EFFECT OF CUTTING PARAMETERS ON SURFACE ROUGHNESS IN FINISH HARD TURNING OF MDN 350 STEEL

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Abstract

Industries around the world constantly strive for lower cost solutions with reduced lead time and better surface quality in order to maintain their competitiveness.In the manufacturing the effect of cutting parameters (cutting speed, feed rate and depth of cut) on cutting forces (feed force, thrust force and cutting force) and surface roughness in finish hard turning of MDN350 steel (equivalent to 18Ni(350) maraging steel) The results show that cutting forces and surface roughness do not vary much with experimental cutting speed in the range of 26.3–87 m/min. Depth of cut is the dominant contributor to the feed force, accounting for 87.4% of the feed force whereas feed rate accounts for 6.56% of the feed force. In the thrust force, feed rate and depth of cut contribute 47.76% and 48.35%, respectively. In the cutting force, feed rate and depth of cut contribute 53.49% and 42.11% respectively, plus interaction effect between feed rate and depth of cut provides secondary contribution of 3.26%.

Key words: Cutting Speed, Feed Rate and Depth of Cut ,Cutting Tool, Surface Roughness, Maraging Steel, Feed Force, Thrust Force, Cutting Force.

Design of Experiments (DOE):

A Design of Experiment (DOE) is a structured, organized method for determining the relationship between factors affecting a process and the output of that process. Conducting and analyzing controlled tests to evaluate the factors that control the value of a parameter or group of parameters. Design of Experiments (DOE) refers to experimental methods used to quantify indeterminate measurements of factors and interactions between factors statistically through observance of forced changes made methodically as directed by mathematically systematic tables.

Design of Experiment Techniques

- Factorial Design
- Response Surface methodology
- Mixture Design
- Taguchi Design

Among these, Response Surface methodology is used for optimizing the Surface Roughness in Turning Operation.

Maraging Steel

Maraging steel is a special class of high-strength steel which differs from conventional steels in the way that they are hardened by metallurgical reaction that does not involve carbon. Maraging steels are strengthened by the precipitation of inter-metallic compound at temperatures of about 4800C (9000 F). The distinguishing feature of this steel is superior toughness compared to other hardened steels. These steels typically have very high nickel, cobalt and molybdenum contents, small amounts of titanium and very low carbon contents. Carbon, in fact, is an impurity in these steels and is kept as low as commercially feasible in order to minimize the formation of titanium carbide (TiC), which can adversely affect strength, ductility and toughness. The nomenclature that has become established for these steels is nominal yield strength (ksi units) in parentheses. Thus, for an example, 18Ni(350) steel is normally age hardened to a yield strength of 2415 MPa (350 ksi). The most widely used and commonly available grades are 18Ni(250), 18Ni(300) and 18Ni(350). Maraging steels have been used in a wide variety of applications, including missile cases, aircraft forging, structural parts, cannon recoil, springs, bellaville springs, bearings, transmission shafts, fan shafts in commercial jet engines, couplings, hydraulic hoses, bolts, punches and dies.

Table 1-Composition of MDN350 steel

C	0.005	Mn	0.02	Si	0.03
S	0.0032	P	0.005	Cr	0.03
Ni	18	Mo	4.2	Co	12.5
Ti	1.6	Al	.1	Fe	Rest

Source: Selection: Irons, Steels, and High-performance Alloys of ASM Handbook

Response Surface Methodology

Response surface methodology is a collection of statistical and mathematical methods that are useful for the modelling and analyzing engineering problems. In this technique, the main objective is to optimize the response surface that is influenced by various process parameters. Response surface methodology also quantifies the relationship between the controllable input

parameters and the obtained response surfaces.
The design procedure of response surface methodology is as follows:
(i) Designing of a series of experiments for adequate and reliable measurement of the response of interest.
(ii) Developing a mathematical model of the second order response surface with the best fittings.
(iii) Finding the optimal set of experimental parameters that produce a maximum or minimum value of response.
(iv) Representing the direct and interactive effects of process parameters through two and three dimensional plots.

RSM Design Points Needed:

Table 2–Design point

Factors	Linear	Quadratic	Cubic
2	3	6	10
3	4	10	20
4	5	15	35
5	6	21	56
6	7	28	84
7	8	36	120

Central Composite Design:

The most popular response surface method (RSM) design is the central composite design (CCD). A CCD has three groups of design points:
(a) Three-level factorial or fractional factorial design points
(b) Axial points (sometimes called "star" points)
(c) Ce

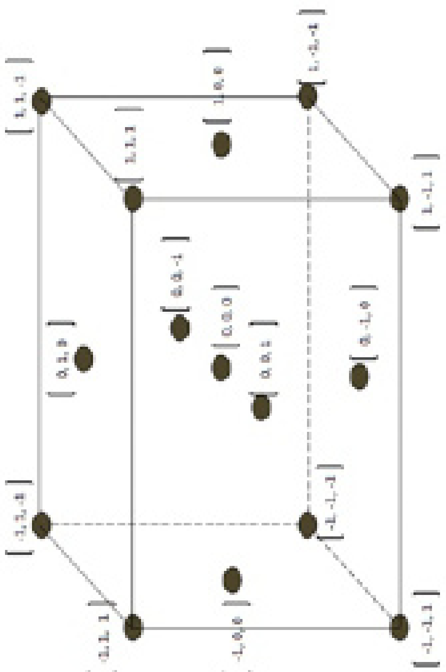

Figure 1: Central Composite Design (CCD)

Format :

- Ra = C Vn fm dp e
- lnRa = lnC + n lnV + m lnf + p lnd + lne
- yˆ = y – e = b0x0 +b1x1+ b2x2 + b3x3
- yˆ =b0 x0+b1x1+b2x2+b3x3 +b11x12+b22x22+b33x32 +b12x1x2+b13x1x3+b23x2x3

Surface roughness model:
The relationship between the surface roughness and machining independent variables (speed, feed and depth of cut) by the following:
Ra = C Vn fm dp e
Cutting force model:
Force is given by the following equation
F = C Vn fm dp e
Experimental Plan Procedure
Specification of the lathe machine
Made : GEDEE WEILER
Swing over bed : 300mm
Admit between centers : 800mm
Spindle variable speed : 45-2500 rpm
Feed range : 0.019-0.528 mm/rev

Cutting conditions:

Table 3-Cutting Parameters and Their Level

Factor	Unit	Low level (-1)	Centre level (0)	High level (+1)
Speed	m/min	26.3	54	87
Feed rate	mm/rev	0.03	0.076	0.12
Depth of cut	Mm	0.1	0.15	0.2

Cutting forces measurement

It was necessary to design a fixture to mount a force dynamometer on the lathe in such a way that tool tip will lie at the exact center of lathe axis. The cutting forces will be measure using Kistler type 9272A Quartz 4-component dynamometer mounted on specially designed fixture. Software used for measuring the values of different forces is Dynoware type 2825A.

Surface roughness measurements:

The measurements of average surface roughness (Ra) were made on TAYLOR HOBSON PRECISION SURTRONIC 3+ . Three measurements of surface roughness were taken at different locations and the average value is used in the analysis. It directly gives the value in digital format.

Results and Discussion

Table 4-Cutting forces vs. cutting speed at various feed rate and constant depth of cut 0.1mm.

Speed	Fx at .03	Fy at .03	Fz at .03	Fx .12	Fy at .12	Fz at .12
26.3	21.4	66.7	29.7	33.3	103	57
87	18.84	61.65	27.5	29.2	101	54.9

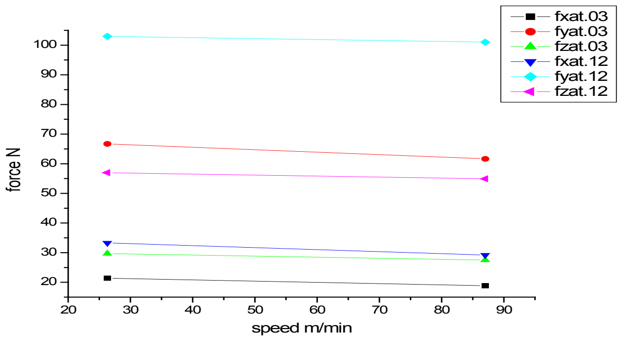

Figure 2 : Cutting forces vs. cutting speed at various feed rate and constant depth of cut 0.1mm.

ANOVA Output

This section is intended to provide definitions for each statistic in the analysis of variance. Some statistics are only given under certain conditions or for certain designs. The ANOVA is built entirely on the premise that the factors are fixed, not random and the design is crossed, not nested.

Feed force (Fx):Table 5-Model Summary Statistics for Fx

Source	Std.Dev	R-Squared	Adjusted R-Squared	Predicted R-Squared	PRESS	
Linear	3.842184641	0.940020182	0.928773966	0.9113427	349.1290713	Suggested
2FI	3.909910977	0.949533197	0.926240827	0.8927913	422.1834853	
Quadratic	3.885422811	0.953996962	0.927161856	0.8824475	462.917037	Aliased
Cubic	4.024724722	0.954752588	0.921845379	0.8637529	536.5355556	Aliased

Thrust Force (Fy):Table 6-Model Summary Statistics for Fy

Source	Std. Dev.	R-Squared	Adjusted R-Squared	Predicted R-Squared	PRESS	
Linear	5.629834034	0.963306295	0.956426226	0.943777	777.0222183	Suggested
2FI	5.245459575	0.974118417	0.962173071	0.9432952	783.6814059	
Quadratic	5.45643733	0.974148843	0.959069002	0.9338302	914.4908642	Aliased
Cubic	5.694574771	0.974189544	0.955418303	0.9217213	1081.84	Aliased

Table 7-Model Summary Statistics for Fz

Source	Std. Dev.	R-Squared	Adjusted R-Squared	Predicted R-Squared	PRESS	
Linear	5.172690457	0.956697273	0.948578012	0.9283977	707.8885316	
2FI	2.391101291	0.992482013	0.989012173	0.9862718	135.7227435	Suggested
Quadratic	2.294025301	0.993612367	0.989886248	0.9850623	147.68	Aliased
Cubic	2.395734846	0.993613948	0.988969546	0.9828939	169.1177778	Aliased

Surface roughness:

Table 8-Model Summary Statistics for Surface Roughness

Source	Std. Dev.	R-Squared	Adjusted R-Squared	Predicted R-Squared	PRESS	
Linear	77.59107785	0.762555581	0.73158457	0.6552873	201023.4314	
2FI	72.33029996	0.820575771	0.766748503	0.726029	159769.582	
Quadratic	54.91650214	0.912084547	0.865541073	0.7775479	129725.7053	Suggested
Cubic	49.27036415	0.945884029	0.891768058	0.6787131	187362.4298	Aliased

Surface Roughness equation

Ra = +612.61 + 157.06*B + 38.94 * B * C + 93.64*B2 - 126.36* C2 ± ε

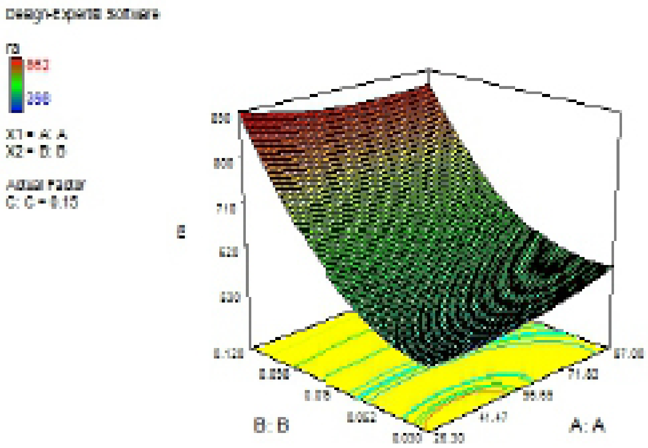

Figure 3: Surface roughness 3D surface in cutting speed and feed rate plane at depth of cut of 0.15mm

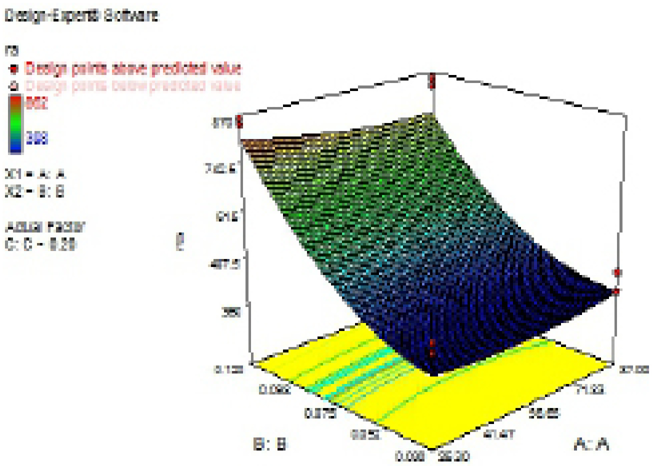

Figure 4 : Surface roughness 3D surface in cutting speed and feed rate plane at depth of cut of 0.2mm

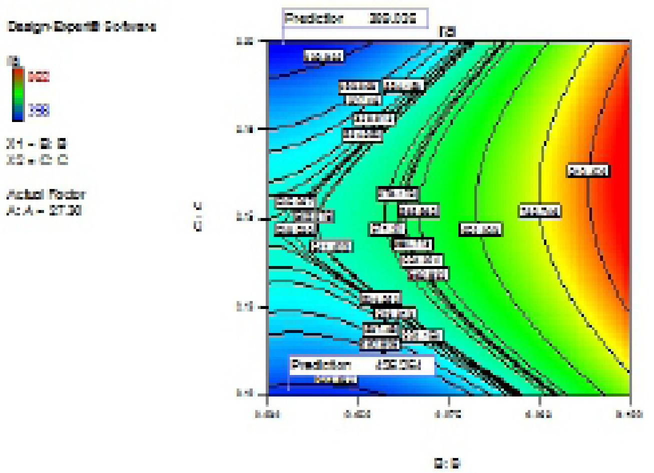

Figure 5: Surface roughness contour in feed and depth of cut plane at cutting speed of 26.30 m/min

Conclusion :

The effect of cutting speed, feed rate and depth of cut on the feed force, thrust force, cutting force and surface roughness in finish hard turning of MDN350 (58 HRC) steel.

1.Thrust force model: the feed rate and depth of cut are significant factor with 47.76% and 48.35%

2.Cutting force model: the feed rate and depth of cut are the most significant factors affecting cutting force and account for 53.49% and 42.11%

3.Surface roughness model: The interaction between feed rate and depth of cut, quadratic effect of feed rate and quadratic effect depth of cut provide secondary contribution to the model.

Good surface roughness can be achieved when depth of cut is set nearer to high level of the experimental range (0.2mm) and feed rate is at low level of the experimental range (0.03mm/rev).

References

Books:

Beddoes J. 1999. Principles of Metal Manufacturing processes, John Wiles & Sons Inc . New York ,

Gupta, B.Gopala, K.V. Yadav, J.S., 1996. Aerospace materials: With General Metallurgy for Engineers. S. Chand and Co. Ltd., New Delhi, India.

Krara, Steve, 1997, Macahine Tool and Manufacturing Technology, Lamb, C., Zecchino, M., 1999. Wyko Surface Profilers Technical Reference Manual. Veeco Metrology Group, Arizona.

Mikel P.Groover, Automation, Production Systems, and CIM, Third Edition, PHI Learning Private Limited, New Delhi.

Machine Elements in Mechanical Design, Mott, and prentice Hall international. Montgomery, D.C., 2001.

Design and Analysis of Experiments, 5th ed. John Wiley & Sons Inc.

Oxley, P.L.B., 1989. The Mechanics of Machining: An Analytical Approach to Assessing Machinability. Ellis Horwood Ltd., West Sussex, England.

Reinfeld, N.V. 1987, Handbook of Production and Inventory Control. Englewood Cliffs, NJ: Prentice-Hall.

R.K Jain and A.K Jain , 1998, January ,Design and Manufacturing, eighth Edition, Khana Publishers New Delhi ,India.

R.K Rajput, 2008 ,Electrical and Electronic Measurements and Instrumentation First Edition, Ram Nagar, New Delhi, India.

Rohrbach, K., Schmidt, M., 1990. Maraging steels. In: Abel, L.A., Kiepura, R.T., Thomas, P., Wheaton, N.D. (Eds.), Properties and Selection: Irons, Steels, and High-performance Alloys of ASM Handbook, Vol. I, 10th ed. ASM Int..Shaw, M.C., 1984. Metal Cutting Principles. Oxford University Press, Oxford, NY. Stephenson David, A. and Agapiou John, S , 1997 “Metal cutting theory and practice”, New York, Marcel Dekker,

Whitehouse, D. J, 2003, Handbook of Surface and Nanometrology. Institute of Physics,

Journals :

Lee, C. Chao, Y. J.,1987, “Surface texture dependence on surface roughness by computer vision,” in IEEE International Conference on Robotics and Automation 4, 520–524 .

O¨ zel, T., Hsu, T.-K.,Zeren, E,2005. Effects of cutting edge geometry, workpiece hardness, feed rate and cutting speed on surface roughness and forces in finish turning of hardened AISI H13 steel. Int. J. Adv. Manuf. Technol. 25, 262–269.

Thiele, J.D., Melkote, S.N., 1999. Effect of cutting edge geometry and workpiece hardness on surface generation in the finish hard turning of AISI 52100 steel. J. Mater. Process. Technol. 94, 216–226.

T¨onshoff, H.K., Arendt, C., Amor, R.B., 2000. Cutting hardened steel. Ann. CIRP 49 (2), 1–19.

Yang, W.H Tarng, Y.S., 1998. Design optimization of cutting parameters for turning operations based on the Taguchi method. J. Mater. Process. Technol. 84, 122–129.

Yen, Y-C Jain, A., Altan, T., 2004. A finite element analysis of orthogonal machining using different tool edge geometries. J. Mater. Process. Technol. 146, 72–81.