is calculated using larger the better characteristics for MRR

$$n= -10\log10 \{(1/n) \sum_{i=1}^{n} 1/y^2\}$$

And the S/N Ratio is calculated using smaller the better Characteristics for surface roughness

$$n= -10\log10 \{(1/n) \sum_{i=1}^{n} y^2\}$$

Where,

n is the number of measurement in a trail/row and Yi is the measured value in the run/row.

IV. EXPERIMENTAL RESULTS AND DISCUSSIONS

A) RESULTS AND ANALYSIS OF EXPERIMENTS FOR COTTON SEED OIL

Table 4 shows the values of the responses obtained from the experimental runs, designed by Taguchi method, the corresponding value of S/N Ratio is mentioned for each run.

Table 4. Results for Experimental Results

Cutting speed(m/min	Feed rate(mm/rev)	Depth of cut(mm)	Material removal rate (mm)	S/N RATIO	Surface roughness(µm)	S/N RATIO
1700	0.15	0.5	38.96	31.8124	1.42	-3.04577
1700	0.2	0.75	64.93	36.2489	2	-6.0206
1700	0.25	1	90.9	39.1713	2.78	-8.8809
1800	0.15	0.75	86.58	38.7484	1.2	-1.58362
1800	0.2	1	108.25	40.6886	1.82	-5.20143
1800	0.25	0.5	103.38	40.2887	2.36	-7.45824
1900	0.15	1	129.87	42.2702	1.64	-4.29688
1900	0.2	0.5	97.4	39.7712	1.54	-3.75041
1900	0.25	0.75	113.63	41.1099	2.46	-7.8187

Table NO. 5 and 6 shows the responses for signal to noise for larger is better for MRR and smaller is better for Surface roughness each level of the parameters.

Table No .5 Response Table For Signal to Noise Ratio Larger Is Better For MRR.

Factors /Levels	Spindle Speed(m/min)	Feed Rate (mm/rev)	Depth Of Cut(mm)
1	-5.982	-2.975	-4.751
2	-4.748	-4.991	-5.141
3	-5.289	-8.053	-6.126
DELTA	1.235	5.077	1.375
RANK	3	1	2

Table No.6 Response Table For Signal to Noise Ratio Smaller Is Better for Surface Roughness.

Factors /Levels	CUTTING SPEED(m/min)	FEED RATE (mm/rev)	DEPTH OF CUT(mm)
1	35.74	37.61	37.29
2	39.91	38.90	38.70
3	41.05	40.19	40.71
DELTA	5.31	2.58	3.42
RANK	1	3	2

Table 5 gives the rank of parameters for MRR cutting speed is the most significant parameters whereas feed rate is the least significant parameters as far as MRR is concerned.

Table 6 gives the rank of parameters for surface roughness feed rate is the most significant parameters whereas spindle speed is the least significant parameters as far as surface roughness is concerned.

Analysis of variance (ANOVA):- The data obtained by via experimental runs for MRR and surface roughness were subjected to ANOVA for finding out the significant parameters, at above 90% confidence level and the result of ANOVA thus obtained for the response parameters are shown in table 7and 8.

Table 7 Analysis of Variance for SN Ratios for MRR.

Source	DF	Seq SS	Adj SS	Adj MS	F	P	%Cont.
S	2	46.802	46.802	23.401	9.38	0.096	62.83
F	2	9.982	9.982	4.991	2.00	0.333	13.40
D	2	17.714	17.714	8.857	3.55	0.220	23.78
Residual Error	2	4.989	4.989	2.495			
Total	8	79.487					

S = 1.579 R-Sq = 93.7% R-Sq(adj) = 74.9%

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Table 8. Analysis of Variance for SN Ratios for Surface Roughness.

Source	DF	Seq SS	Adj SS	Adj MS	F	P	%Cont.
S	2	2.298	2.298	1.149	1.09	0.479	5.17
F	2	39.214	39.21	19.60	18.55	0.051	88.03
D	2	3.013	3.013	1.507	1.43	0.412	6.78
Residual Error	2	2.114	2.114	1.057			
Total	8	46.640					

S = 1.028 R-Sq = 95.5% R-Sq (adj) = 81.9%

From table 7 observe that the spindle speed (p=0.096) is most significant parameter having 62.83% effect on MRR followed by depth of cut (p=0.220) influence the response 23.785%. On comparing the percentage contribution of the process parameters on response.

From table 8 it was found that feed have 88.03% influence on surface roughness whereas depth of cut and 6.78%and spindle speed 5.17% contributes less towards surface roughness.

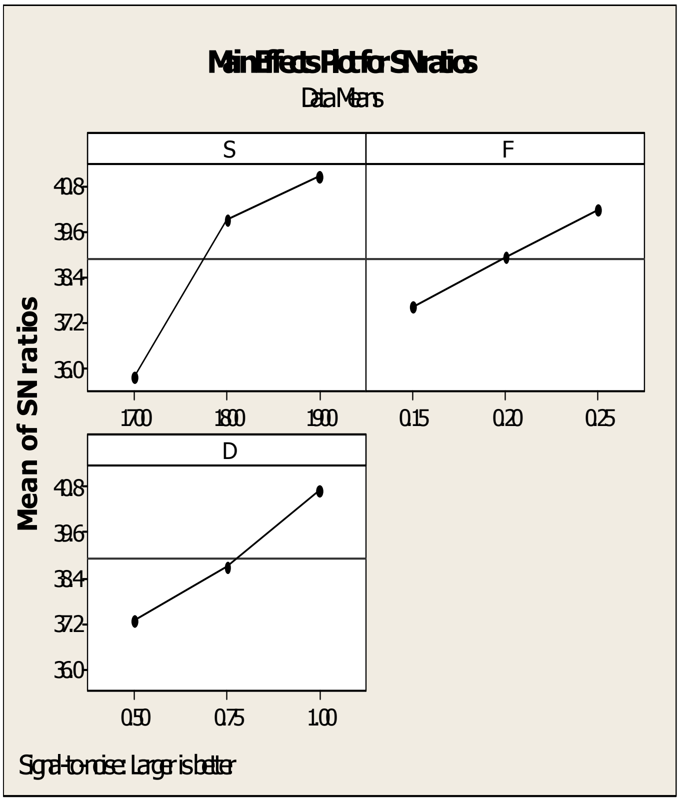

Figure.3 Effect of Depth of Cut, Feed and Spindle Speed on MRR.

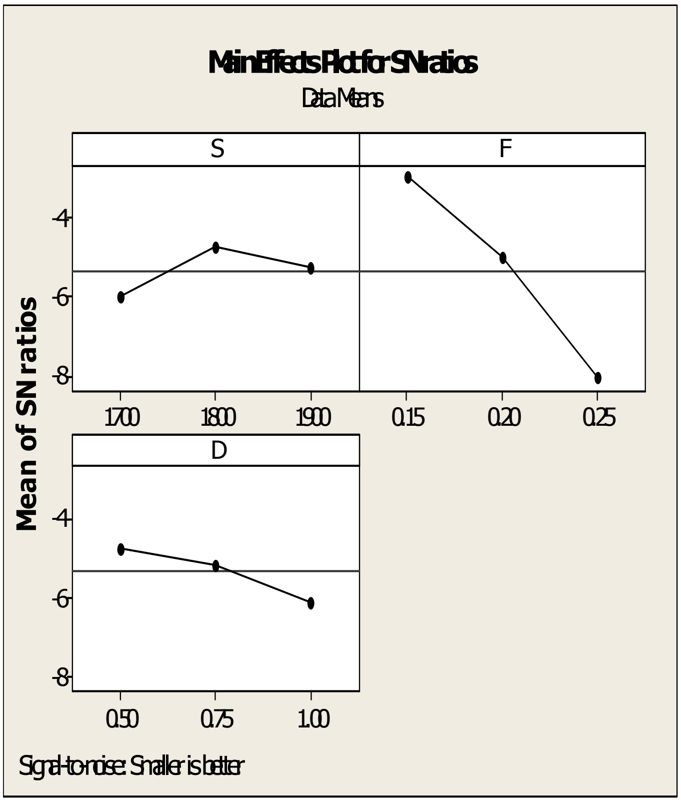

Figure.4 Effect of Depth of Cut, Feed and Spindle Speed on Surface Roughness

The following discussion focuses on the different of process parameters to the observed values (MRR and Ra) based on the Taguchi methodology.

Material Removal Rate (MRR):-

Main effects of MRR of each parameter for various level conditions are shown in Figure 3. According to figure 3 the MRR increases with three major parameter S, F and D. MRR is maximum in the case of spindle speed(S) at level 3 (1900 m/min), in the case of feed (F) at level 3 (0.25mm/rev) and in the case of Depth of cut (D) at level 3 (1mm) So the optimal parameter setting for the MRR found **S3F3D3** and greatest variation found was due to spindle speed on MRR.

Surface Roughness (Ra):- Figure 4 evaluates the main effects of each parameters for various level conditions. According to the Figure 4 the surface Roughness decreases with three major parameter S, F and D. SR will be minimum in the case of spindle speed (S) at level 2(1800m/min), in the case of feed (F) at level 1 (0.15mm/rev) and in the case of depth of cut (D) condition surface Roughness will be minimum at level 1(0.50mm). So the optimal parameter setting for minimum surface roughness is **S2F1D1** and greatest variation found was due to feed on surface roughness.

B) RESULTS AND EXPERIMENTAL RESULTS ANALYSIS OF EXPERIMENTS FOR SREVO CUT OIL:-

Table 9. Shows the values of the responses obtained from the experimental runs, designed by Taguchi method, the corresponding value of S/N Ratio is mentioned for each run.

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Table 9. Results for Experimental Results

Cutting speed(m/min	Feed rate(mm/rev)	Depth of cut(mm)	Material removal rate (mm)	S/N RATIO	Surface roughness(μm)	S/N RATIO
1700	0.15	0.5	48.7	33.7506	1.3	-2.28
1700	0.2	0.75	64.93	36.2489	1.8	-5.11
1700	0.25	1	97.4	39.7712	2.14	-6.61
1800	0.15	0.75	77.92	37.833	1.21	-1.65
1800	0.2	1	108.25	40.6886	1.64	-4.3
1800	0.25	0.5	103.89	40.3315	2.3	-7.23
1900	0.15	1	129.87	42.2702	1.62	-4.71
1900	0.2	0.5	81.16	38.1868	1.74	-4.19
1900	0.25	0.75	116.88	41.3548	2.22	-6.93

Table No .10 Response Table For Signal to Noise Ratio Larger Is Better For MRR

Factors /Levels	CUTTING SPEED(m/min)	FEED RATE (mm/rev)	DEPTH OF CUT(mm)
1	36.59	38.29	37.42
2	39.96	38.37	38.82
3	40.60	40.49	40.91
DELTA	4.01	2.19	3.49
RANK	1	3	2

Table No .11 Response Table for Signal to Noise Ratio Smaller Is Better for Surface Roughness.

Factors /Levels	CUTTING SPEED(m/min)	FEED RATE (mm/rev)	DEPTH OF CUT(mm)
1	-4.664	-2.487	-4.775
2	-4.175	-4.738	-4.342
3	-5.309	-6.923	-5.032
DELTA	1.135	4.436	0.690
RANK	2	1	3

Table NO. 10 and 11 shows the responses for signal to noise for larger is better for MRR and smaller is better for Surface roughness each level of the parameters

Table 10 gives the rank of parameters for MRR cutting speed is the most significant parameters whereas feed rate is the least significant parameters as far as MRR is concerned.

Table 11 gives the rank of parameters for surface roughness feed rate is the most significant parameters whereas spindle speed is the least significant parameters as far as surface roughness is concerned.

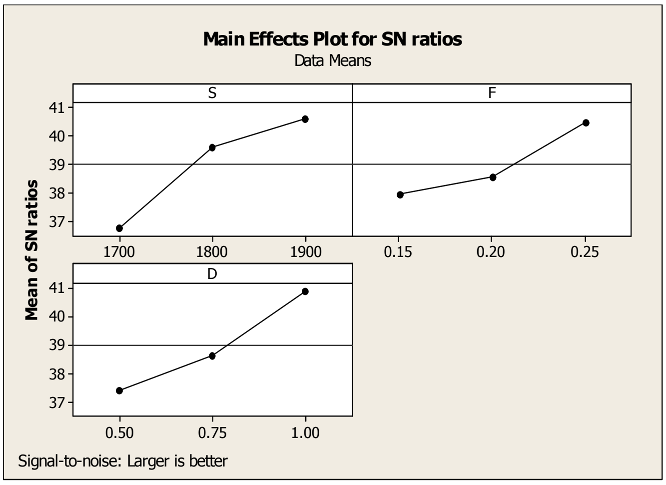

Figure.5 Effect of Depth of Cut, Feed and Spindle Speed on MRR

Analysis of variance (ANOVA):-

The response data obtained by via experimental runs for MRR and surface roughness were subjected to ANOVA for finding out the significant parameters, at above 90% confidence level and the result of ANOVA thus obtained for the response parameters are shown in table 12 and 13.

Table 12. Analysis of Variance for SN Ratios for MRR.

Source	DF	Seq SS	Adj SS	Adj MS	F	P	%Cont.
S	2	26.24	26.24	13.12	12.63	0.073	46.46
F	2	11.06	11.060	5.530	5.32	0.158	19.57
D	2	19.18	19.184	9.592	9.23	0.098	33.95
Residual Error	2	2.078	2.078	1.039			
Total	8	58.571					

S = 1.019 R-Sq = 96.5% R-Sq(adj) = 85.8%

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Table 13. Analysis of Variance for SN Ratios for Surface Roughness.

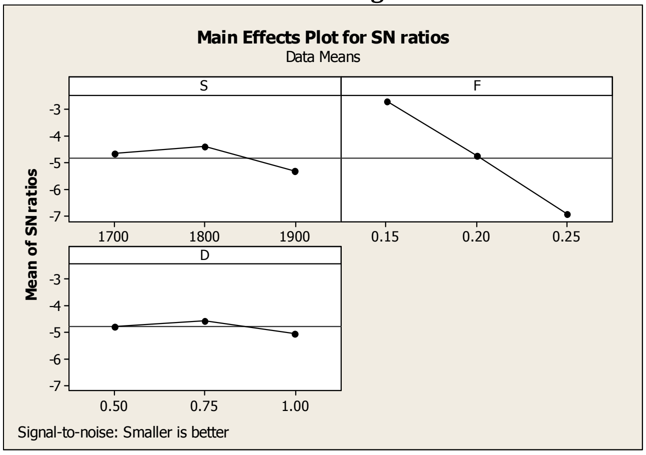
Source	DF	Seq SS	Adj SS	Adj MS	F	P	%Cont.
S	2	1.323	1.323	0.661	0.56	0.641	4.67
F	2	26.66	26.66	13.33	11.27	0.081	94.15
D	2	0.331	0.331	0.165	0.14	0.877	1.16
Residual Error	2	2.3654	2.3654	1.1827			
Total	8	30.6813					

S = 1.088 R-Sq = 92.3% R-Sq (adj) = 69.2%

From table 12, one can observe that the spindle speed (p=0.073) is most significant parameter having 46.46% effect on MRR followed by depth of cut (p=0.098) having 33.95%.where as feed (p=0.158) influence the response only by 19.57%.On comparing the percentage contribution of the process parameters on response.

From table 13 it was found that feed have 94.15% influence on surface roughness where as spindle speed 4.67% and epth of cut 1.16% contributes less towards surface roughness.

Figure 6. Effect of Depth of Cut and Spindle Speed on Surface Roughness



The following discussion focuses on the different of process parameters to the observed values (MRR and Ra) based on the Taguchi methodology.

Material Removal Rate (MRR) :-

Main effects of MRR of each parameters for various level conditions are shown in Figure 5. According to Figure 5 the MRR increases with three major parameter S, F and D. MRR is maximum in the case of spindle speed(S) at level 3 (1900 m/min), in the case of feed (F) at level 3 (0.25mm/rev) and in the case of Depth of cut (D) at level 3 (1mm) So the optimal parameter setting for the MRR found **S3F3D3** and greatest variation found was due to spindle speed on MRR.

Surface Roughness (Ra):-

Figure 6 evaluates the main effects of each parameters for various level conditions. According to the Figure 6 the surface Roughness decreases with three major parameter S, F and D. SR will be minimum in the case of spindle speed (S) at level 2(1800m/min), in the case of feed (F) at level (0.15mm/rev) and in the case of depth of cut (D) condition surface Roughness will be minimum at level (0.75mm). So the optimal parameter setting for minimum surface roughness is **S2F1D2** and greatest variation found was due to feed on surface roughness.

C) Results And Analysis Of Experiments For Soya bean Oil:-

Table NO .14 shows the values of the responses obtained from the experimental runs, Designed by Taguchi method, the corresponding value of S/N Ratio is mentioned for each run. Table NO. 15 and 16 shows the responses for single to noise for larger is better and smaller is better for each level of the parameters.

Table No .14 Results for Experimental Results

Cutting speed(m/min)	Feed rate(mm/rev)	Depth of cut(mm)	Material removal rate (mm)	S/N RATIO	Surface roughness(µm)	S/N RATIO
1700	0.15	0.5	38.96	31.8124	1.3	-2.27887
1700	0.2	0.75	64.93	36.2489	2	-6.0206
1700	0.25	1	90.9	39.1713	2.78	-8.8809
1800	0.15	0.75	81.16	38.1868	1.62	-4.1903
1800	0.2	1	97.4	39.7712	2.1	-6.44439
1800	0.25	0.5	97.4	39.7712	2.4	-7.60422
1900	0.15	1	110.38	40.8578	1.22	-1.7272
1900	0.2	0.5	81.16	38.1868	1.44	-3.16725
1900	0.25	0.75	116.88	41.3548	2.2	-6.84845

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Table no 15 &16 shows the response for larger is better & smaller is better for each level of parameters.

Table No .15 Response Table For Signal to Noise Ratio Larger Is Better For MRR.

Factors /Levels	CUTTING SPEED (m/min)	FEED RATE (mm/rev)	DEPTH OF CUT (mm)
1	35.74	36.95	36.59
2	39.24	38.07	38.60
3	40.13	40.10	39.93
DELTA	4.39	3.15	3.34
RANK	1	3	2

Table No .16 Response Table For Signal to Noise Smaller Is Better for Surface Roughness

Factors /Levels	CUTTING SPEED (m/min)	FEED RATE (mm/rev)	DEPTH OF CUT (mm)
1	-5.727	-2.732	-4.350
2	-6.080	-5.211	-5.686
3	2.165	5.046	-5.684
DELTA	2.165	5.046	1.336
RANK	2	1	3

Table 15 gives the rank of parameters for MRR cutting speed is the most significant parameters whereas feed rate is the least significant parameters as far as MRR is concerned.

Table 16 gives the rank of parameters for surface roughness feed rate is the most significant parameters whereas spindle speed is the least significant parameters as far as surface roughness is concerned.

Analysis of variance (ANOVA):-

The response data obtained by via experimental runs for MRR and surface roughness were subjected to ANOVA for finding out the significant parameters, at above 90% confidence level and the result of ANOVA thus obtained for the response parameters are shown in table 17 and 18.

Table 17. Analysis of Variance for SN Ratio for MRR.

Source	DF	Seq SS	Adj SS	Adj MS	F	P	%Cont.
S	2	32.29	32.29	16.14	12.07	0.077	50.04
F	2	15.27	15.27	7.635	5.70	0.149	23.63
D	2	16.99	16.99	8.495	6.35	0.136	26.33
Residual Error	2	2.677	2.677	1.338			
Total	8	67.235					

S = 1.157 R-Sq = 96.0% R-Sq (adj) = 84.1%

Table 18. Analysis of Variance for SN Ratio for Surface Roughness.

Source	DF	Seq SS	Adj SS	Adj MS	F	P	%Cont.
S	2	8.098	8.098	4.049	57.01	0.017	16.24
F	2	38.19	38.19	19.09	268.85	0.004	76.60
D	2	3.56	3.56	1.782	25.10	0.038	7.15
Residual Error	2	0.1421	0.1421	0.0710			
Total	8	49.9989					

S = 0.2665 R-Sq = 99.7% R-Sq (adj) = 98.9%

From table 17 observe that the spindle speed (p=0.077) is most significant parameter having 50.04% effect on MRR followed by depth of cut (p=0.149) having 23.63%.where as feed (p=0.136) influence the response only by 26.33%. On comparing the percentage contribution of the process parameters on response.

From table 18 it was found that feed have 76.60% influence on surface roughness where as spindle speed 16.24% and depth of cut 7.15%contributes less towards surface roughness.

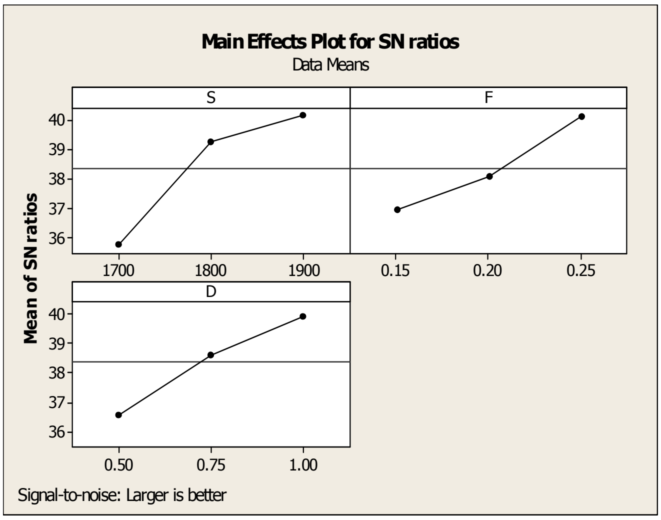

Figure.7 Effect of Depth of Cut, Feed and Spindle Speed on MRR.

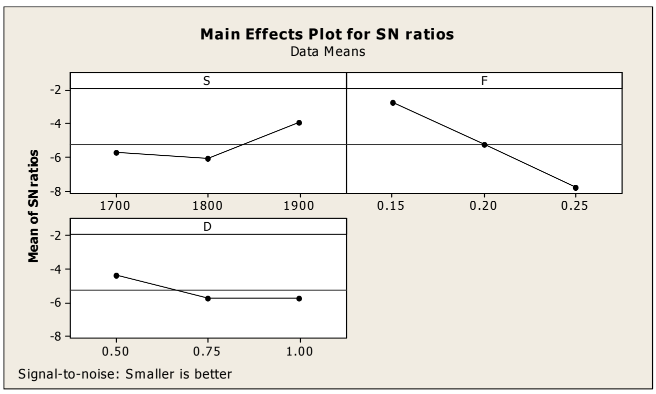

Figure. 8 Effect of Depth of Cut, Feed and Spindle Speed on Surface Roughness

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The following discussion focuses on the different of process parameters to the observed values (MRR and Ra) based on the Taguchi methodology.

Material Removal Rate (MRR):-

Main effects of MRR of each parameter for various level conditions are shown in Figure 7. According to Figure 7 the MRR increases with three major parameter S, F and D. MRR is maximum in the case of spindle speed(S) at level 3 (1900 m/min), in the case of feed (F) at level 3 (0.25mm/rev) and in the case of Depth of cut (D) at level 3 (1mm) So the optimal parameter setting for the MRR found **S3F3D3** and greatest variation found was due to spindle speed on MRR.

Surface Roughness (SR):-

Figure 8 evaluates the main effects of each parameters for various level conditions. According to the Figure 8 the surface Roughness decreases with three major parameter S, F and D. SR will be minimum in the **case of spindle speed (S) at level 2(1900m/min), in the case of feed (F) at level 1 (0.15mm/rev) and in the case of depth of cut (D)** condition surface Roughness will be minimum at level 3 (0.50mm). So the optimal parameter setting for minimum surface roughness is **S2F1D3** and greatest variation found was due to feed on surface roughness.

Table No.19 Comparison Result for Surface Roughness and MRR for Different Cutting Fluids

L9 Control Factor Array				Surface Roughness (µm)			Material Removal Rate (mm)		
EXP. NO	SPEED	FEED	DEPTH OF CUT	COTTON SEED OIL	SERVO CUT OIL	SOYA BEAN OIL	COTTON SEED OIL	SERVO CUT OIL	SOYA BEAN OIL
1	1	1	1	1.42	1.3	1.3	38.96	48.7	38.96
2	1	2	2	2	1.8	2	64.93	64.93	64.93
3	1	3	3	2.78	2.14	2.78	90.9	97.4	90.9
4	2	1	2	1.2	1.21	1.62	86.58	77.92	81.16
5	2	2	3	1.82	1.64	2.1	108.25	108.25	97.4
6	2	3	1	2.36	2.3	2.4	103.38	103.89	97.4
7	3	1	3	1.64	1.62	1.22	129.87	129.87	110.38
8	3	2	1	1.54	1.74	1.44	97.4	81.16	81.16
9	3	3	2	2.46	2.22	2.2	113.63	116.88	116.88

V. CONCLUSION

The main objective of experimental investigation done was to compare the performance of cutting fluid in terms of material removal rate and surface roughness by using different cutting parameters such as spindle speed, feed, depth of cut and different cutting fluids such as servo cut oil, cotton seed oil and soya bean oil. A statistically designed experiment based on Taguchi method was performed using L_9 orthogonal array to analyse surface roughness and MRR. The results obtained from analysis of S/N ratio and ANOVA were in close agreement.

1.Optimal parameters for surface roughness using servo cut oil was at spindle speed 1800m/min, feed 0.25 mm/rev and depth of cut 0.5 mm.

2. Optimal parameters for surface roughness using cotton seed oil was at spindle speed 1700m/min, feed 0.25and depth of cut 1 mm.

3. Optimal parameter for surface roughness using soya bean oil was at spindle speed 1700m/min, feed 0.25and depth of cut 1 mm.

The result obtained for the surface roughness of all the three cutting fluids i.e servo cut oil ,cotton seed oil and soya bean oil are in close proximity with each other as there is hardly difference of 1% to 10% and feed was found to be most significant factor for surface roughness.

4. Optimal parameters for MRR using servo cut oil was at spindle speed 1900m/min, feed 0.15 mm/rev and depth of cut 1 mm.

5. Optimal parameters for MRR using cotton seed oil was at spindle speed 1900m/min, feed 0.15 mm/rev and depth of cut mm.

6. Optimal parameters for MRR using soya bean oil was at spindle speed 1900m/min, feed 0.15 mm/rev and depth of cut 1mm.

The result obtained for the MRR of all the three cutting fluids those are servo cut oil ,cotton seed oil and soya bean oil are also in close proximity with each other as there is hardly difference of 1% to 10% and Spindle speed is found to be most significant factor for MRR. It was found that servo cut oil, cotton seed oil and soya bean oil had more considerable effect on the surface roughness and MRR. The cost of vegetable oils i.e. cottonseed oil & soya bean oil is lesser as compared with the servo cut oil and it is non hazardous , eco-friendly and easily available in ample amount.

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