

Study of Parameter Optimization Vanadium Steel Using Taguchi Technique

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Abstract: The aim of the present study is to show the influence of different input parameters such as machining, surface finish & mechanical properties during the turning Process of Vanadium steel. The microstructure, hardness and tensile strength of Vanadium steel are investigated in this study. The selected three input parameters were varied at three levels. On the analogy, nine experiments were performed based on L9 orthogonal array of Taguchi's methodology, which consist three input parameters. Analysis of variance (ANOVA) was employed to find the levels of significance of input parameters.

Keywords: Turning, Vanadium Steel, ANOVA, Taguchi

1. Introduction

Turning is a method that can be used to remove unwanted material from steel in order to get its required shape and size. Turning process is defined as machining of steel with hardness greater than 207 BHN. The temperature generated during turning is substantially higher when compared to conventional machining. Turning is a machining process to produce parts round in shape by a single point tool on lathes. The tool is fed either linearly in the direction parallel or perpendicular to the axis of rotation of the work piece, or along a specified path to produce complex rotational shapes. The primary motion of cutting in turning is the rotation of the work piece, and the secondary motion of cutting is the feed motion.

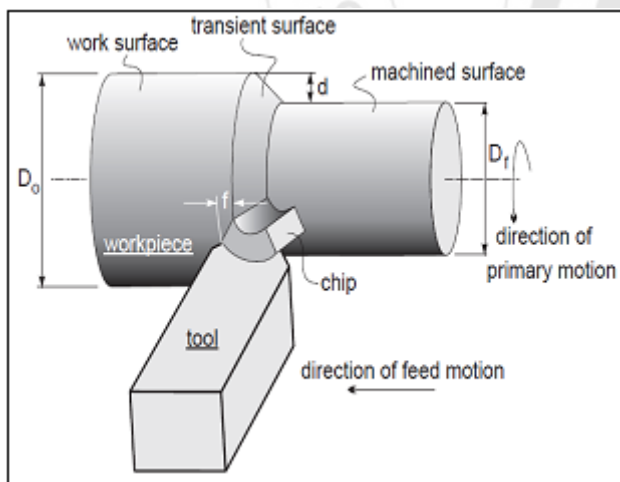


Figure 1.1: Turning Operations

1.1 Background

Turning has emerged as a viable alternative to grinding for finish machining of steels. Steel is widely used in manufacturing components such as gear, bearing, tools and die (Kalpakjian and Schmid, 2006). Its properties of high wear resistance, good corrosion resistance and high surface finish have resulted in this material to be used in producing the components mentioned. Hard turning is performed on materials with hardness within the 45–68 Rockwell Hardness range using a variety

of tipped or solid cutting inserts. Although grinding is known to produce good surface finish at relatively high feed rates, hard turning can produce as good or better surface finish at significantly higher material removal rates (Huddle D., 2001). Grinding has traditionally been used to finish machine hardened steel. The technique has some limitations: it is time consuming and only limited range of geometries can be produced. The development of advanced cutting tool materials has led to the improvement in the cutting process of hardened steel. Studies have shown that using the right combination of insert nose radii, feed rate or the new insert technology, hard turning can produce better surface finish and less tool wear than grinding.

1.2 Cutting Conditions in Turning

Cutting speed in turning V in m/s is related to the rotational speed of the workpiece by the equation:

$$V = \pi DN$$

Where D is the diameter of the workpiece, m; N is the rotational speed of the workpiece, rev/s.

One should remember that cutting speed V is always a linear vector. In the process planning of a turning operation, cutting speed V is first selected from appropriate reference sources or calculated as discussed in Section 5.10 Selection of Cutting Conditions, and the rotational speed N is calculated taking into account the workpiece diameter D . Rotational speed, not cutting speed, is then used to adjust lathe setting levers.

Feed in turning is generally expressed in mm tr-1 (millimetre per revolution).

The turning operation reduces the diameter of the workpiece from the initial diameter D_0 to the final diameter D_f . The change in diameter is actually two times depth of cut, d :

$$2d = D_0 - D_f$$

The volumetric rate of material removal (so-called material removal rate, mrr) is defined by

$$mrr = Vfd$$

When using this equation, care must be exercised to assure that the units for V are consistent with those for f and d.

2. Literature Review

In this chapter, review of relevant literature explaining various factors affecting, material removal rate, surface roughness during finish hard turning has been made. The salient features of the most relevant research works are reported in the following text.

Patel et al [2014] explains in his paper that Alloy Steel has a wide variety of applications in different industries. The Challenge of modern machining industries is mainly focused on achieving high quality, in term of part/component accuracy, surface finish, high production rate and increase the product life with lesser environmental impact. It is necessary to change and improve existing technology and develop product with reasonably priced. So, it is necessary control the process parameter in any manufacturing process. The typical controllable machining parameters for the CNC lathe machines are speed, feed, depth of cut, tool geometry, cutting environment, tool material, work material, etc. which affect desired output like material removal rate, surface roughness, power consumption, tool wear, vibration etc. Optimization of machining parameters and also need to determine which parameters are most significant for required output. One of the techniques widely used for optimization of machining parameters is Taguchi and ANOVA approach help to determine which parameters are most significant.

Quazi et al [2014] study various techniques for the optimization for that purpose literature review and industrial survey is conducted. The objective of this study was to utilize Taguchi methods to optimize surface roughness in turning mild steel, EN-8 and EN-31. The turning parameters evaluated are cutting speed of 200, 250, and 300 m/min, feed rate of 0.08, 0.12 and 0.15 mm/rev, depth of cut of 0.5 mm and tool grades of TN60, TP0500 and TT8020, each at three levels. The experiment was designed and carried out on the basis of standard L9 Taguchi orthogonal array. The results show that the Taguchi method is suitable to solve the stated problem with minimum number of trials as compared with full factorial design.

Kumar et al [2013] states that many manufacturing industries involve machining operations. In metal cutting the turning process is one of the most fundamental cutting processes used. Surface finish and dimensional tolerance, are used to determine and evaluate the quality of a product, and are major quality attributes of a turned product. In this paper experimental work has been carried out for the optimization of input parameters for the improvement of quality of the product of turning operation on CNC machine. Feed Rate, Spindle speed & depth of cut are taken as the input parameters and the dimensional tolerances as output parameter. In the present work L9 Array has been used in design of experiment for optimization of input parameters. This paper attempts to introduce and thus verifies experimentally as to how the Taguchi parameter design could be used in identifying the significant processing parameters and optimizing the surface roughness in the turning operation. The present work shows that spindle speed is the

key factor for minimizing the dimensional variation for minimizing the surface roughness.

Korat et al [2012] outlines an experimental study to optimize the effects of cutting parameters on surface finish and MRR of EN24/AISI43 work material by employing Taguchi techniques.

The orthogonal array, signal to noise ratio and analysis of variance were employed to study the performance characteristics in turning operation. Five parameters were chosen as process variables: Speed, Feed, Depth of cut, Nose radius, Cutting environment (wet and dry). The experimentation plan is designed using Taguchi's L18 Orthogonal Array (OA) and Minitab 16 statistical software is used. Optimal cutting parameters for, minimum surface roughness (SR) and maximum material removal rate were obtained. Thus, it is possible to increase machine utilization and decrease production cost in an automated manufacturing environment

3. Methodology

The work piece material was Vanadium steel shown as in Figure 3.1. Vanadium steel is a high carbon Alloy steel which achieves a high degree of hardness with compressive strength and abrasion resistance. By its character this type of steel has high resisting nature against wear and can be used for components which are subjected to severe abrasion, wear or high surface loading.



Figure 3.1: Material: Vanadium steel

3.1 Statistics of the use of vanadium

The world consumption of vanadium is today (1999) some 34000 tonnes per annum, of which 28000 tonnes in the Western world.

The predominant application of vanadium is for alloying of steel and cast iron. It amounts to about 85 % of the total consumption, a share that appears rather stable over time.

The remaining part goes to chemicals and to alloying of titanium. World-wide about 65% of the vanadium for alloying of steel is used in micro alloyed structural steels, whereas the remaining 35% is used in V-alloyed steels, such as high speed and tools steels, high temperature low alloy steel, etc.

Table 1: Composition of alloying element in Vanadium steel

C%	Si%	Mn%	S%	P%	Ni%	Cr%
0.20	0.29	1.49	0.014	0.035	0.043	0.126

Mo%	V%	Cu%	Al%	B%	Pb%	Fe%
0.018	0.106	0.084	0.023	0.0005	<0.0005	97.5

3.2 Surface Roughness Analyzer

A Mitutoyo SurfTest SJ-301 Portable Surface Roughness Tester was used to measure the roughness profile data after each cut. Specifications are given below:

- Make Mitutoyo, Japan
- Model SurfTest SJ-301
- Measurement range 200 μm to +250 μm
- Stylus material Diamond
- Tip radius 2 μm / 5 μm
- Measuring force 4 mN (0.4 gf)
- Cut-off length 0.8 mm-2.5 mm



Figure 3.2: Mitutoyo Surface Roughness tester

Experimental Plan

In this experiment, Taguchi OA Design L_9 was used to design the experimental plan. Cutting speed, feed rate and depth of cut were varied in this experiment.

Table 2: Cutting condition for the experiment

Cutting parameter	Unit	Level 1	Level 2	Level 3
Cutting speed	m/min	120	140	160
Feed rate	mm/rev	0.05	0.10	0.15
Depth of cut	mm	0.1	0.2	0.3

The concept of Design of Experiment was first introduced in early 1920 in a small station of Agricultural Research in England, by a scientist called Sir. Ronald Fisher. He showed that a valid experiment could be conducted in the presence of many natural conditions variables, such as: temperature, soil conditions and rainfall. The principles of experimental design first used in agriculture have been adapted successfully in industry and in military applications since 1940 (Franceschini and Macchietto, 2008).

Montgomery (1997) states that before starting the experimentation it is important to establish the planning of experiments. He emphasized the importance of the problem domain by all those involved in the experiment, and recommended that during the implementation process is carefully monitored to ensure that everything be done according to plan.

The DOE is a technique used to define what data, in what quantity and conditions should be collected during an experiment, trying to satisfy two major goals: the statistical accuracy of the response and lower cost (Gunasegaram et al., 2009).

3.3 Procedure to determine the appropriate Orthogonal Array (OA)

- 1) Define the number of factors and their levels.
- 2) Determine the degrees of freedom.
- 3) Select an orthogonal array.
- 4) Consider any interactions.
- 5) Degree of freedom of orthogonal array is always greater than degree of freedom of factors and interactions.

For this case the Orthogonal Array of $L_9(3)^3$ has been selected.

Where,

9 means number of trials

(3) Means number of levels of each factor

()³ means number of factors.

L_9 Orthogonal Array- (3)³ for Surface Roughness (Ra) and Material Removal Rate

Table 3: Taguchi's recommended orthogonal array design

Experiment	Speed	Feed	D.O.C
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

Experimental Orthogonal Array – L_9 OA (3)³ for Surface Roughness (Ra) and Material Removal rate

Table 4: Experimental orthogonal array

Experiment	A	B	C
	Speed	Feed	D.O.C
1	120	0.05	0.1
2	120	0.10	0.2
3	120	0.15	0.3
4	140	0.05	0.2
5	140	0.10	0.3
6	140	0.15	0.1
7	160	0.05	0.3
8	160	0.10	0.1
9	160	0.15	0.2

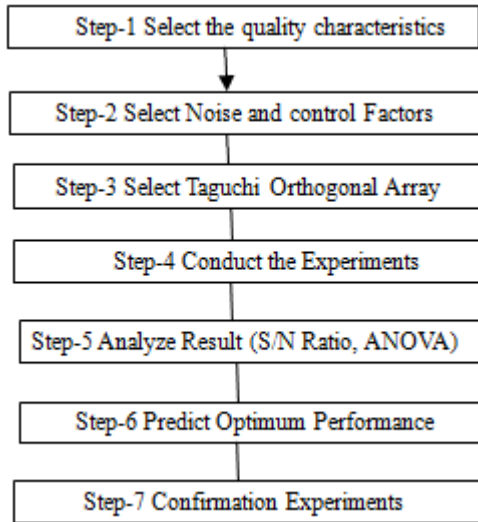
Response Parameters for orthogonal array- OA $L_9(3)^3$ Surface Roughness (Ra) and Material Removal rate.

Table 5: Response Ra and MRR

Experiment	A	B	C	Ra	MRR
	Speed	Feed	D.O.C		
1	120	0.05	0.1	4.90	5.29
2	120	0.10	0.2	5.50	4.87
3	120	0.15	0.3	5.70	4.61
4	140	0.05	0.2	7.75	7.89
5	140	0.10	0.3	6.32	5.70
6	140	0.15	0.1	6.80	6.83
7	160	0.05	0.3	5.45	6.15
8	160	0.10	0.1	4.50	6.10
9	160	0.15	0.2	7.29	7.50

4. Result and Discussion

The main effects can be studied by the level average response analysis of raw data or of S/N data. The analysis is done by averaging the raw or S/N data at each level of each parameter and plotting the values in graphical form. The level average responses from the raw data help in analyzing the trend of the performance characteristics with respect to the variation of the factor under study. The level average response plots based on the S/N data help in optimizing the objective function under consideration. The lower points of these plots correspond to the optimum condition for average surface roughness.



Analysis of variance (ANOVA) is performed and signal-to-noise (S/N) ratio will be determined to know the level of importance of the machining parameters. To obtain the optimal machining performance the higher the better quality characteristics for Surface Roughness and MRR. As can be seen from Table (above), the MRR is most significantly influenced by the feed followed by the Depth of cut. The respective values of these parameters are 1.71 and 2.11. S/N ratio are calculated and graph for analysis is drawn by using Minitab 16 software. The S/N ratio for MRR is calculated on Minitab 16 Software using Taguchi Method.

The greater average S/N ratio corresponds to the max MRR. From the S/N response table 5.5, it is concluded that the optimum parametric combination is Speed (140), Feed (0.15), and depth of cut (0.2). In other words, it is this combination of parameters that gives the max MRR for the machined material.

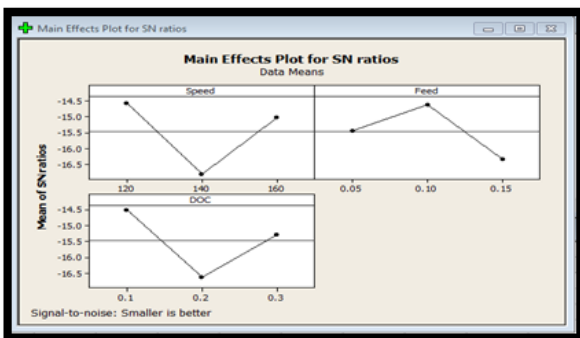


Figure 4.1: S/N graph for Surface Roughness

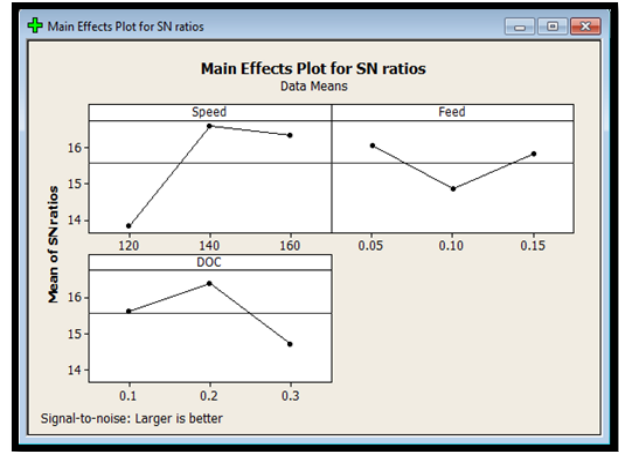


Figure 4.2: S/N graph for Material Removal Rate

Table 6: Response for Means

Level	Speed(A)	Feed(B)	DOC(C)
1	5.367	6.033	5.400
2	6.957	5.440	6.847
3	5.747	6.597	5.823
Max-min	1.590	1.157	1.447
Rank	1	3	2

S/N Ratio analysis for Material Removal Rate (MRR)

Analysis of MRR versus Speed, Feed, DOC

Table 7: Response for Signal to Noise Ratios Larger is better

Level	speed	feed	DOC
1	13.83	16.06	15.62
2	16.58	14.86	16.40
3	16.33	15.82	14.72
Max-min	2.75	1.20	1.67
Rank	1	3	2

Table 8: Response for Means

Level	Speed	Feed	DOC
1	4.923	6.443	6.073
2	6.807	5.557	6.753
3	6.583	6.313	5.487
Max-min	1.883	0.887	1.267
Rank	1	3	2

ANOVA results for Surface roughness (Ra)

Table 9: ANOVA results for Surface roughness

	Degree of Sum of Mean Percentage of freedom(DF)	Square s	Square	Contribution (%)
Speed	2	4.14	2.07	43.24
Feed	2	2.01	1.00	20.98
DOC	2	3.32	1.66	34.70
Error	2	0.10	0.052	1.08

Table 10: ANOVA results for Material Removal Rate (MRR)

	Degree of Freedom (DF)	Sum of square S	Mean square	Percentage of contribution (%)
Speed	2	6.35	3.18	61.98
Feed	2	1.38	0.69	13.42
DOC	2	2.41	1.21	23.53
Error	2	0.11	0.052	1.07

5. Conclusions

Based on analysis of data and discussion of results, several important conclusions are drawn during hard turning of Vanadium steel as under.

The percentage contribution of input parameters on Surface Roughness (Ra) is: Speed = 43.24%, Feed rate = 20.98% and DOC. =34.70%, signifying the cutting speed to be the most contributing factor influencing Surface Roughness.

The percentage contribution of input parameters on Material Removal Rate (MRR) is: Speed = 18.36%, Feed rate = 23.67% and DOC. =8.74%, signifying the feed rate to be the most contributing factor influencing surface roughness.

The optimized machining conditions for minimizing Surface Roughness from Taguchi analysis are approaching: cutting speed 140 m/min., feed 0.15 mm/rev., depth of cut 0.20 mm.

The optimized machining conditions for maximizing Material Removal rate from Taguchi analysis are approaching: cutting speed 140 m/min., feed 0.05 mm/rev., depth of cut 0.2 mm.

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Author Profile



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