

OPTIMIZING SURFACE ROUGHNESS DURING HARD TURNING OF AISI H13 STEEL USING PCBN CUTTING TOOLS

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Abstract: During the last few decades, the application of hard turning has been increasing in various automotive industries. Hard turning is a great interest to both the manufacturing industry and research community. Hard turning is a critical machining operation that imposes strict requirements on both the cutting and machine tools. With the development of new cutting tool, the precision and rigidity of machine tools have been improved to allow hard turning to become a viable process. The application of hard turning has been increasing due to the demand of precision components at 55-70 HRC. In this study the experimental data were collected on the basis of five factors and five levels central composite design, and an attempt have been made to optimize the cutting parameters to minimize the surface roughness of AISI H13 die tool Steel using PCBN tool.

0.010mm or better over long production runs and achieve surface finish less than 0.3 micron. Advances in the machine tool accuracy enhancement and cutting tool technologies have made it a viable process. This process is also a good choice for manufacturer as it can be done without the use of lubricant or coolant and has lower energy consumption. [2][3]. Various researchers have been conducted to study the performance of AISI H13 steel with coated carbide, ceramic and CBN tool. AISI H13 tool steel encompass high hardness, high hardenability, high strength and possess good resistance to thermal softening [4]. AISI H13 tool steel has been extensively used to produce different types of hot working dies, such as extrusion and forging dies etc. Now a days surface roughness is the major concern of the manufacturing industries. Hence the significant enhancement in the quality of the dies can be accomplished with the control of the surface roughness induced during its manufacturing.

1. INTRODUCTION

In recent years, the manufacturing industries are mainly focused on the achievement of high quality parts, in terms of dimensional accuracy, surface finish, less wear on the cutting tools and high production rate. Hard turning is a process, in which materials in the hardened state (50–70 HRC) are machined to meet the requirements of precision accuracy and surface quality. Most hard turning applications involve turning of hardened steels, due to their great demand in bearings, camshafts, gearshafts, cutting tools, dies, moulds, etc. [1]. Hard turning is a great interest to both the manufacturing industry and research community; it has been used since the early 1980s. This process made a great impact to both the manufacturing industry and research community. Hard turning can today consistently maintain a size tolerance of +/-

II. EXPERIMENTAL PROCEDURE

2.1 Workpiece Material

AISI H13 is a hot working die tool steel and have a wide wide application in the die making industries. AISI H13 commonly used to make hot forming dies, extrusion dies, and manderals etc. The work piece material is in the form of round bars having 50mm diameter and 150 mm length. The work piece material was available in three different hardness range of 45HRC, 50HRC and 55HRC. The work piece was thoroughly hardened followed by tempering process to attain the respective hardness. The chemical composition of the material are as in Table 1.

Table 1. Chemical composition of H13 tool steel

C	Mn	Si	Cr	Ni	Mo	V	Cu	P	S	Al	W	Fe
0.35	0.324	0.871	5.038	0.117	1.635	1.052	0.185	0.013	0.003	0.006	0.007	90.310
%	%	%	%	%	%	%	%	%	%	%	%	%

2.2 Cutting Tool:

In machining of hardened tool steels, conventional tools wear rapidly because of high temperature and strong adhesion between the tool and the work piece material. PCBN tool are widely used in the metalworking industry for the cutting of various hard materials such as, die steels, bearing steels, case-hardened steels, white cast iron, and alloy cast irons [5]. The ability of polycrystalline cubic boron nitride (PCBN) cutting tools to maintain a workable cutting edge at elevated temperature due to its high hot-hardness, good thermal resistance and a high coefficient of thermal conductivity. However, the difficulty associated with compact CBN processing (high temperature and high pressure) and the high cost of CBN tools, have shifted the challenges for hard turning from technological feasibility to economical viability [6]. CBN inserts grade CNMG0904 and CNMG0908 was used to turn the AISI H13 steel.

2.3 Experimental details

The dry turning experiments were conducted on a (HAAS USA TL) CNC Lathe (Fig. 1.) of 5000 rpm. Spindle speed. After turning experiments the surface roughness were measured using Mitutoyo Surface roughness tester machine.



Machine Specification:

Model : TL Make : HAAS-USA

Program Controller : HAAS

Max. Holding Diameter : 20mm

Max. Turning Length : 600mm

Spindle Speed : 50-5000 rpm

Feed rate range : 0.0025-100mm/rev

Accuracy : 10microns

Fig.1 CNC lathe

III. DESIGN OF EXPERIMENTS

The objective of this study is to model the surface roughness for AISI H13 steel and to determine the optimum formulation to minimize the surface roughness. In the present work experimental results were optimized by using Response Surface Methodology (RSM). Response Surface Methodology is an interaction of mathematical and statistical techniques that are useful for modeling and analyzing the response variables which is

influenced by several variables. RSM can also establish the relationship between one or more response variable and essential controllable input variables [7].

Central composite design is the most commonly used design methods in RSM to find the functional relationship between response and the input variables. In the present study the experiments were designed on the basis of rotatable CCD technique [8]. This is the most widely used experimental design for experimentation of second order response surface modeling. In the rotatable design, all the points are at same radial distance from the centre points and have the same magnitude and infirmity prediction error. A rotatable CCD consists of 2^k fractional factorial points augmented by $2k$ central points.

Five factors were selected to describe this model such as Cutting speed, Feed rate, Depth of Cut, Nose radius and Workpiece hardness. The range of input variables is selected on the basis of extensive literature survey. Factors and their corresponding value are described in Table.2

Table 2. Input factors and their levels

S.No.	Parameters	(Unit)
Lower	Level	Upper Level
1	Cutting Speed (m/min)	75 175
2	Feed Rate (mm/rev)	0.0 0.15
3	Depth of cut (mm)	0.0 0.13
4	Nose radius (mm)	0.4 0.8
5	Work piece Hardness (HRC)	45 55

IV. RESULTS AND DISCUSSION

Based on the various studies and assessment through the previous studies, a methodology has been developed to analyze the effect of cutting condition on AISI H13 steel during hard turning. The cutting parameters are cutting speed (V_c), feed rate (f), depth of cut (ap), Nose radius and Workpiece hardness (H). The objective of the study optimizes the machining parameters for optimum surface roughness (R_a).

The values of the response factors surface roughness obtained during each run was analyzed through Response Surface Methodology to generate their respective models in terms of machining parameters. For all the response factors, the best fit was observed for 2FI model (two factor interaction term add to linear model) while the cubic and quadratic models were aliased. The analysis of variance (ANOVA) test was used to investigate the statistical significances of the fitted models. The fitted model

was found to be significant. All the responses, the probability of F (Prob. > F) are observed to be less than 0.0001. The values of "Prob > F" less than 0.050 observed for some factors involved in model equations, indicate that the contribution of these terms to the model is significant. The ANOVA results for surface roughness found this case showed that following input variables and their interactions are significant- Cutting speed, Feed, Nose radius, workpiece hardness, Feed-Nose Radius, Feed-Workpiece Hardness, Nose Radius-Workpiece Hardness are significant .

4.1 Effect of machining parameters on response factors

Fig. 1-4, shows the effect of cutting speed, feed rate, depth of cut, nose radius and work piece hardness on the surface roughness. The Best surface roughness was achieved corresponding to the combination of lowest feed rate and higher cutting speed, and surface roughness increases tremendously with increase in feed rate. Depth of cut has lowest influence on the surface roughness in all the parameters. Fig. 4 show that better surface roughness at higher nose radius, while fig. 3 shows the same at lower work piece hardness.

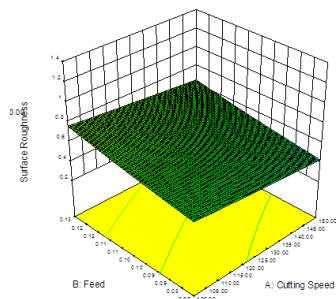


Fig.1 Cutting Speed versus Feed

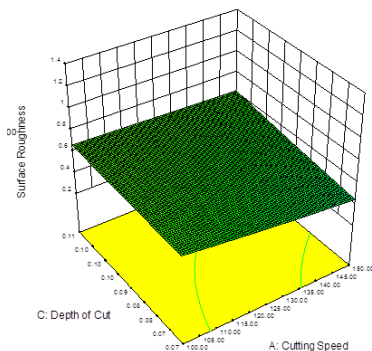


Fig.2. Cutting Speed versus Depth of Cut

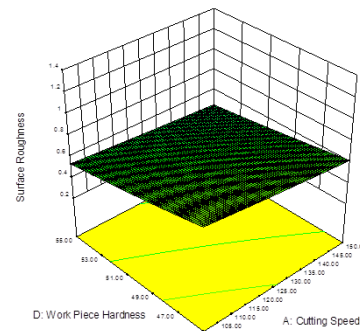


Fig.3 Cutting Speed versus Workpiece Hardness

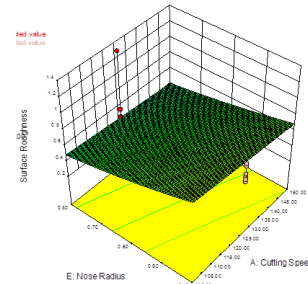


Fig.4 Cutting Speed versus Nose Radius

V. OPTIMIZATION OF CUTTING CONDITIONS

In the present study desirability function optimization of RSM has been employed for Surface roughness optimization. The optimization module searches for a combination of factor levels that simultaneously satisfy the requirements placed on each of the responses and factors in an attempt to establish the appropriate model. During the optimization process the aim was to find the optimal values of cutting parameters in order to minimize the surface roughness (Ra). Table 3. summarized the results..

VI. CONCLUSION

In this study, a Response surface methodology was applied to develop a model to investigate the influences of various machining parameters on surface roughness of AISI H13 die tool steel and the following conclusions were drawn.

- 2FI model (two factor interaction term added to linear model) for surface roughness and linear model for main because of their best performance modeling compared to quadratic model.
- The ANOVA results for surface roughness found the Cutting speed, Feed, Nose radius, and workpiece hardness, Feed-Nose Radius, Feed-Workpiece Hardness, Nose Radius-Workpiece Hardness are significant

The surface roughness decreases with the increase in cutting speed, and with [3] Janos Kunderak, Tibor Toth and Karoly Gyani "How To Make A Choice Of

Machining Methods On The Basis Of Economy: Comparison Between Hard Turning And Grinding “The Eleventh International Conference on Machine Design and Production 13-15 October (2004), Antalya, Turkey

- increases in feed rate
- Depth of cut does not have any significant effect on the surface roughness as compared to other parameters.
- Surface finish abruptly rise with the nose radius.
- Highest workpiece hardness have the better surface roughness.
- The optimized machining conditions for minimizing tool wear and surface roughness are approaching: cutting speed = 150 m/min , feed rate = 0.08mm/rev, depth of cut = 0.07 mm, Nose Radius 0.8 and workpiece hardness 45HRC and surface roughness 0.23 μ m.

REFERENCES

[1] Manu Dogra¹, Vishal S Sharma, Anish Sachdeva, Narinder Mohan Suri and Jasminder Singh Dureja “Tool Wear, Chip Formation and Workpiece Surface Issues in CBN Hard Turning: A Review” International Journal of Precision Engineering And Manufacturing Vol. 11, No. 2, pp. 341-358 April (2010) / 341

[2] D.Gillibrand, M.Sarwar, C.T.Pierce “The economic benefit of finish turning with coated carbide”, Surface & Coatings Technology, Vol. 86-87, pp. 809-813, (1996).

[4] Gerard Poulachon, B.P. Bandyopadhyay, I.S. Jawahir, Sebastien Pheulpin, Emmanuel Seguin “Wear behavior of CBN tools while turning various hardened steels” Received 30 July 2002; Wear 256 302–310 Elsevier, (2004).

[5] Zone-Ching Lin, Din-Yan Chen “A study of cutting with a CBN tool” Journal of Materials Processing Technology 49 ,149-164(1995)

[6] S. Dolinsek, J. Kopac “Mechanism and types of tool wear; particularities in advanced cutting materials” Journal of Achievements in Materials and Manufacturing Engineering, Volume 19 Issue, 1 November (2006).

[7] R.Suresh, S.Basavarajapp and G.L.Samuel “Predictive modeling of cutting forces and tool wear in hard turning using response surface methodology” Procedia Engineering 38 (2012) 1893 – 1904

[8] M.A.A. Aldahdooh, N. Muhamad Bunnori and M.A. Megat Johari “Evaluation of ultra-high-performance-fiber reinforced concrete binder content using the response surface method” Materials and Design 52 (2013) 957–965

Table 3. Response Optimisation For Surface Roughness Parameters.

Parameters	Goal	Optimum conditions					Surface Roughness	lower	upper	Desirability
		v (m/min)	f (mm/rev)	ap (mm)	NR (mm)	W/P Hardness				
Ra	Minimum	150.00	0.08	0.07	0.8	45	0.230378	0.18	1.91	0.965