Optimization of process parameters using Taguchi approach with minimum quantity lubrication for turning

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ABSTRACT

The performance of the manufactured products is often evaluated by several quality characteristics and responses and experimental techniques. In the present investigation a single characteristic response optimization model based on Taguchi Technique is developed to optimize process parameters, such as speed, feed, depth of cut, and nose radius of single point cutting tool. Taguchi's L9 orthogonal array is selected for experimental planning. The experimental result analysis showed that the combination of higher levels of cutting speed, depth of cut and lower level of feed is essential to achieve simultaneous maximization of material removal rate and minimization of surface roughness. This paper also aims to determine parametric relationship and its effect on surface finish.

Keywords: Optimization, Surface roughness ,Taguchi method, Orthogonal array & MRR.

1. INTRODUCTION

In the present investigation, a single characteristics optimization model based on Taguchi method employed to determine the best combination of the machining parameters such as cutting speed, feed, depth of cut and nose radius to attain the minimum surface roughness and maximum MRR simultaneously. In order to obtain optimal cutting parameters to achieve the best possible surface finish, manufacturing industries have resorted to the use of handbook based information and operators' experience. This traditional practice leads to improper surface finish and decrease in the productivity due to sub-optimal use of machining capability. This causes high manufacturing cost and low product quality [1]. In addition to the surface finish quality, the material removal rate (MRR) is also an important characteristic in turning operation and high MRR is always desirable . Hence, there is a need to optimize the process parameters in a systematic way to achieve the output characteristics/responses by using experimental methods and statically models. Dr. Taguchi employed design of turning of Free-machining [1,2]. Mild steel finds its application in general industrial and process-industry machinery and equipment, electrical machines-equipment, automotive industry, Structural, bus body etc., [3]. But, it is found that no work has been reported in the literature on single -response optimization of surface roughness and material removal rate in turning of mild steel. The predictive models obtained for performance measures. Confirmation tests are also conducted to verify the results. The conventional turning operation are unable to get a results at high cutting speed, feed of mild steel at minimum consumption of cutting fluid[5,6] . its an alternative approach to study the minimum quantity lubrication (MQL) as an alternative to conventional machining for quality and economical machining. The common factors that generally affected by improper cooling in conventional machining.

2. EXPERIMENTAL PROCEDURE

Turning is carried on a lathe that provides the power to turn the work piece at a given rotational speed and to as mentioned in table.1 feed to the cutting tool at specified rate and depth of cut. Therefore three cutting parameters namely cutting speed, feed and depth of cut need to be determined in a turning operation The turning operations are accomplished using a cutting tool with high hardness help to sustain the high cutting forces and temperature during machining create a harsh environment for the cutting tool. Therefore tool life is important to evaluate cutting performance in a turning operation. Surface roughness is another important factor to evaluate cutting performance.

2.1 Turning with minimum quantity lubrication

The MQL needs to be supplied at high pressure and impinged at high speed through the spray painting gun on the cutting zone. Considering the conditions required for the present work and uninterrupted supply of MQL at a constant pressure of around 6 bar over a reasonably long cut, a MQL delivery system was designed, fabricated and used. The schematic view of the MQL set-up is shown in Fig 1.

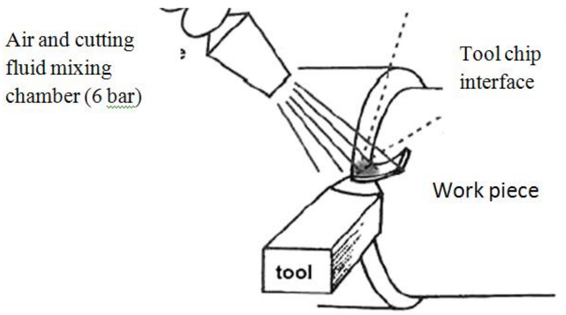

Figure.1minimum quantity lubrication set up

2.2Experimental condition for MQL

Basically, tool life and surface roughness correlated strongly with cutting parameters such as cutting speed, feed rate, and depth of cut. Proper selection of cutting parameters and tool can produce longer tool life and lower surface roughness. Hence, design of experiments by Taguchi method on cutting parameters was adopted to study the surface roughness, chip formation and tool wear.

Table1. : Experimental conditions

Machine tool:	3hp Lathe
Work-piece:	Mild Steel (size: Ø20mm×80 mm)
Cutting tool	HSS ,Miranda,S-400
Working tool geometry	8^0, 8^0, 6^0, 6^0, 12^0, 15^0, 0.8 (mm)
Cutting velocity, (Vc)	35,45, and 54 m/min
Feed rate, *So*:	0.034,0.058 and 0.80 mm/rev
Depth of cut, t:	0.18,0.25 and 0.32 mm
MQL supply:	Air: 6 bar, Lubricant: 160 ml/h
Environment:	Minimum (vegetable oil)Quantity lubrication (MQL)

3. TAGUCHI APPROACH

The philosophy of Taguchi is widely used. He suggested that engineering optimization of a process or product should be carried out in a three-step approach, i.e., system design, parameter design, and tolerance design. In system design, the engineer applies scientific and engineering knowledge to produce a basic functional prototype design, this design including the product design stage and the process design stage. In the product design stage, the selection of materials, components, tentative product parameter values, etc., are involved.[7] As to the process design stage, the analysis of processing sequences, the selections of production equipment, tentative process parameter values, etc., are involved. Since system design is an initial functional design, it may be far from optimum in terms of quality and cost.

3.1 Taguchi methods for design of experiments

Taguchi methods of experimental design provide a simple, effective and systematic approach for the optimization of experimental designs for performance quality and for expected economic production. This method is a unique and powerful statistical experimental design technique, which greatly improves the engineering productivity. For present study, identifying the product parameter values under the optimal process parameter values and the objective of the parameter design is to optimize the settings of the process parameter values for improving performance characteristics . the optimal process parameter values obtained from the parameter design are not responding to the variation of environmental conditions ,vibration etc. Therefore, the parameter design is the key step in the Taguchi method to achieving high quality without increasing cost. Nature and the economic consequences of quality engineering in the world of manufacturing.

3.2 Orthogonal arrays

Taguchi suggested, the use of the loss function to measure the performance characteristic deviating from the desired value, further transformed into a signal-to-noise ratio. there are three types of the performance characteristic in the analysis of the signal-to-noise ratio, i.e. the lower-the-better, the higher-the-better, and the nominal- the-better [1,6]. The S/N ratio for each level of process parameters is computed based on the S/N analysis. Regardless of the category of the performance characteristic, the larger S/N ratio corresponds to the better performance characteristic [6,10].Hence, the optimal level of the process parameters is the level with the highest S/N ratio. Furthermore, a statistical analysis of variance (ANOVA) is performed to see which process parameters are statistically significant. the optimal combination of the process parameters can be predicted. Finally, a confirmation experiment is conducted to verify the optimal process parameters obtained from the parameter design. In this paper, the cutting parameter design by the Taguchi method is adopted to obtain optimal machining performance in turning.

category-3 : $S/N_S = -10 \log (1/n \sum^{n}_{t=} y_i^2)$ (1)

Where, S/N_S –signal to noise ratio,$_y^2$ = Variance of y,

n = Number of observation ly = Observed data

the objective of S/N_T is to reduce variability around a specific target ,the goal of present work is to produce minimum surface roughness (Ra) and tool wear (V_B) in a turning operation. Smaller Ra and V_B values represent better or improved surface roughness and tool wear. Therefore, a smaller-the-better quality characteristic was implemented and introduced in this experiment. The use of the parameter design of the Taguchi method to optimize a process with multiple performance characteristics includes the following steps.

- Objective identification of an experiment
- The performance measures and its measurement systems identification.
- The characteristic of performance, their levels, Possible interactions identification
- Selection of OA and its allotment to the factors at their levels of the OA .
- Testing for the trials in the orthogonal array.
- Analysis of the experimental data using the signal-to-noise ratio
- verification of the optimal design parameters through confirmation experiment.

3.3 Selection of the factors and their levels

The cutting experiments were carried out on a 3hp Lathe by HSS cutting tool for the machining of Mild steel bars. The operating conditions such as speed, feed, and depth of cut and mode of machining which are generally controllable in any turning situation were selected as factors for study as per manufacturing data book as shown in table. 2.Therefore the initial cutting parameters were as follows: cutting speed 45 m/min; feed rate 0.054mm/rev; and depth of cut 0.2 mm. The feasible space for the cutting parameters was defined by varying the cutting speed in the range 35-54 m/min, the feed rate in the range 0.034-0.80, and the depth of cut in the range 0.2-0.4 mm .Three levels, having equal spacing, within the operating range of the machine were selected for each of the factors as shown in Table 2. By selecting three levels the curvature or the non-linearity effects could be studied.

Factor	Code	Level 1	Level 2	Level 3
Cutting Speed (m/min)	A	35	45	54
Feed (mm/rev)	B	0.034	0.58	0.80
Depth of Cut (mm)	C	0.18	0.25	0.32

Table 2. Process Parameter and their levels

3.4. Selection of OA and Assignment of factors

For the present study, Cutting speed, feed rate and depth of cut were selected as the machining parameters to analyze their effect on surface roughness, chip formation and tool wear as well. A total of 27 experiments based on Taguchi's L9 orthogonal array were carried out with different combinations of the levels of the input parameters. Experimental planning was prepared by using cutting parameters and test conditions that were advised for a couple of tool work piece by tool manufacturer and the information available in the literature. For the experiment having three factors at three levels the associated degree of freedom is 9. So the selected OA should have a minimum of nine rows (representing nine trials). The L9 OA which meets this requirement was selected. The layout of L9 OA with the factor level assignment from a table .3 shown below.

		Number of parameters							
No.	1	2	3	4	5	6	7	8	9
of levels	2	L4	L4	L8	L8	L8	L8	L12	L12
	3	L9	L9	L9	L18	L18	L27		
	4	L16	L16	L16					

Table 3. Standard L9 OA levels

The first column of the Table 4 was assigned to the Number of trial, the second to the Cutting speed (V), the third one to the Feed rate (S) and the Fourth one were assigned to the Depth of cut(D). It means a total 9 experimental number must be conducted using the combination of levels for each independent factor (speed, S; feed, F and depth of cut, D) for each environmental condition i.e. MQL with vegetable oil. It means that total 36 experimental numbers must be conducted using the combination of levels for each independent factor.

4. RESULT AND DISCUSSION

Taguchi uses the S/N ratio to measure the quality characteristic deviating from the desired value The transformation of the repetition data in a trial into a consolidated single value called the S/N ratio. the term S represents the mean value for the output characteristic while the N represents the undesirable value for the output characteristic. So the S/N ratio represents the amount of variation present in the quality characteristic. With the S/N and ANOVA analyses, the optimal combination of the process parameters can be predicted. Finally, a confirmation experiment is conducted to verify the optimal process parameters obtained from the parameter design. In this paper, the cutting parameter design by the Taguchi method is adopted to obtain optimal machining performance in turning. tool life and the corresponding S/N ratio for both under different environment condition using Eq^n.1 Since the experimental design is orthogonal, it is then possible to separate out the effect of each cutting parameter at different levels. For example, the mean S/N ratio for the cutting speed at levels 1, 2 and 3 can be calculated by averaging the S/N ratios for the experiments.

4.1 Experimental Results of Surface Roughness and Tool Wear V_B in MQL Condition

The relative importance amongst the cutting parameters for tool life still needs to be known so that optimal combinations of the cutting parameter levels can be determined more accurately in minimum quantity lubrication. the results of MQL condition experimentation will show the corrective ranges of surface roughness , tool wear at different levels of machining parameter levels in table.5

. N	tting Speed (m /min)	ed rate (mm /rev)	ept of cu (mm)	Surface oughness R_a mm	ool wear V_B Mm
1	1	1	1	1.65	0.18
2	1	2	2	2.0	0.15
3	1	3	3	3.9	0.17
4	2	1	3	2.23	0.31
5	2	2	1	3.7	0.36
6	2	3	2	3.2	0.31
7	3	1	2	1.0	0.57
8	3	2	3	2.3	0.67
9	3	3	1	4.1	0.58

Table 5. Surface roughness and Tool wear V_B in MQL condition

4.2 Experimental results for surface roughness, tool wear and S/N ratio in MQL condition

The mean S/N ratio for each level of the other cutting parameters can be computed in the similar manner. The mean S/N ratio for each level of the cutting parameters is summarized and called the S/N response table for surface roughness and tool life. In addition, the total mean S/N ratio for the nine experiments for surface roughness, tool wear is also calculated ,listed in Table.6 The greater S/N ratio corresponds to the smaller variance of the output characteristic around the desired value.

Sr.No.	A	B	C
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	3
5	2	2	1
6	2	3	2
7	3	1	2
8	3	2	3
9	3	3	1

Table 6. surface roughness, tool wear and S/N ratio

4.2.1 Average of mean S/N response for surface roughness in MQL condition

The Average mean S/N ratio for the nine experiments for

Trail no.	A	B	C	Surface oughness R_a –µm	Flank Wear V_B mm	S/N ratio For surface Roughness	S/N ratio for tool wear
1	1	1	1	1.65	0.18	-5.30	12.25
2	1	2	2	2.0	0.15	-6.38	13.79
3	1	3	3	3.9	0.17	-10.85	9.17
4	2	2	3	2.23	0.31	-7.64	6.85
5	2	3	1	3.7	0.36	-10.16	8.15
6	2	1	2	3.2	0.31	-9.88	7.67
7	3	3	2	1.0	0.57	0.87	3.81
8	3	1	3	2.3	0.67	-6.54	3.54
9	3	2	1	4.1	0.58	-12.22	3.82

surface roughness, tool wear is also calculated ,listed in Table.7 for surface roughness and tool wear. The greater

Table 7. S/N response table for surface roughness

S/N ratio corresponds to the smaller variance of the output characteristic around the desired value. 1 Since the experimental design is orthogonal, it is then possible to separate out the effect of each cutting parameter at different levels. the mean S/N ratio for the cutting speed at levels 1, 2 and 3 can be calculated by averaging the S/N ratios for the experiments.

Symbol	Cutting Parameter	Mean S/N ratio (dB)			
		Level 1	Level 2	Level 3	Max-Min
A	Cutting speed	-7.30	-9.11	-5.76	3.35
B	Feed rate	-3.32	-7.72	-11.13	7.8
C	Depth of cut	-9.14	-4.51	-8.43	3.41

Total mean S/N ratio = -7.36 db

The mean S/N ratio for the cutting speed at levels 1, 2 and 3 can be calculated by averaging the S/N ratios for the experiments and in Fig. 2 shows the S/N response graph for surface roughness and tool wear.

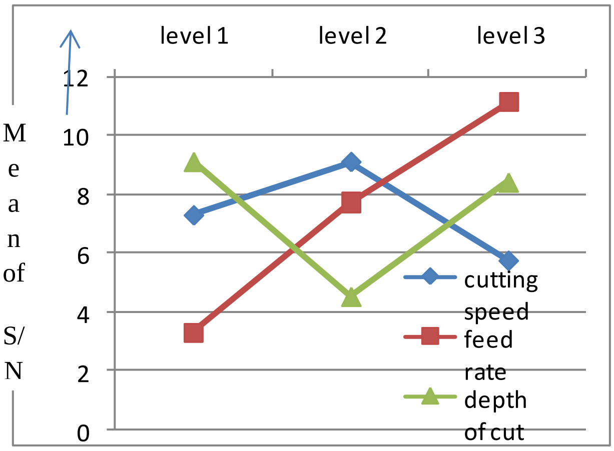

Figure .2 The mean single-to-noise graph for surface roughness.

4.2.2 Average of mean S/N response for tool wear in MQL condition

The Average mean S/N ratio for the nine experiments for tool wear is also calculated ,listed in Table.8.The greater S/N ratio corresponds to the smaller variance of the output characteristic around the desired value. 1 Since the experimental design is orthogonal, it is then possible to separate out the effect of each cutting parameter at different levels. the mean S/N ratio for the cutting speed at levels 1, 2 and 3 can be calculated by averaging the S/N ratios for the experiments.

Symbol	Cutting Parameter	Mean S/N ratio (dB)			
		Level 1	Level 2	Level 3	Max-Min
A	Cutting speed	12.17	5.85	1.52	8.65
B	Feed rate	7.43	7.48	6.75	0.71
C	Depth of cut	7.43	8.02	6.32	0.9

Table 8. S/N response table for tool wear

The total mean S/N ratio = 7.25 dB

The mean S/N ratio for the cutting speed at levels 1, 2 and 3 can be calculated by averaging the S/N ratios for the experiments and in Fig. 3 shows the S/N response graph for tool wear.

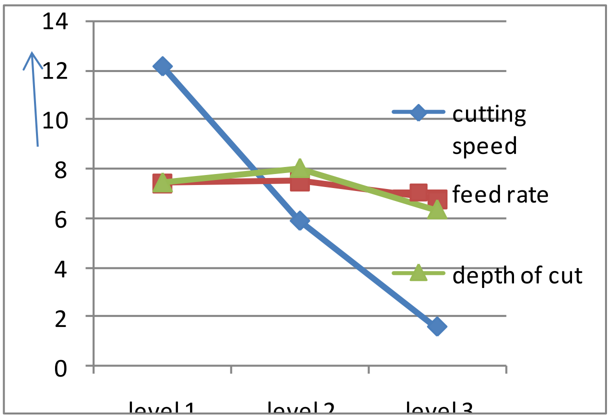

Figure.3 The mean S/N graph for tool (flank) wear.

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5.Conclusion

Optimisation of turning parameters using this technique is directly inclined toward s economic solution for the user machining industry.MQL is a technique that could reduce many cutting problems coming from high consumptions of lubricant, like high machining costs or environmental and worker health problems. Taguchi's robust orthogonal array design method is most suitable for analysis of the surface roughness and tool wear problem during turning operation. The cutting performance of MQL machining is better than that of conventional machining with flood cutting fluid supply. In the turning of mild steel ,The experimental results shows that the cutting speed , feed rate and depth of cut are the main parameters that can control the tool wear

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References

[1] W.H.Yang, Y.S.Tarng. Design optimization of cutting parameters for turning operations based on the Taguchi method. J Mater Process Technol 1998; 84:122–9.

[2] N.R.Dhar, S.Islam, M.W., Islam, Mithu, M.A.H., 2006. The influence of minimum quantity of lubrication (MQL) on cutting temperature, chip and dimensional accuracy in turning AISI-1040 steel.J.Mater. Process.Technol. 171, 93–99.

[3] J.P.Davim, Sreejith, P.S., Silva, J., 2007. Turning of brasses using minimum quantity of lubricant (MQL) and flooded-lubricant conditions. Mater. Manuf. Process. 22, 45–50.

[4] J.P.Davim, P.S.Sreejith, R.Gomes, C.Peixoto, 2006.Experimental studies on drilling of aluminium (AA1050) under dry, minimum quantity of lubricant, and flood-lubricated conditions. Proc. ImechE Part B: J. Eng. Manuf. 220, 1605–1611.

[5] M.C. Shaw, Metal Cutting Principles, Oxford University Press, New York, 1984.

[6] W.H.Yang, Y.S.Tarng, 1998, Design optimization of cutting parameters for turning operations based on the Taguchi method, Journal of Material Processing Technology.

[7] N.R. Dhar, M.T. Ahmed, S. Islam, An experimental investigation on effect of minimum quantity lubrication in machining AISI 1040 steel, International Journal of Machine Tools & Manufacture 47 (2007) 748–753.

[8] S. Shaji, V. Radhakrishnan, Analysis of process parameters in surface grinding with graphite as lubricant based on the Taguchi metsssssssssssssshod, Journal of Materials Processing Technology 141 (2003) 51–59.

[9] A. Attanasio, M. Gelfi, C. Giardini, C. Remino, Minimal quantity lubrication in turning: Effect on tool wear, Journal of Materials Processing Technology 260 (2006) 333–338.

[10] M.M.A. Khan, M.A.H. Mithu, N.R. Dhar, Effects of minimum quantity lubrication on turning AISI 9310 alloy steel using vegetable oil-based cutting fluid, Journal of Materials Processing Technology 209 (2009) 5573–5583.

[11] Minimum Quantity Lubrication Product Range.

[12] Vishal S.Sharma, Manu Dogra, N.M.Suri, Cooling techniques for improved productivity in turning, International Journal of Machine Tools & Manufacture 49 (2009) 435–453.

[13] V.N. Gaitondea, S.R. Karnik, J. Paulo Davim, Selection of optimal MQL and cutting conditions for enhancing machinability in turning of brass, journal of materials processing technology204 (2008) 459–464.