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Effect of Inset Coating on Surface Finish While Machining SGI Component

Swastik V. Ghume¹, Akash R. Bhopale², Avadhoot D. Bhosale³

UG Student, Department of Mechanical Engineering, D.Y.Patil College of Engineering and Technology, Kasaba
Bawada, Kolhapur, Maharashtra, India.

Under The Guidance of Professor N.M.Qureshi Sir, Department of Mechanical Engineering, D.Y.Patil College of
Engineering and Technology, Kasaba Bawada, Kolhapur, Maharashtra, India.

ABSTRACT: In this research work, the TAGUCHI optimization method is used for optimizing the speed, feed, cutting depth & tool geometry for individual performance characteristics by examining effects of different turning insert having similar tool geometry and material composition but with different manufacturing firms, & we are also examining effects of different speed, feed, cutting depth on surface roughness, dimensional accuracy in machining turning operation on CNC lathe machine.

We also have different controlling parameters as cutting speed, depth of cut & feed rate. For investigating, we also used ANOVA & REGRESSION analysis to find out the influence of parameters on above characteristics. The array L27 derived from TAGUCHI optimization method was used to perform series of trials on SGI component.

By using L27 array we have optimized best surface finish with CVD-coated insert and by ANOVA we got most significant control parameter- speed and feed . The order of importance of factors is-
Feed>Speed>Insert> Depth of cut.

KEYWORDS: Spheroidal Graphite Iron (Material), Minitab, Inserts, TAGUCHI, speed, feed, depth of cut, surface roughness.

I. INTRODUCTION

The machining process is a process in which material is removed to get desired shape & size by removal of unwanted excess material. The process of removing material from the surface of the job to get the desired shape by 'single point cutting tool' is known as Turning. Optimization is nothing but to determine ideal or best value. For this operation, different turning insert with same grades, tool geometry & material composition and a different coating along with different manufacturer are used in presence of different levels of cutting variables like speed, feed, depth of cut for performing turning operation on flange valve (material SGI). This different inserts & cutting variables shows the different effect on characteristics like surface finish, dimension etc. on component turned. Use of coolant in CNC machine may also create a difference in above parameter. It is important to choose the best machining parameters for achieving optimum performance in turning operation. This study demonstrates detailed methodology of the proposed optimization technique which is based on Taguchi method; and ranks the parameters namely cutting speed, feed, depth of cut and inserts for optimum surface finish on SGI component.

II. EXPERIMENTAL SETUP

i) **Material** - Spheroidal Cast Iron:

SG Iron is also known as Ductile Cast Iron, Nodular Cast Iron, Spheroidal Graphite Iron and Spherulitic Cast Iron.

The main characteristic of this material is the structure of the graphite. In SG Cast Iron the graphite is in the form of spherical nodules (hence the name Spheroidal Graphite) rather than flakes as in Grey Iron. This nodular graphite structure inhibits the creation of linear cracks hence the ability to withstand distortion.

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Composition -

- Carbon 3.2 to 3.60%
- Silicon 2.2 to 2.8%
- Manganese 0.1 to 0.5%
- Magnesium 0.03 to 0.05%
- Phosphorus 0.005 to 0.04%
- Sulfur 0.005 to 0.02%
- Copper <0.40%
- Iron balance

ii) CNC Turning Centre -

Askar Spinner 15 Classik with Siemens controller is used to carry out the experimentation.

Table of Specifications of CNC turning center

Max. Turning diameter	320mm
Max. Turning length	435mm
Chuck Size	200mm
Spindle Speed	3000 rpm
Spindle motor power	11KW/15KW

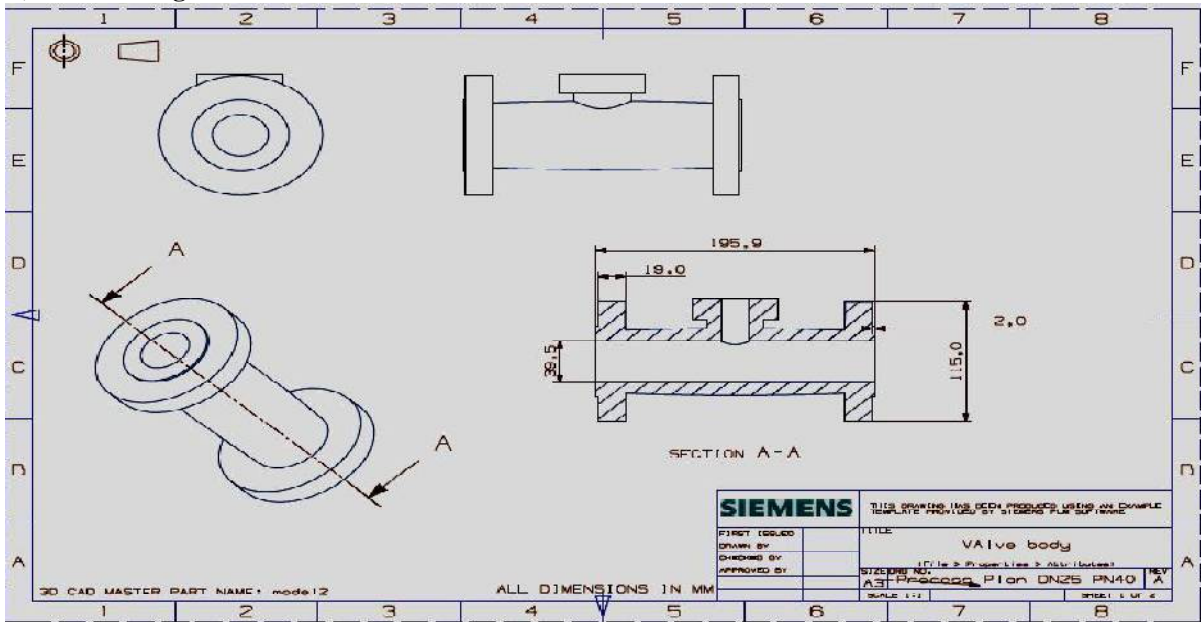


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iii) Job Drawing -



DETAILS: turning on flange of flange valve

NAME OF THE JOB: Flange valve

OPERATION PERFORMED ON JOB: Turning

iv) Selection of Cutting Tools (Inserts) -

The inserts (ANSI coding) used in present work are

- Widia Uncoated Insert (TNMG160408WC K10PT)
- Widia CVD Coated Insert (TNMG160408RH)
- Kennametal PVD Coated Insert (TNMG160408MP KCU10)

- a) **Widia Uncoated Insert** b) **Widia CVD Coated** c) **Kennametal PVD Coated**



*CVD - Chemical Vapour Deposition

*PVD - Physical Vapour Deposition

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Insert ISO designation for Turning :

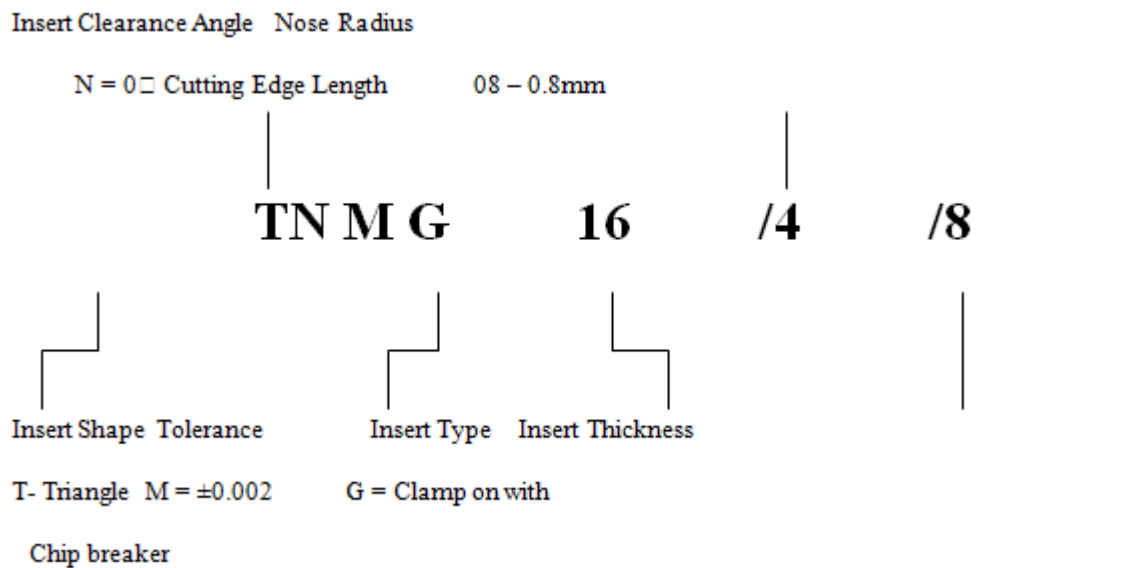


Table 2: The tool geometry of the inserts used :

Insert Name	Insert Shape	Insert Clearance Angle	Tolerance	Insert Type	Cutting Edge Length	Insert Thickness	Nose Radius
Widia Uncoated	Triangle	0	±0.002mm	Clamp on with chip breaker	16mm	4mm	0.8mm
Widia CVD Coated	Triangle	0	±0.002mm	Clamp on with chip breaker	16mm	4mm	0.8mm
Kennametal PVD Coated	Triangle	0	±0.002mm	Clamp on with chip breaker	16mm	4mm	0.8mm

v) Coolant used -

For lubrication, water based coolant was used which influenced better surface finish.

vi) Roughness measurement by using Surface Roughness Tester-

Surface roughness: A roughness value can either be calculated on a profile (line) or on a surface (area). The profile roughness parameter (Ra, Rq, ...) are more common.

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The most common parameter is Ra or Arithmetic Average Roughness. It basically reflects the average height of roughness component irregularities from a mean line. Ra provides a simple value for accept /reject decisions. It is a default parameter on a drawing if not otherwise specified, and is available even in the least sophisticated instruments.

Portable surface roughness tester used in project: SURFTESTSJ210



Drive unit type	Standard
Detector type	4mN measuring force, 5 μ m stylus tip radius
Standards met	JIS (1982, 1994, and 2001), ISO 1997, VDA, and ANSI
Measuring range	X-axis: .69 inches (17.5mm); Z-axis 14200 μ m (-7900 μ m ~+6300 μ m)/360 μ m / .08 μ m (25 μ m / 0.002 μ m)
Resolution	14170 μ m / .8 μ m (360 μ m / 0.02 μ m), 4000 μ m / .2 μ m (100 μ m / 0.006 μ m), 1000 μ m / .08 μ m (25 μ m / 0.002 μ m)
Assessed profile	Primary profile (P), roughness profile (R), DIN4776 [Primary profile (P), Roughness profile (R), MOTIF (R): M-type
Parameters	Rv, Rsk, Rku, Rc, R _{PC} , R _{Sm} , R _{max} , Rz1 _{max} , RzJIS, R _{ppi} , R Δ a, R Δ q, Rlr, Rmr, R δ , ζ , HSC, R _{pm} , t _p , H _{tp} , Ra, Ry, Rz, Rq, S, Sm, Pc, R3z, mr \odot , Rt, Rp, Rk, R _{pk} , R _{vk} , Mr1, Mr2, A1, A2, Vo (customizable)(R, AR, Rx: M-type)
Overall dimensions	52.1 x 65.8 x 160 mm / 2.05 x 2.6 x 6.3 inches (H x W x D)
Weight	1.1 lb (500g) including display unit, drive unit, and detector

Features:

1. The 2.4- inch color graphic LCD
2. The display interface supports 16 languages
3. The optional memory card
4. Warning alarm

vii) MINITAB (Version 17) Software-

Minitab is a software or statistical package designated mainly as a teaching tool.

Although it is easy to use, it is quite powerful and flexible for moderate size data sets.

Minitab will conduct a variety of statistical calculations. These are found under the main menu option of STAT. Each category also has subcategories.

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Uses of Minitab :

Statistics & Analysis

- Regression Analysis
- Analysis of Variance - to determine the difference between data points
- Taguchi design of experiment & Analysis
- Data and File Management - spreadsheet for better data analysis
- Tables and Graphs
- Time Series and Forecasting - tools that help show trends in data as well as predicting future values. Time series plots, exponential smoothing.
- Statistical Process Control
- Measurement System Analysis

ORTHOGONAL ARRAY

Orthogonal arrays allow you to investigate each effect independently from the others and may reduce the time and cost associated with the experiment when fractionated designed are used.

Each column in the orthogonal array represents a specific factor with two or more levels.

Each row represents a run; the cell values indicate the factor settings for the run. By default, Minitab's orthogonal array designs use the integers 1, 2, 3...to represent factor levels. If you enter factor levels, the integers 1, 2, 3,..., will be the coded levels for the design.

The following table displays the L8 (2**7) Taguchi design (orthogonal array). L8 means 8 runs. 2**7 means 7 factors with 2 levels each. If the full factorial design were used, It would have 2**7=128 runs. The L8 (2**7) array requires only 8 runs***a fraction of the full factorial design. This array is orthogonal; factor levels are weighted equally across the entire design. The table columns represent the control factors, the table rows represent the runs (combination of factor levels), and each table cell represents the factor level for that run.

L8 (2⁷) Taguchi Design:

A	B	C	D	E	F	G
1	1	1	1	1	1	1
1	1	1	2	2	2	2
1	2	2	1	1	2	2
1	2	2	2	2	1	1
2	1	2	1	2	1	2
2	1	2	2	1	2	1
2	2	1	1	2	2	1
2	2	1	2	1	1	2

TABLE1: TABLE FOR EXPERIMENT (MACHINING PARAMETERS & THEIR LEVELS):

Control Variable	Level 1	Level 2	Level 3
Spindle Speed (m/min)	150	200	250
Feed (mm/rev)	0.1	0.15	0.2
Depth of cut (mm)	0.45	0.35	0.25
Inserts	1	2	3

*1-Uncoated Insert, 2- CVD Insert, 3- PVD Insert.

**Level of speed, feed, depth of cut is selected from the reference manual provided by insert manufacturing company.

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TABLE 2: EXPERIMENT LAYOUT USING TAGUCHI L27 ORTHOGONAL ARRAY

Insert	Speed	Feed	DoC
1	1	1	1
1	1	1	2
1	1	1	3
1	2	2	1
1	2	2	2
1	2	2	3
1	3	3	1
1	3	3	2
1	3	3	3
2	1	2	1
2	1	2	2
2	1	2	3
2	2	3	1
2	2	3	2
2	2	3	3
2	3	1	1
2	3	1	2
2	3	1	3
3	1	3	1
3	1	3	2
3	1	3	3
3	2	1	1
3	2	1	2
3	2	1	3
3	3	2	1
3	3	2	2
3	3	2	3

From table no. 2, it is clear that 27 experiments were carried out accordingly to study the effect of input cutting parameters. For example: In 1st experiment the cutting parameters levels are =1, 1, 1, 1 That means experiment was conducted with 150 m/min, 0.1feed, 0.45 DoC& with 1stINSERT. Accordingly, other experiments are performed. Each experiment was repeated three times for three different depth of turned component to minimize experimental error.

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As per the table no. 2 the values are as follows :

Insert	Speed	RPM	Feed	DoC
UC	150	400	0.1	0.45
UC	150	400	0.1	0.35
UC	150	400	0.1	0.25
UC	200	550	0.15	0.45
UC	200	550	0.15	0.35
UC	200	550	0.15	0.25
UC	250	700	0.2	0.45
UC	250	700	0.2	0.35
UC	250	700	0.2	0.25
CVD	150	400	0.15	0.45
CVD	150	400	0.15	0.35
CVD	150	400	0.15	0.25
CVD	200	550	0.2	0.45
CVD	200	550	0.2	0.35
CVD	200	550	0.2	0.25
CVD	250	700	0.1	0.45
CVD	250	700	0.1	0.35
CVD	250	700	0.1	0.25
PVD	150	400	0.2	0.45
PVD	150	400	0.2	0.35
PVD	150	400	0.2	0.25
PVD	200	550	0.1	0.45
PVD	200	550	0.1	0.35
PVD	200	550	0.1	0.25
PVD	250	700	0.15	0.45
PVD	250	700	0.15	0.35
PVD	250	700	0.15	0.25

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III. OBSERVATION TABLE

Insert	Speed	RPM	Feed	DoC	Ra
UC	150	400	0.1	0.45	1.995
UC	150	400	0.1	0.35	2.583
UC	150	400	0.1	0.25	1.552
UC	200	550	0.15	0.45	2.532
UC	200	550	0.15	0.35	2.826
UC	200	550	0.15	0.25	2.854
UC	250	700	0.2	0.45	2.617
UC	250	700	0.2	0.35	3.012
UC	250	700	0.2	0.25	2.69
CVD	150	400	0.15	0.45	3.486
CVD	150	400	0.15	0.35	2.772
CVD	150	400	0.15	0.25	3.564
CVD	200	550	0.2	0.45	2.466
CVD	200	550	0.2	0.35	2.25
CVD	200	550	0.2	0.25	2.955
CVD	250	700	0.1	0.45	1.667
CVD	250	700	0.1	0.35	1.225
CVD	250	700	0.1	0.25	0.976
PVD	150	400	0.2	0.45	2.368
PVD	150	400	0.2	0.35	2.759
PVD	150	400	0.2	0.25	2.449
PVD	200	550	0.1	0.45	1.407
PVD	200	550	0.1	0.35	1.656
PVD	200	550	0.1	0.25	2.438
PVD	250	700	0.15	0.45	2.132
PVD	250	700	0.15	0.35	2.259
PVD	250	700	0.15	0.25	1.375

*Ra- Arithmetic Mean Value

IV. RESULTS

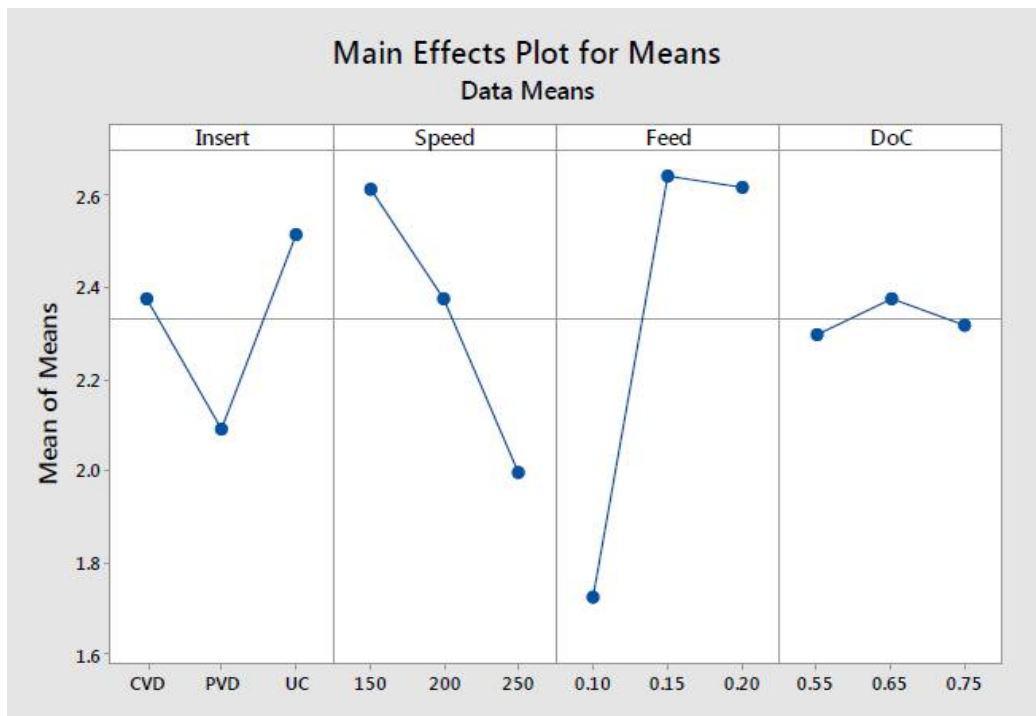
INTERACTION PLOT:

An interactions plot is a plot of means for each level of a factor with the level of a second factor held constant. Interactions plots are useful for judging the presence of interaction, which means that the difference in the response at two levels of one factor depends on upon the level of another factor. Parallel lines in an interactions plot indicate no interaction. The greater the departure of the lines from being parallel, the higher the degree of interaction.

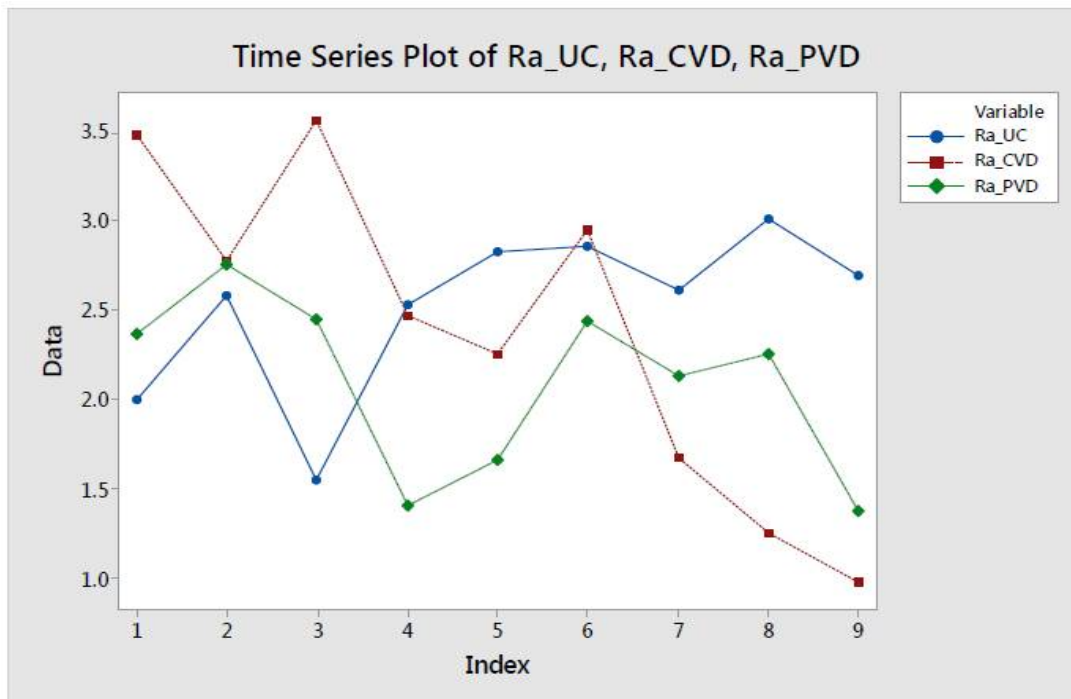
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From above graph, we can conclude the interaction of different factors (variables) & responses (parameters). This gives the mean (average) of the parameter at various factors (variables).



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From graph, it can be concluding that:

1. Surface roughness value is more at lower speeds and it is maximum at 13th no. Experiment.
2. Ra value is lower and it is much desirable. Experiment no. Of 18th job of CVD gives minimum surface roughness.

V. ANALYSIS & RESULTS USING TAGUCHI METHOD

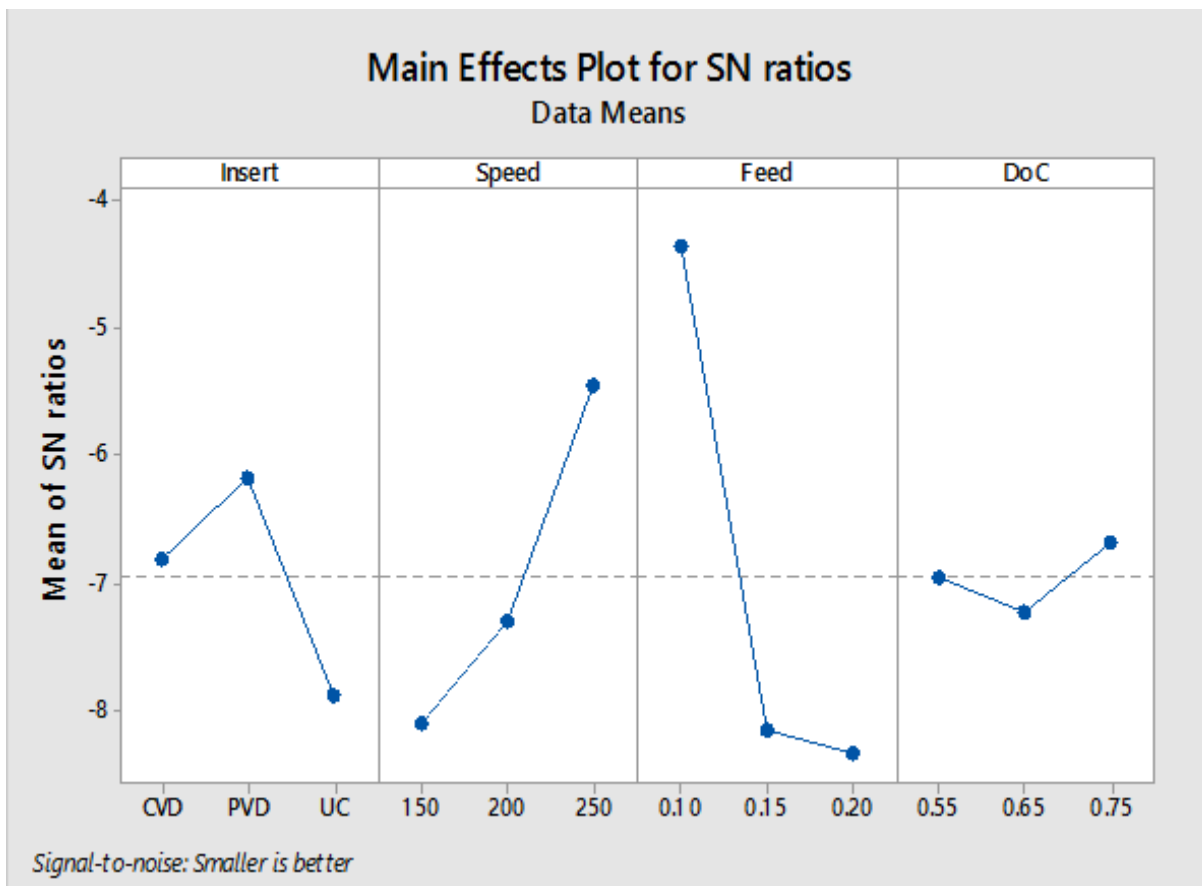
SURFACE ROUGHNESS -

Taguchi Analysis: Ra versus RPM, FEED, DoC, Insert Response Table for Signal To Noise Ratio

Smaller is better

Level	Insert	Speed	Feed	DoC
1	-6.804	-8.098	-4.372	-6.953
2	-6.177	-7.287	-8.151	-7.221
3	-7.865	-5.461	-8.323	-6.672
Delta	1.689	2.637	3.951	0.549
Rank	3	2	1	4

* Feed has maximum influence on surface finish, whereas depth of cut has negligible influence on surface finish.



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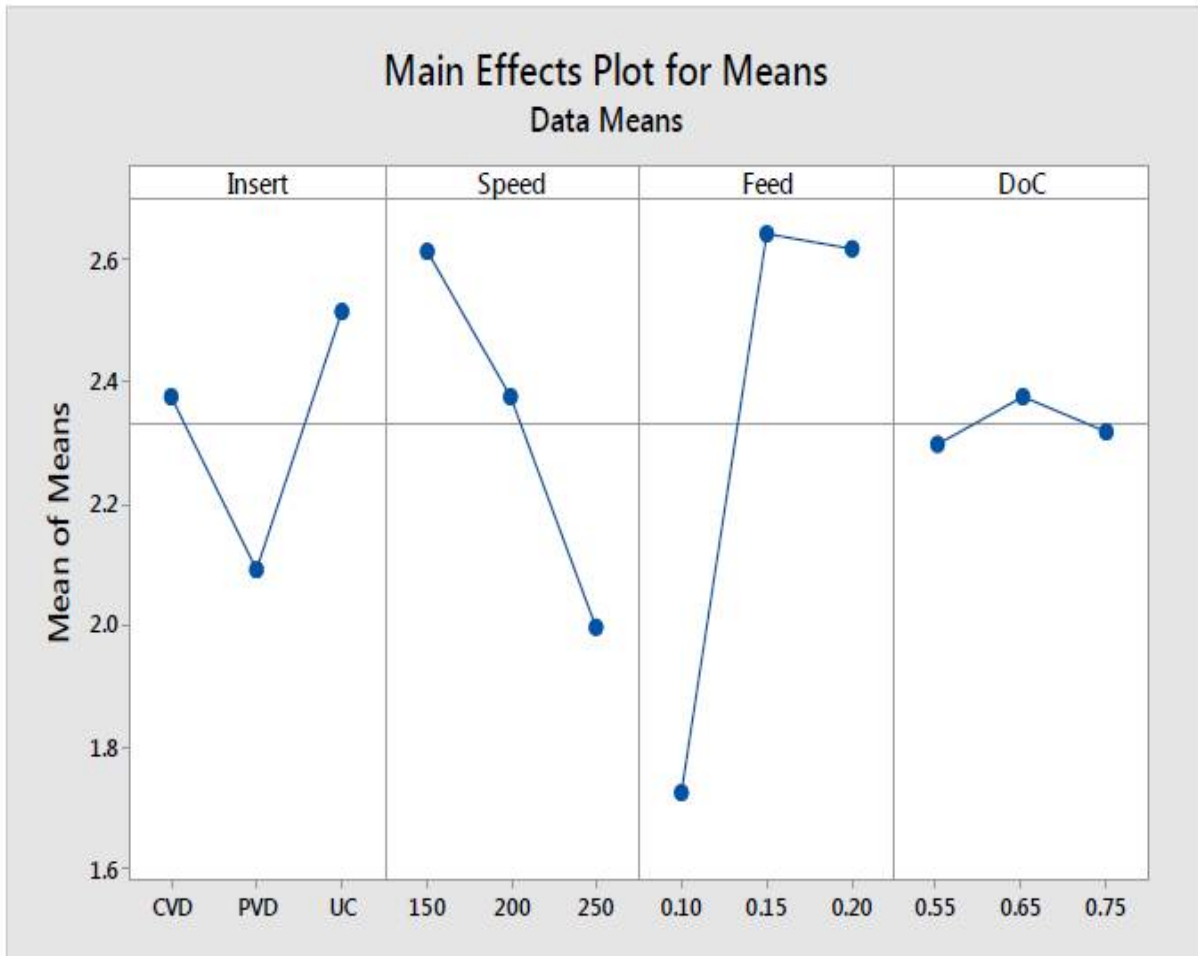
- From above graph, it is observed that PVD insert gives us excellent surface finish compared to other two inserts.
- At higher speed surface finish is better.
- The fine speed improves quality of surface finish.
- DoC has very little influence on quality of surface finish.

Roughness:

Response table for Data Means:

Smaller is Better

Level	Insert	Speed	Feed	DoC
1	2.377	2.614	1.725	2.297
2	2.094	2.376	2.644	2.375
3	2.518	1.998	2.618	2.317
Delta	0.424	0.616	0.919	0.078
Rank	3	2	1	4



- The above graph confirms the observation noted in the graph of main effects plot for SN ratios.

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- Here also, DoC has a very little influence on surface finish, however smaller DoC is better for improved surface finish.

As shown in figure :

**For the better surface finish, the surface roughness (Ra value) must be smaller. Therefore there, 'smaller is better' condition is used.

V. CONCLUSION

1) Taguchi Analysis:

TAGUCHI analysis is the best method to optimize process parameter for single performance characteristic. From Taguchi analysis, following results is concluded:

Optimized parameters are:

To obtain the best surface finish the best factors are speed 250 m/min, feed 0.10 mm/rev, DoC 0.75mm with Insert CVD

2) ANOVA analysis gives the importance of individual factors as:

For surface finish, most significant factor is Feed and speed, And order of importance of the factor is:

Feed > Speed > Insert >> DoC

And order of P value for respective factors are:

0.01 < 0.035 < 0.170 < 0.934

3) From Regression equation, it is estimated that responses are indirectly or inversely proportional with all cutting parameters with some constant.

With increase in 1 unit of Speed, Insert; the Surface Roughness **Decreased** by 0.00616 and 0.212 units respectively & **increases** by 8.93 and 0.10 respectively with increase in 1 unit of feed And DoC.

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