Comparison and Optimization of Machining Parameters by using Taguchi Method

Atam Parkash Papreja
Principal
GGS POLYTECHNIC COLLEGE, Punjab, India

Vishav Kainth
Lecturer Mechanical
GGS POLYTECHNIC COLLEGE, Punjab, India

***Abstract* - In this study, three different conditions of cutting fluids viz. dry, synthetic oil and vegetable based coconut oil cutting fluids were used to determine optimum conditions for cutting force, tool chip inter face temperature, material removal rate and surface roughness. Taguchi L9 orthogonal array design of experiment was used for the experiment plan. Cutting speed, feed rate, depth of cut and coconut oil based cutting fluid were considered as machining parameters. Response tables and main effects plots ratios were used to analyze the results. The optimum values were calculated by using regression equations and were found to be cutting force (fx)- 27.93 kgf, cutting force (fy)- 34 kgf, tool inter face temperature -42.28 0^C, material removal rate -0.1175 gms/sec and surface roughness was 29.03 µm.**

Keywords - ***Cutting force, MRR, Ry, Tool chip inter face temperature, dry, synthetic oil, Vegetable based cutting fluids.***

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I. INTRODUCTION

With the opening of world economy and liberalization, there has been a cut throat competition among the manufacturers, suppliers and exporters Around the world leading to optimization of manufacturing practices for increasing productivity. For increasing productivity either cutting speed, depth of cut or feed has to be increased but this may lead to increase in cutting forces and tool chip inter face temperature because of higher friction which might cause reduction of tool life because of toolwear. F.W.Taylor in year 1894 observed that merely application of water jet at the cutting edge enabled increase of 33% cutting speed without compromising tool life. This led to extensive use of metal working fluids using crude oil derivatives because of their good lubricating properties. But, however, atomization and formation of mist and its inhalation by the workers posed severe health problems in addition to the serous loss to the environment (Dhar *et al*., 2007). Consequently, the stringent guidelines and standards set up by OSHA and ecological regulations have emphasized the need for dry machining, MQL or eco-friendly cutting fluid.

II. EXPERIMENTAL SET UP

A set of experiments were conducted on Lathe machine using EN31 material to determine effect of machining parameters namely feed rate (mm/rpm), Work speed (rpm), depth of cut (mm) and cutting fluid on metal removal rate, surface finish, cutting force and tool chip inter face temperature. L9 orthogonal array comprising three levels and four factors was used for design of experiments (DOE) based on Taguchi design. The machining parameters and their levels are shown in table 1. The chemical composition of EN 31 is shown in table 2 and L 9 orthogonal ray design of experiment is shown in table 3.

Table 1: Machining parameters and their levels

Parameters	Units	Levels		
Cutting speed	rpm	115	900	1800
Feed	mm/rev.	0.043	0.327	0.653
Depth of cut	mm	0.5	1.0	1.5
Cutting fluid		Dry	Synthetic oil	Coconut oil

Table II . Chemical composition of work piece material

Element	C	Si	Mn	P	S	Cr
Wt (%)	0.93	0.20	0.43	0.018	0.0047	1.43

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Table III. L9 orthogonal array and experimental results of Output Response parameters.

Cutting speed (m/min)	Feed (mm/rev)	Depth of cut (mm)	Cutting fluid	Cutting force (Fx)	Cutting force (Fy)	Ry (µm)
115	0.043	0.5	Dry	9	7	14.69
115	0.327	1.0	Synthetic oil	32	13	27.10
115	0.653	1.5	Coconut oil	39	14	23.18
900	0.043	1.0	Coconut oil	4	8	12.96
900	0.327	1.5	Dry	25	94	16.53
900	0.653	0.5	Synthetic oil	3	20	32.89
1800	0.043	1.5	Synthetic oil	7	12	16.90
1800	0.327	0.5	Coconut oil	12	12	14.69
1800	0.653	1.0	Dry	4	4	9.51

Table V. Analysis of variance

Source	DF	SS	MS	F	P
Cutting force (fx)	3	991.29	330.43	3.52	0.104
Cutting force (fy)	3	1119	373	0.36	0.783
Tool inter face temperature	3	73.65	24.55	1.17	0.409
Material removal rate	3	2.6854	0.8951	4.57	0.068
Surface roughness	3	176.16	58.72	1.07	0.439

TABLE IV. L9 orthogonal array and experimental results of Output Response parameters.

Cutting speed (m/min)	Feed (mm/rev)	Depth of cut (mm)	Cutting fluid	Tool/chip interface temp. 0^{C}	MRR (gms/sec)
115	0.043	0.5	Dry	34	0.078
115	0.327	1.0	Synthetic oil	35	0.19
115	0.653	1.5	Coconut oil	38	1.64
900	0.043	1.0	Coconut oil	35	0.105
900	0.327	1.5	Dry	37	0.85
900	0.653	0.5	Synthetic oil	33	0.33
1800	0.043	1.5	Synthetic oil	32	0.16
1800	0.327	0.5	Coconut oil	34	0.21
1800	0.653	1.0	Dry	33	1.79

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III CRITERIA USED FOR ANALYSIS OF OUTPUT RESPONSE PARAMETERS

Cutting force: The relative forces in a turning operation are important in the design of machine tools. The machine tool and its components must be able to withstand these forces without causing significant deflections, vibrations, or chatter during the operation and hence it is desired to have minimum cutting forces. Therefore, smaller the better criterion is used.

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Tool chip interface temperature: During metal cutting, the heat generated is significant enough to cause local ductility of the work piece material as well as of the cutting edge. Although softening and local ductility are required for machining hard materials, the heat generated has a negative influence on the tool life and performance [16]. Therefore minimum cutting temperature is required to achieve the desired tool performance and hence smaller the better criterion is used.

Material removal rate: In order to achieve higher productivity, it is desired to have maximum material removal rate and hence larger the better criterion is used.

Surface roughness: Surface roughness plays an important role in determining how a real object will interact with its environment. Rough surfaces usually wear more quickly and have higher friction coefficients than smooth surfaces. Roughness is often a good predictor of the performance of a mechanical component, since irregularities in the surface may form nucleation sites for cracks or corrosion. On the other hand, roughness may promote adhesion and hence smaller the better criterion is used.

IV. RESULTS AND ANALYSIS

Cutting force (Fx,Fy), Ry, MRR and Tool chip interface temperature versus Cutting speed, Feed, Depth of cut and cutting fluid

Result and analysis-cutting force (Fx): From the response table and main effects plot for S/N ratio, it has been observed that feed plays a significant role in influencing fx component of cutting force during metal cutting. The optimum value of cutting force-fx has been achieved with cutting speed of 115 rpm, feed of 0.325 mm/rev., depth of cut of 1.5 mm and coconut oil as cutting fluid and is calculated by following regression equation.
Regression equation for optimum value of cutting force-fx:
The regression equation is Fx in Kgf. = 5.2 - 0.0111 Cutting speed rpm + 13.5 Feed mm/rpm +15.7 Depth of cut mm

$= 5.2 – 0.0111*115 + 13.5 * 0.325 + 15.7 *1.5$

$= 5.2 – 1.2765 + 4.3875 + 23.55= 27.9375$

Table VI. Response table for S/N ratio for Fx

Level	**Cutting speed**	**Feed (mm/rev)**	**Depth of cut (mm)**	**Cutting fluid**
	Fx	**Fx**	**Fx**	**Fx**
1	-27.00	-16.01	-16.74	-19.69
2	-16.51	-26.55	-18.06	-18.85
3	-16.84	-17.80	-25.56	-21.82
Delta	-10.49	10.54	8.82	2.97

Table VII. Response table for S/N ratio for Fy

Level	**Cutting speed**	**Feed (mm/rev)**	**Depth of cut (mm)**	**Cutting fluid**
	Fy	**Fy**	**Fy**	**Fy**
1	-20.70	-18.85	-21.50	-22.80
2	-27.85	-27.78	-17.46	-23.29
3	-18.40	-20.33	-27.99	-20.86
Delta	9.45	8.93	10.53	2.44
Rank	2	3	1	4

Table VIII. Response table for S/N ratio for Ry

Level	**Cutting speed**	**Feed (mm/rev)**	**Depth of cut (mm)**	**Cutting fluid**
	Ry	**Ry**	**Ry**	**Ry**
1	-26.43	-23.38	-25.67	-22.42
2	-25.65	-25.46	-23.49	-27.85
3	-22.49	-25.74	-25.41	-24.30
Delta	3.95	2.35	2.18	5.43
Rank	2	3	4	1

Table IX. Response table for S/N ratio for Tool interface temperature

Level	**Cutting speed**	**Feed (mm/rev)**	**Depth of cut (mm)**	**Cutting fluid**
	T deg(0^C)	T deg(0^C)	T deg(0^C)	T deg(0^C)
1	-32.01	-30.98	-31.20	-31.70
2	-31.85	-32.02	-31.51	-30.59
3	-30.67	-31.53	-31.83	-32.23
Delta	1.33	1.04	0.63	1.64
Rank	2	3	4	1

Table XI. Response table for S/N ratio for Material removal Rate

Level	**Cutting speed**	**Feed (mm/rev)**	**Depth of cut (mm)**	**Cutting fluid**
	MRR	MRR	MRR	MRR
1	-10.762	-19.217	-15.114	-6.170
2	-10.259	-9.797	-9.648	-13.324
3	-8.138	-0.091	-4.3441	-9.611
Delta	2.623	19.125	10.770	7.153
Rank	4	1	2	3

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Result and analysis-cutting force (Fy): From the response table and main effects plot for S/N ratio, it has been observed that depth of cut plays a significant role in influencing fy component of cutting force during metal cutting. The optimum value of Cutting force-fy has been achieved with cutting speed of 900 rpm, feed of 0.325 mm/rev., depth of cut of 1.5 mm and synthetic oil as cutting fluid and is calculated by following regression equation. Regression equation for optimum value of cutting force-fy: -6.0 - 0.0020 Cutting speed rpm + 4.0 Feed mm/rpm + 27.0 Depth of cut mm

= -6.0 – 0.0020 * 900 + 4.0 * 0.325 +27 * 1.5

= -6.0 – 1.8 + 1.3 + 40.5= 34.0

Result and analysis for surface roughness (μm): From the response table and main effects plot for S/N ratios, it has been observed that cutting fluid plays a dominant role in influencing surface roughness during Metal cutting. The optimum value of surface roughness has been achieved with cutting speed of 115 rpm, feed of 0.647 mm/rev., depth of cut of 0.5 mm and synthetic oil and is calculated by the following regression equation.

The regression equation surface roughness (Ry): 21.2 – 0.00480 Cutting speed rpm + 11.5 Feed mm/rpm - 1.89 Depth of cut mm

= 21.2 – 0.0048* 115 + 11.5 * 0.647 + 1.89 * 0.5

= 21.2 -0.552 + 7.4405 + 0.945

= 29.0335

Result and analysis for tool inter face temperature: As observed from response table and main effects plot for SN ratios for tool inter face temperature that cutting fluid plays an important role in dissipating the heat generated during machining process. The optimum value of tool inter face temperature has been achieved with cutting speed of 115 rpm, feed of 0.325 mm/rev, depth of cut of 1.5 mm and coconut cutting fluid and is calculated by regression equation as given below.Regression equation for Tool inter face temp. (0c) = 36.5 - 0.00342 Cutting speed rpm + 3.63 Feed mm/rpm+ 3.33 Depth of cut mm

= 36.5-0.00342* 115 + 3.63*0.325 + 3.33 * 1.5

= 36.5-0.3933 + 1.1795 + 4.995

= 42.2812

Result and analysis for material removal rate: As is evident from response table and main effects plot for SN ratio that feed is predominant in achieving higher material removal rate and productivity. The optimum value of MRR has been achieved with cutting speed of 115 rpm, feed of 0.043 mm/rev, depth of cut of 0.5 mm and synthetic oil. The optimum value of material Removal rate is given by regression equation as given below.The regression equation for MRR gms. /sec = -0.779 + 0.000057 Cutting speed rpm + 1.90 Feed mm/rpm + 0.677 Depth of cut mm

= -0.779 + 0.000057 * 115 + 1.90 * 0.5

= -0.779 + 0.006555 + 0.95

= 0.177

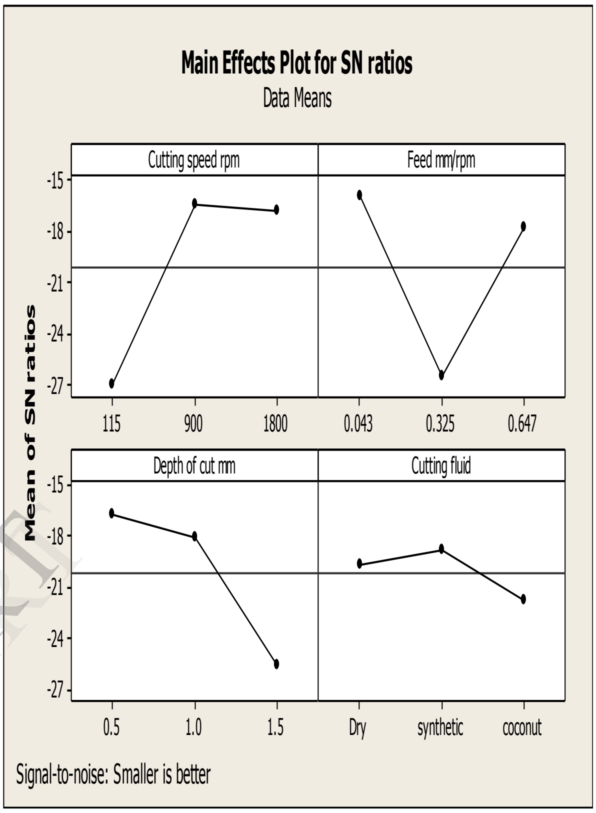

Figure1: Main effects plot for S/N ratio for cutting force Fx

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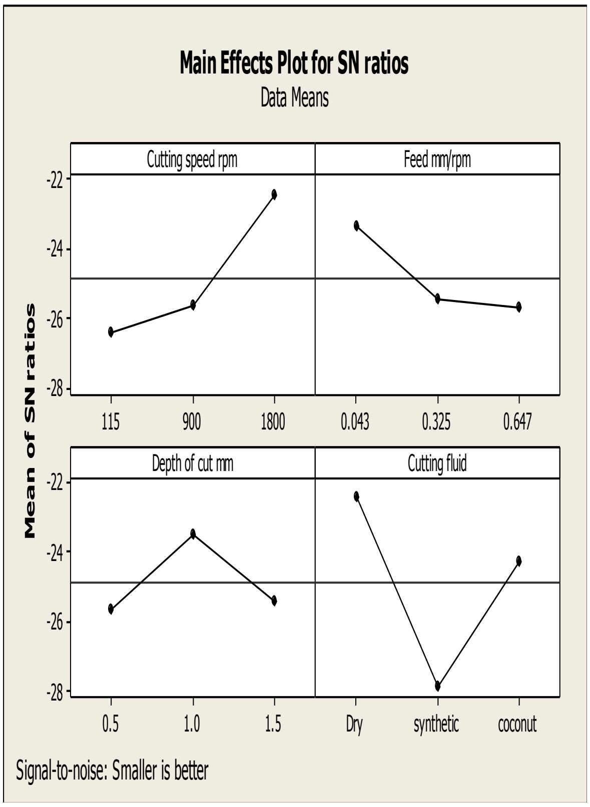

Fig 2: Main effects plot for S/N ratios For Cutting force-Fy

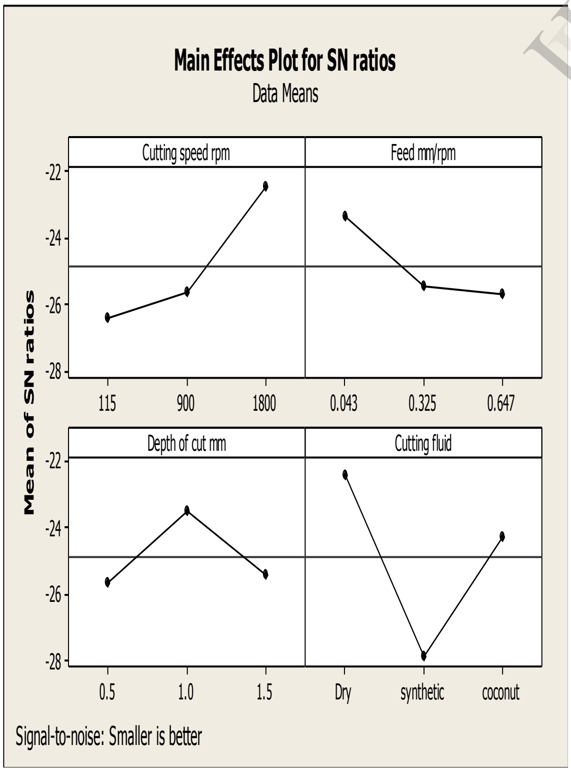

Fig 3: Main effects plot for S/N ratios for Ry

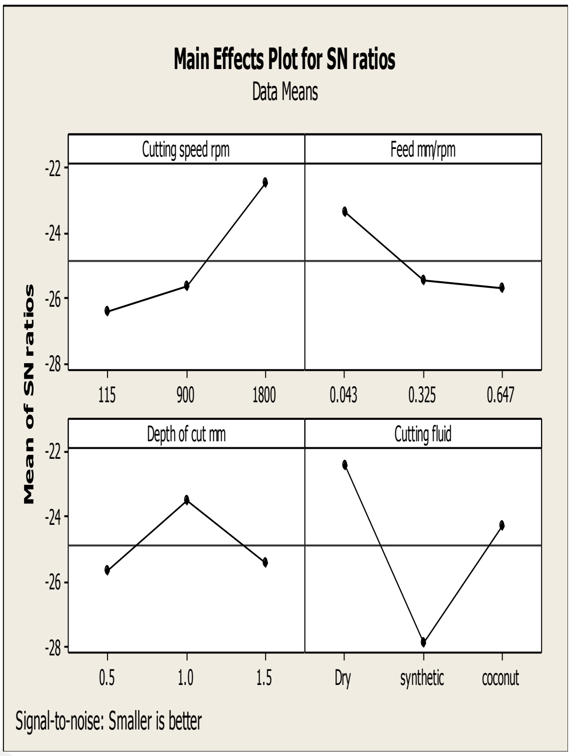

Fig 4: Main effects plot for S/N ratios for Tool inter face Temperature

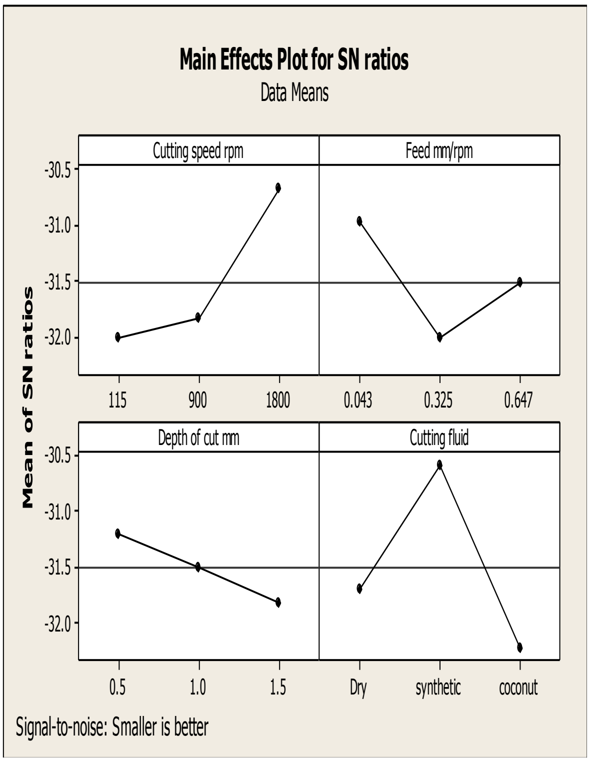

Fig 5: Main effects plot for S/N ratios for Material removal rate

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V CONCLUSION:

After comparing and analyzing the output response parameters of cutting force, tool chip interface temperature, material removal rate and surface roughness with different Cutting fluids, the optimum values of each output response parameter has been established and its use would depend upon type and criticality of application.

VI REFERENCES

[1] Galanis,N.I, Manolakos,D.E. and N. M. Vaxevanidis N.M "Comparison between dry and wet machining of stainless steel".
[2] University of Pretoria "Cutting fluid properties".
[3] Iowa Waste Reduction Center "A Practical Pollution Prevention Guide".
[4] Dr. Neil Canter Contributing Editor "The Possibilities and Limitations of dry machining."
[5] Shshidharna, Y.M and Jayaram, S.R "Experimental Determination of Cutting Power for Turning and Material Removal Rate for Drilling of AA 6061-T6 Using Vegetable Oils as Cutting Fluid."
[6] Chiffre, L., DE and Belluco, B. "Investigations of Cutting Fluid Performance Using Different Machining Operations."
[7] Kuram, E. and Ozcelik, B. "Fuzzy logic and regression modeling of cutting parameters in drilling using vegetable based cutting fluids."
[8] Lawal, S.A, , Choudhury, I.A. and Nukman, Y."Application of vegetable oil-based metal working fluids in machining ferrous metals—A review"
[9] Zhang,J.Z. Rao,P.N and Eckman,M. University "Experimental evaluation of a bio-based cutting fluid using multiple machining characteristics.
[10] Paul. S and Pal. P.K. "Study of Surface Quality during high speed machining using eco-friendly cutting fluid."
[11] Lavanya,T.D. and Annamalai,V.E. "Design of an Eco-Friendly coolant for grinding applications."
[12] Vaibhav Koushik A.V, Narendra Shetty,S and Ramprasad,C "Vegetable Oil-Based Metal Working Fluids-A Review"
[13] Silva, R.B.D, Machado, A.R, Almeida, D.O and Costa, E.S "Turning of Medium Carbon Steel with Vegetable-Based Oil delivered by MQL."
[14] Steven J. Skerlos "Prevention of metal working fluid pollution: Environmentally conscious manufacturing at the machine tool."
[15] Korat, M and Agarwal, N "Optimization of Different Machining Parameters of En24 Alloy Steel In CNC Turning by Use of Taguchi Method."
[16] Abhang, L.B and Hameedullah, M "Chip-Tool Interface Temperature Prediction Model for Turning Process".

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