Experimental investigation of effect of PVD , CVD and CERAMIC tool inserts in turning of hardened EN 19 / AISI 4140 for optimization of surface roughness

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ABSTRACT

The experimental study evaluates the influence of different turning parameters on quality of surface produced on CNC turning of high performance EN series material. Experiments were conducted with the combination of various input parameters for turning round bar of AISI 4140 material and hardened at 35 – 40 HRC. The experimental runs have been carried out with proper variation in the levels of input turning parameters. Three machining parameters are chosen as process parameters: type of Tool Insert, nose radius of tool insert and feed rate. The levels and ranges were determined from pilot experimentation results.The experimentation plan is designed using full factorial L27 Orthogonal Array (OA) using Minitab-15 statistical software. Optimum values of input parameters for desired performance characteristics are obtained by full factorial design of experiment. the optimal and obtained results are also verified with the help of confirmation experiments The results with full factorial design is discussed analytically to find the significant and sub significant turning parameters affecting the surface roughness. For the analysis and results, statistical technique of ANOVA is used. ANOVA for data means for turning with L27 DOE shows that surface finish is most significantly affected by feed rate and subsequently by tool nose radius and type of insert. The analysis of 3^3 full factorial DOE shows that surface finish is most significantly affected by of interaction among tool nose radius and feed rate.

1. INTRODUCTION:

Turning is the removal of metal from the outer diameter of a rotating cylindrical workpiece. Turning is used to reduce the diameter of the work piece, usually to a specified dimension, and to produce a smooth finish on the metal. Often the work piece will be turned so that adjacent sections have different diameters.

In manufacturing field, turning operation is a very common material removal technique. Researches on this topic take into account several aspects, such as: geometrical and metallurgical characteristics of the cutting tool, workpiece material influence on the process and process parameters. The interaction of all these factors during a cutting operation causes a series of effects on output parameters that influence the process

Significant advances have been seen in cutting tools and machine tools in recent years. Cutting parameters may be specified according to hardness of materials and roughness of the surface of a work piece. Though many advanced processes can be used for various machining but turning has its own importance in manufacturing engineering.

Nowadays, more and more Computer Numerical Controlled (CNC) machines are being used in every kind of manufacturing processes. In a CNC machine, functions like program storage, tool offset and tool compensation, program-editing capability, various degree of computation, and the ability to send and receive data from a variety of sources, including remote locations can be easily realized through on board computer. The computer can store multiple-part programs, recalling them as needed for different parts.

So there arises a need to study different parameters which affect the integration of different materials , their different properties and the appropriate tooling used for optimum machining process like turning. The following study on literature determines the need for the experimental study

2. LITERTATURE SURVEY:

Ashish Kabra et al[2] This paper outlines an experimental study to optimize and study the effects of process parameters in CNC turning on Surface roughness, feed and radial forces of EN19/AISI4140 (medium carbon steel) work material in dry environment conditions. The orthogonal array, signal to noise ratio and analysis of variance are employed to study the performance characteristics in CNC turning operation.

Jakhale Prashant P, Jadhav B. R.[3] In this paper attempt has been made to investigate the effect of cutting parameters (cutting speed, feed rate, depth of cut) and insert geometry(CNMG and DNMG type insert) on surface roughness in the high turning of alloy steel. The experiments have been conducted using L9 orthogonal array in a TACCHI lathe CNC turning machine. Turning process carried out on the high alloy steel(280 BHN).The optimum cutting condition was determined by using the statistical methods of signal-to-noise (S/N) ratio and the effect of cutting parameters and insert type on surface roughness were evaluated by the analysis of variance (ANOVA).

Dr. C. J. Rao, et al [5] This research reports the significance of influence of speed, feed and depth of cut on cutting force and surface roughness while working with tool made of ceramic with an A12O3+T1C matrix (KY1615)and the work material of

AISI 1050 steel (hardness of 484 HV). The results have indicated that it is feed rate which has significant influence both on cutting force as well as surface roughness. Depth of cut has a significant influence on cutting force, but has an insignificant influence on surface roughness.

Ashvin J. Makadia, J.I. Nanavati[6] In this paper, application of RSM on the AISI 410 steel is carried out for turning operation. A quadratic model has been developed for surface roughness (Ra) to investigate the influence of machining parameters. The results For the surface roughness was the feed rate is the main influencing factor on the roughness, followed by the tool nose radius and cutting speed. Depths of cut have no significant effect on the surface roughness. It can be seen that interaction between most factors has no significant effect except feed rate and tool nose radius which have the highest influence.

Mohamed Elbah, et al [8] This study considers the comparison between the surface roughness criteria (Ra, Rz and Rt) of the wiper inserts with conventional inserts during hard turning of AISI 4140 hardened steel (60 HRC).The statistical analysis reveals that the feed rate and depth of cut have significant effects in reducing the surface roughness.

Mustafa Gunay, Emre Yucel[9] This paper focuses on optimizing the cutting conditions for the average surface roughness (Ra) obtained in machining of high-alloy white cast iron (Ni-Hard) at two different hardness levels (50 HRC and 62 HRC). Machining experiments were performed at the CNC lathe using ceramic and cubic boron nitride (CBN) cutting tools on Ni-Hard materials. Optimal cutting conditions was determined using the signal-to-noise (S/N) ratio which was calculated for Ra according to the "the-smaller-the-better" approach.

A.P.Paiva, et al [11]This paper presents an experimental study of AISI 52100 hardened steel turned with wiper mixed ceramic (A12O3+TiC) inserts coated with TiN, using Multivariate Robust Parameter Design (MRPD). The main characteristic of this new optimization approach consists of considering both controllable (xi) and noise (zi) variables of the hard turning process to find out the parameter levels which minimize the distance of each response (yi) from its respective targets (Ti) while keeps each variance caused by the noise variables as low as possible.

llhan Asilturk , Harun Akkus[12] This study focuses on **optimizing** turning parameters bused on the Taguehi method to minimize surface roughness (Ra and *Rz).*Dry turning tests arc carried out on hardened AISI 4140 (51 HRC) with coated carbide cutting tools, Results of this study indicate that the feed rate has the most significant effect on Ra and Rz. In addition, the effects of two factor interactions of the feed rate-cutting speed and depth of cut-cutting speed appear to be important

Suleyman Neseli, et al[13] This investigation focuses on the influence of tool geometry on the surface finish obtained in turning of AISI 1040 steel. The results indicated that the tool nose radius was the dominant factor on the surface roughness

Hamdi Aouici, et al [14] This paper, aims to investigate, under turning conditions of hardened AISI Hll (X38CrMoV5-l), the effects of cutting parameters on flank wear (VB) and surface roughness (Ra) using CBN tool. The results show that the flank wear is influenced principally by the cutting time and in the second level by the cutting speed. Also, it is that indicated that the feed rate is the dominant factor affecting workpiece surface roughness.

N.R. Dhar, et al[15] This paper deals with experimental investigation on the role of MQL on tool wear and surface roughness in turning AISI-4340 steel at industrial speed-feed combination by uncoatcd carbide insert. The encouraging results include significant reduction in tool wear rule and surface roughness by MQL mainly through reduction in the cutting /.one temperature and favorable change in the chip-tool and work-tool interaction.

3. EXPERIMENTAL DETAIL

3.1. WORK MATERIAL

The present work deals with the turning of material such EN-19(AISI 4140) steel hardened at 35 – 40 HRC. This material is chosen because of its wide use in manufacturing machine parts, gears, wheels, tie rods, bolts, pins and shaft requiring high resistance. Since the present trend in the manufacturing industry is high speed machining, it is applied to evaluate the performance of tools coated by various methods for high performance in typical manufacturing processes. The table 3.1 gives detail data about chemical composition of EN-19(AISI 4140)

Table 3.1 chemical composition of EN-19(AISI 4140)

Element	Fe	Cr	Mn	C	Si	Mo	S	P
Content(%)	96.785 - 97.77	0.8 - 1.1	0.75 - 1.0	0.380 - 0.43	0.15 - 0.3	0.15 - 0.25	0.04	0.035

3.2 CNC MACHINE SELECTION

The ELECTRONICA make ELTURN industrial CNC was used for experiments , it is shown in image 3.1

Image 3.1 ELECTRONICA ELTURN CNC

3.3 SELECTION OF TOOL HOLDER AND CUTTING TOOLS

The cutting tool selected for machining EN19 steel are three type of inserts. The specifications of tool inserts are given in table 3.2

Table 3.2 tool inserts to be used experimentation

Sr. No	Type Of Tool Insert	Nose Radius	Grade
1	PVD	0.4	KC5010
2	PVD	0.8	TN8135
3	PVD	1.2	KCK15
4	CVD	0.4	FM8135
5	CVD	0.8	TN30M
6	CVD	1.2	TN2000
7	CERAMIC	0.4	PF5015
8	CERAMIC	0.8	PF5015
9	CERAMIC	1.2	PF5015

3. 4 METHODOLOGY

To study the effect of selected turning parameters on performance characteristic like surface roughness developed on the surface of turned round bar. Hardened round bars of material AISI 4140 are used in experiments. Nine round bars having length 200 mm and diameter 25 mm are respectively used for each tool insert. The details are shown schematically in images 3.2 and 3.3.

Image 3.2 round bars before turning

Image 3.3 round bars after turning

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To decide the ranges of selected turning parameters for final experimentation the pilot study observations are used. The results obtained for surface finish for each pilot experimental run is shown in table 3.3. The statistical and graphical method used to define the feasible region for deciding the range for insert , nose radius and feed is explained below.

Thus there are total three parameters selected namely type of insert, nose radius of insert, and feed, all three parameters are varied in three levels. In all the total 27 experimental runs have been taken as total number of runs = $L^F = 3^3 = 27$. Various performance measures are analyzed separately with respect control parameters to see their effects of on each response parameter. The basic statistical techniques ANOVA is used to decide the significant and sub significant parameters and to find out the optimum levels of turning parameters for every response characteristic.

Table 3.3 Turning parameters levels and response parameters

Factor ↓	Levels ↓			Response Parameters ↓
Type of Insert	PVD	CVD	CERAMIC	Surface roughness (*Ra*)
nose radius	0.4	0.8	1.2	
Feed Rate	0.08	0.12	0.16	

3.5 Surface roughness Measurement

Surface roughness is measured with Mitutoyo SJ-210 surface roughness tester for pilot experimentation as well as final experiments at KBP College of Engg. Satara.

Image 3.4 surface roughness testing

Table 3.4 observations for surface roughness

Sr. No.	Run order	Insert	Nose radius	Feed rate	Ra (µm)
1	1	1	0.4	0.08	1.089
2	2	1	0.4	0.12	1.478
3	3	1	0.4	0.16	1.721
4	4	1	0.8	0.08	1.391
5	5	1	0.8	0.12	2.017
6	6	1	0.8	0.16	2.767
7	7	1	1.2	0.08	1.743
8	8	1	1.2	0.12	2.545
9	9	1	1.2	0.16	3.157
10	10	2	0.4	0.08	0.865
11	11	2	0.4	0.12	1.170
12	12	2	0.4	0.16	1.483
13	13	2	0.8	0.08	1.137
14	14	2	0.8	0.12	1.465
15	15	2	0.8	0.16	1.722
16	16	2	1.2	0.08	1.361

Sr. No.	Run order	Insert	Nose radius	Feed rate	Ra (µm)
17	17	2	1.2	0.12	1.778
18	18	2	1.2	0.16	2.851
19	19	3	0.4	0.08	1.127
20	20	3	0.4	0.12	1.461
21	21	3	0.4	0.16	1.751
22	22	3	0.8	0.08	1.287
23	23	3	0.8	0.12	1.543
24	24	3	0.8	0.16	1.859
25	25	3	1.2	0.08	1.599
26	26	3	1.2	0.12	1.905
27	27	3	1.2	0.16	2.829

(Insert 1 – PVD, Insert 2 – CVD, Insert 3 – Ceramic)

4 ANALYSIS AND RESULTS

For the observations obtained in the table 3.4 for surface roughness , the analysis is done by full factorial design method using L27 orthogonal array. For the analysis the assistance MINITAB 15 software is taken in order to find the ANOVA results and F-test ratios to find the significant and sub significant input parameters.

The following part of this section shows various figures and tables obtained in the full factorial design of Experimental investigation of effect of PVD , CVD and CERAMIC tool inserts in turning of hardened EN 19 / AISI 4140 for optimization of surface roughness

ANOVA for *Ra* considering 3^3 full factorial DOE

Table 4.1 ANOVA for *Ra* (3^3 full factorial)

Source	DOF	SS	MS	F-Ratio	Prob.	%P
INSERT	2	0.94218	0.47109	19.08	0.001	10.10
NOSERD	2	3.27209	1.63604	66.26	0.000	35.10
FEED	2	4.07178	2.03589	82.45	0.000	43.67
INSERT*NOSERD	4	0.22542	0.05635	2.28	0.149	2.41
INSERT*FEED	4	0.11388	0.02847	1.15	0.399	1.22
NOSERD*FEED	4	0.49903	0.12476	5.05	0.025	5.35
Error	8	0.19753	0.02469			2.15
Total	26	9.32192				100

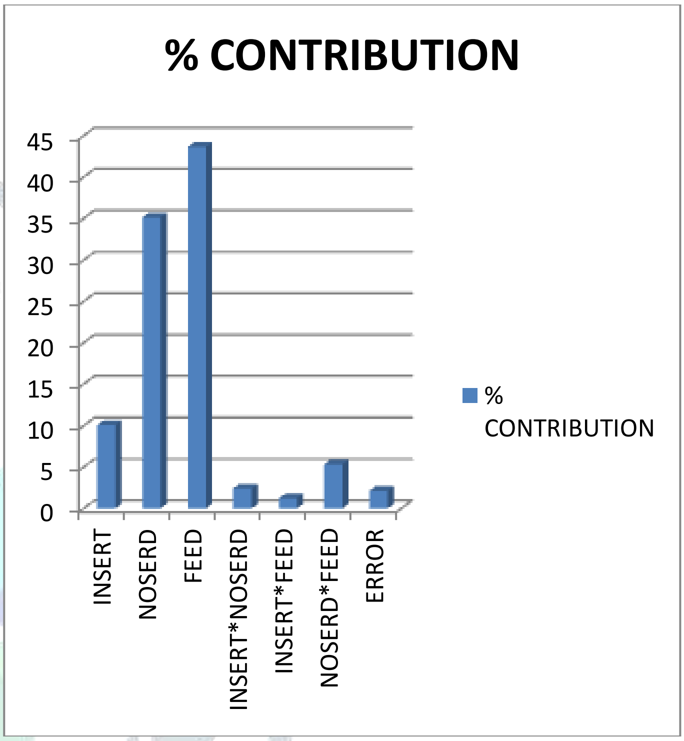
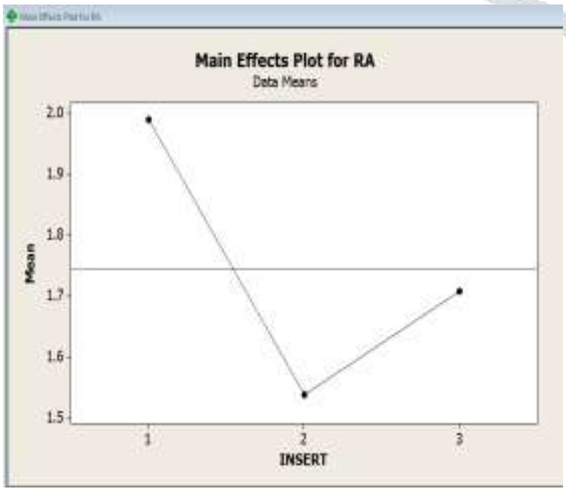


Figure 4.1 graphical representation of % contribution



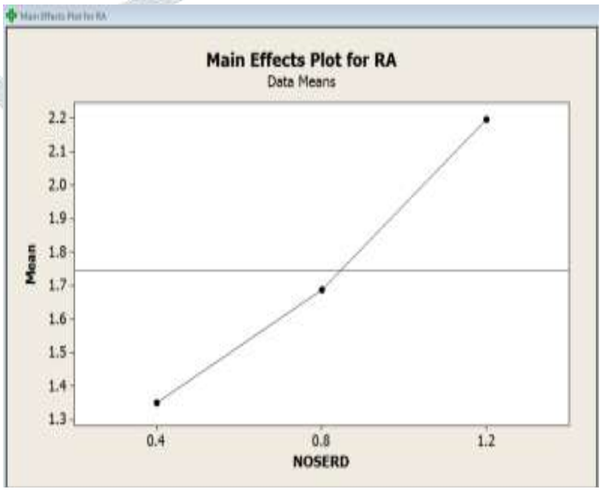
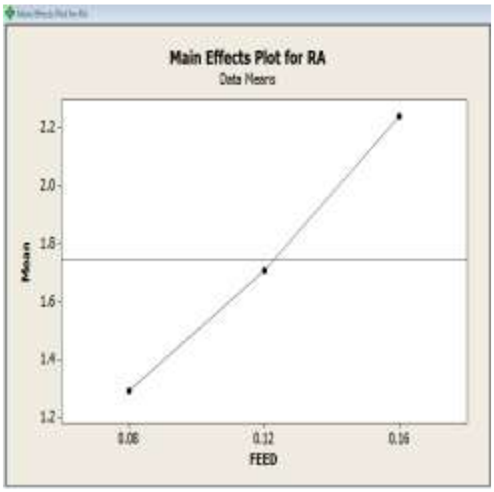


Figure **Error! No text of specified style in document.**.2 **Main effect plot for *Ra* means v/s type of tool** **Figure** Error! No text of specified style in document.**.3** Main effect plot for *Ra* means v/s nose radius

Fig. 4.2 represents the average *Ra* values obtained at various levels of type of insert. The maximum value of *Ra* average is for level 1 = 1.990 µm while the level 2 gives lowest *Ra* = 1.537 µm. Hence it is desirable to keep type of insert at level 2 to have lower *Ra*.

Fig. 4.3 shows the average *Ra* values plotted against corresponding levels of nose radius of tool insert. For level 1, average *Ra* 1.349 is µm while for level 2 and level 3 it is 1.688 and 2.196 µm respectively. Thus level 1 is desirable level to keep *Ra* at lower values. The range of variation of Ra between level 1 and 2 is negligible as compare to variation at level 3.

Fig. 4.4 shows the average *Ra* values at each level of feed rate. It indicates the level 3 of feed rate is having maximum *Ra* = 2.238 µm while level 1 has lowest *Ra* = 1.289 µm. Level 2 is in between 1 and 3. Hence this main plot suggests using feed rate with level 1 to have lower *Ra* values.



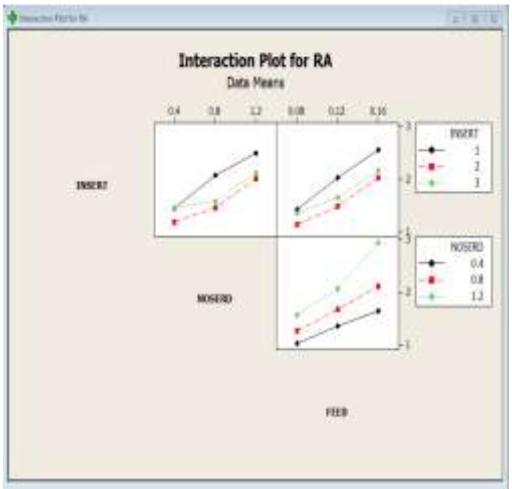


Figure Error! No text of specified style in document..**4** Main effect plot for *Ra* means v/s Feed rate **Figure** Error! No text of specified style in document..**5** interaction among input parameters

Table 4.1 presents the ANOVA for data means for *Ra* values. Interaction among the parameters is highly affecting the value of Ra. Interaction between nose radius of tool insert and feed rate has highest contribution i.e. 5.35 %. Fig 4.5 shows the percentage contribution of turning parameters affecting surface roughness in turning of round bar made of AISI 4140 and hardened at 35 – 40 HRC

The graphs of interaction effects are shown in fig 4.1. The optimum levels for turning parameters can be predicted from the main plots for minimum *Ra*. Hence from main plot the levels for type of insert, nose radius and feed rate are 2, 1 or 2, and 1 or 3 respectively.

CONCLUSION

1. It is hereby concluded that CERAMIC type of tool inserts can be replaced by CVD type of tool inserts as turning can be done efficiently and the lowest surface roughness is also achieved by CVD type of tool insert with nose radius 0.4 at 35 – 40 HRC.
2. ANOVA for data means for turning with L27 DOE shows that surface finish is most significantly affected by feed rate and subsequently by tool nose radius and type of insert. The analysis of 3^3 full factorial DOE shows that surface finish is most significantly affected by of interaction among tool nose radius and feed rate.
3. From analysis of 3^3 full factorial DOE suggest that by setting of feed rate at higher level i.e. 0.16 gives maximum value of surface roughness and at lower level i.e. 0.08 gives minimum value of surface finish where type of insert and nose radius is kept at level 2 and level-1 respectively.

Scope for Future Work

The scope of this study is limited to some turning parameters keeping speed and depth of cut constant, which can be further extended by considering various other important turning parameters like tool life, MRR, rake angle, cutting forces, minimum lubricant condition etc. further ANN (artificial neural network) model for pattern recognition and prediction can be developed. Optimization techniques like GA or Harmony search algorithms can be implemented.

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