

Research Article

Optimization of Process Parameters on CNC Turning

Ankush Singla* and Taljeet Singh

Chandigarh Group of Colleges, Landran (Punjab), India

Accepted 22 April 2016, Available online 27 April 2016, Vol.6, No.2 (April 2016)

Abstract

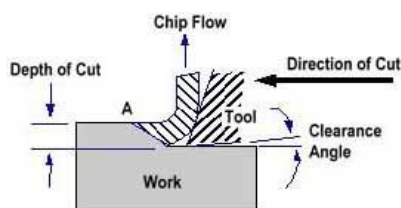
Machining process involves several process parameters. Achieving the right dimension, good surface quality, and maximized metal removal are of utmost importance. The research work Vanadium steel machining with CNC surface roughness parameters for turning cutting optimization is described. Required surface quality control is necessary. In this study, Taguchi method for surface roughness in turn is used to find the optimal cutting parameters. L-9 orthogonal array, the signal-to-noise ratio, and analysis of variance vanadium steel turning operations are employed to study the performance characteristics. A precise knowledge of the optimal machining parameters to facilitate cost reduction and product quality improvement. The process of turning the present study the most effective process parameters, namely, cutting feed, speed and depth of cut, which surface roughness and material removal rate are adapted to consider a response surface method is applied.

Keywords: Optimization, CNC turning etc.

Introduction

Hard turning is a method that can be used to remove unwanted material from hardened steel in order to get its required shape and size. The hard turning process is defined as machining of steel with hardness greater than 45 HRC. The temperature generated during hard turning is substantially higher when compared to conventional machining.

Metal cutting and turning -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 shows the turning operation.



Chip formation

There are three types of chips that are commonly produced in cutting,

- Discontinuous chips
- Continuous chips
- Continuous chips with built up edge

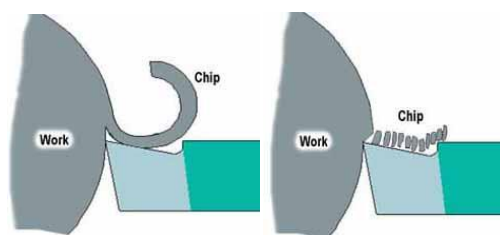


Fig. Continuous Chip & Discontinuous Chip

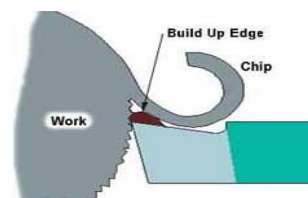


Fig. Continuous Chip with build up edge

- A discontinuous chip comes off as small chunks or particles. When we get this chip it may indicate, brittle work material, small or negative rake angles, coarse feeds and low speeds
- A continuous chip looks like a long ribbon with a smooth shining surface. This chip type may indicate, ductile work materials, large positive rake angles, Fine feeds and high speed

*Corresponding author: Ankush Singla

Cutting tool materials for Hard Turning

The cutting tool materials must possess a number of important properties to avoid excessive wear, fracture failure and high temperatures in cutting, the following characteristics are essential for cutting materials to withstand the heavy conditions of the cutting process:

- **Hardness:** at elevated temperatures (so-called hot hardness) so that hardness and strength of the tool edge are maintained in high cutting temperatures:
- **Toughness:** ability of the material to absorb energy without failing. Cutting is often accompanied by impact forces especially if cutting is interrupted, and cutting tool may fail very soon if it is not strong enough
- **Wear resistance:** although there is a strong correlation between hot hardness and wear resistance, later depends on more than just hot hardness. Other important characteristics include surface finish on the tool, chemical inertness of the tool material with respect to the work material, and thermal conductivity of the tool material, which affects the maximum value of the cutting temperature at tool-chip interface.
- **Cutting tool can be categorized into several groups;** high speed steels, carbides, ceramic, cubic boron nitride and diamond. Each type of tools has different properties and this makes it suitable for use to machine certain material.

Literature Review

Mihir T. 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 terms of part/component accuracy, surface finish, high production rate and increase the product life with lesser environmental impact. So, it is necessary to 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.

Durai Matinsuresh Babu *et al* [2012] explains the findings of the experimental results that were obtained to select appropriate cutting parameters that ensure less power consumption in high-tare CNC machines. Using Taguchi's technique, experiment was conducted with an extruded aluminium shaft on a CNC lathe with cutting speed, feed rate and depth of cut as process

parameters. Power consumed (energy), the output characteristic was measured with the help of a data acquisition system. The data were analyzed and appropriate process parameters were selected for minimum energy consumption.

Taquiuddin 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.

Y.B. Kumbhar *et al* [2013] illustrates that Tool wear and surface roughness prediction plays a significant role in machining industry for proper planning and control of machining parameters and optimization of cutting conditions. In this paper, Taguchi approach is used to find optimum process Parameters for turning while semi hard machining of hardened EN31 alloy steel. A L9 orthogonal array, signal-to-noise ratio and analysis of variance (ANOVA) are applied to study performance characteristics of machining parameters (cutting speed, feed rate and depth of cut) with consideration of surface finish and tool life. The conclusions revealed that the feed rate was the most influential factor on the surface roughness and tool life. Experimental results are provided to illustrate the effectiveness of the proposed approach.

Problem Formulation

From the literature review, it is revealed that a number of studies pertaining to hard turning of various grades of hardened steels with carbide tools have been conducted.

- Most of the investigation done on hard turning was on hardened steel between 40-50 HRC.
- The present study will be focused on hard turning of vanadium steel. The study will attempt to investigate the following objectives:
- Investigation of the effect of cutting speed, feed rate and depth of cut on surface roughness.
- Investigation of the effect of cutting speed, feed rate and depth of cut on material removal rate.

Research Methodology

Work piece material

Vanadium is the most widely used alloying element for strengthening steels used in buildings and bridges, and

is the most effective alloy for increasing the strength of reinforcing bars used in construction.

Vanadium steel is ideal for use with heavy machinery because it creates good castings, retains a cutting edge, and exhibits very little wear even at high temperatures. It is also commonly used in cars for doors and chassis, and for joists and girders in buildings and bridges. Often desired for its lighter weight, it is also desirable for its resistance to erosion by salt water and hydrochloric and sulfuric acids

Applications

- The most important use of vanadium is as an additive for steel, with approximately 80% of vanadium going into ferrovanadium, a steel additive. It is used for the production of rust resistant, spring and high speed tool steels. It is also added to steels to stabilise carbides.
- Vanadium foil is also used to bond titanium to steel. Due to its low fission neutron cross section vanadium is also used in nuclear applications.



Fig. Material: Vanadium Steel

Experimental Plan

In this experiment, Taguchi OA Design L₉ was used to design the experimental plan. Cutting speed, feed rate and depth of cut were varied in this experiment.

Cutting parameter	Unit	Level 1	Level 2	Level 3
Cutting speed	m/min	1000	1200	1400
Feed rate	mm/rev	0.1	0.2	0.3
Depth of cut	mm	0.4	0.5	0.6

Experimental Orthogonal Array -L₉ OA (3)³ for Surface Roughness (Ra) and Material Removal rate

Experiment	A	B	C
	Speed	Feed	DOC
1	1000	0.1	0.4
2	1000	0.2	0.5
3	1000	0.3	0.6
4	1200	0.1	0.5
5	1200	0.2	0.6
6	1200	0.3	0.4
7	1400	0.1	0.6
8	1400	0.2	0.4
9	1400	0.3	0.5

Response Parameters for orthogonal array- OA L₉ (3)³ Surface Roughness (Ra) and Material Removal rate

Experiment	A	B	C	Ra	MRR
	Speed	Feed	D.O.C		
1	1000	0.1	0.4	9.18	11.98
2	1000	0.2	0.5	9.04	12.41
3	1000	0.3	0.6	8.64	11.39
4	1200	0.1	0.5	8.69	11.38
5	1200	0.2	0.6	9.67	10.01
6	1200	0.3	0.4	7.87	11.95
7	1400	0.1	0.6	8.77	10.58
8	1400	0.2	0.4	8.08	12.18
9	1400	0.3	0.5	7.11	13.55

ANOVA for Ra

Table Analysis of Variance for Surface Roughness (Ra)

Source	DF	Seq SS	Adj SS	Adj MS	F	P	%Contribution
Speed	2	1.55109	1.55109	0.77554	30.76	0.031	32.84
Feed	2	2.13242	2.13242	1.06621	42.29	0.023	45.15
DOC	2	0.98936	0.98936	0.49468	19.62	0.046	20.95
Error	2	0.05042	0.05042	0.02521			1.07
Total	8	4.72329					

ANOVA for MRR

Table Analysis of Variance for Material Removal rate (MRR)

Source	DF	Seq SS	Adj SS	Adj MS	F	P	%Contribution
Speed	2	1.6728	1.6728	0.8364	21.26	0.045	19.44
Feed	2	1.5980	1.5980	0.7990	20.31	0.047	18.57
DOC	2	5.2555	5.2555	2.6277	66.79	0.015	61.07
Error	2	0.0787	0.0787	0.0393			0.91

Total	8	0.6050					
-------	---	--------	--	--	--	--	--

Analysis of Ra versus Speed, Feed, DOC

Table Response for Signal to Noise Ratios Smaller is better

Level	Speed(A)	Feed(B)	DOC(C)
1	-19.04	-18.97	-18.44
2	-18.80	-18.99	-19.31
3	-18.02	-17.90	-19.10
Delta	1.02	1.10	0.79
Rank	2	1	3

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 Speed. The respective values of these parameters are 1.10 and 1.02.

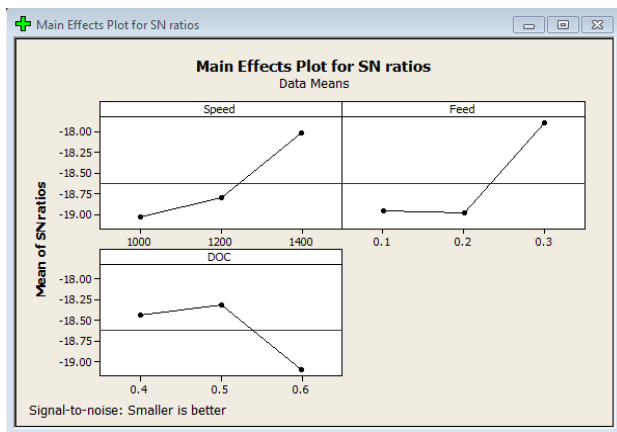


Fig.S/N graph for Surface Roughness

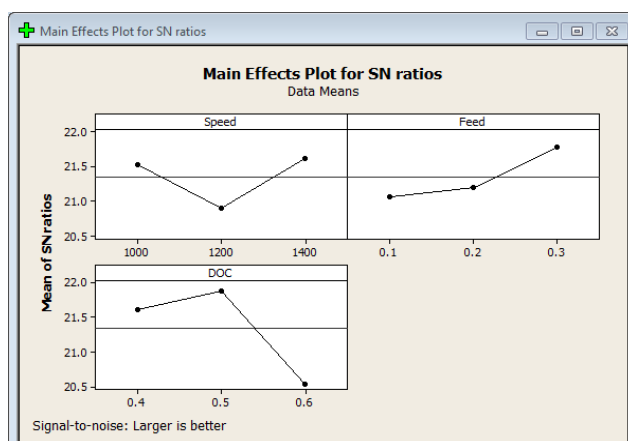


Fig. S/N graph for Material Removal Rate

Analysis of MRR versus Speed, Feed, DOC

Table Response for Signal to Noise Ratios Larger is better

Level	speed	feed	DOC
1	21.53	21.06	21.61
2	20.89	21.20	21.88
3	21.61	21.77	20.54
Delta	0.72	0.71	1.34
Rank	2	3	1

Discussion of results

The S/N ratios for Ra Vs. speed and DOC (Main effects) are given in Table 5.3-5.4 and S/N ratios (Main effects) for Ra Vs. feed and DOC is given in Table 5.5-5.6. Based on the Taguchi prediction larger difference between values of S/N ratio, will have a more significant effect on material removal rate (MRR) and surface roughness (Ra). Speed is most significant factor and the feed is less significant for the Surface Roughness.

Conclusion

- 1) 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.
- 2) 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.
- 3) The optimized machining conditions for minimizing Surface Roughness from Taguchi analysis are approaching: cutting speed 1000 m/min., feed 0.2 mm/rev, depth of cut 0.6 mm.
- 4) The optimized machining conditions for maximizing Material Removal rate from Taguchi analysis are approaching: cutting speed 1400 m/min., feed 0.3 mm/rev., depth of cut 0.5 mm.

Recommendations for future work

The current study investigates the effect of cutting speed, feed and depth of cut on surface roughness and material removal rate, while keeping constant work piece hardness.

- 1) In the future, the effect of varying work hardness may also be investigated.
- 2) The change in input parameters strongly influence the cutting forces on tool edge, which is helpful in condition monitoring of material removal rate and surface roughness of machined surface may also be investigated in future research work.

References

- Abdullah, A. (1996), Machining of aluminum based metal matrix composite (MMC), Ph.D. Thesis, University of Warwick, Warwick, UK, 1996.
- Anyilmaz M. S, (2006) Design of Experiment and an Application for Taguchi Method in Quality Improvement Activity, M.S. Thesis, Dumlupınar University, Turkey, 2006.
- Armarego E.J.A. and Brown R.H. (1969), The Machining of Metals, Prentice-Hall, Inc., 1969.
- Armarego, E. J. A., Verezub, S., Samaranayake, P. (2002), The effect of coatings on the cutting process, friction, forces and predictive cutting models in machining operations, Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture 216, pp.347-356, 2002.
- Aslan E., Camus N., Bingoren B. (2007), Design optimization of cutting parameters when turning hardened AISI 4140 (63 HRC) with $Al_2O_3 + TiCN$ mixed ceramic tool, Mater. Des. 28, pp. 1618-1622, 2007.
- Azman Ajri Bin. (2010), Performance evaluation of different process conditions when hard turning ASSAB 760, 2010.
- Bonifacio, M. E. R., Diniz, A. E. (1994), Correlating tool wear tool life, surface roughness and tool vibration in finish turning with coated carbide tools, Wear 173, pp.137-144, 1994.
- Boothroyd, G. and Knight, W.A. (1989), Fundamental Machining and Machine Tools 2nd edition, Marcel Dekker Inc. 1989.
- Chattopadhyay A.K., and Chattopadhyay A.B. (1982), Wear and performance of coated carbide and ceramic tools, Vol. 80, Issue 2, pp.239-258, 1982.
- Cho, S. S., Komvopoulos, K. (1997), Wear Mechanisms of Multi-Layer Coated Cemented Carbide Cutting Tools, Journal of Tribology 119, pp. 8-17, 1997.