

# AN INVESTIGATION ON SURFACE ROUGHNESS OF A356 ALUMINIUM ALLOY IN TURNING PROCESS BY OPTIMIZING THE PROCESS PARAMETERS

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**Abstract** - In today's market situation quality and productivity of a product plays significant role. All the manufacturing or production units are greatly concerned with Quality of the product. The profit level and goodwill of any industry or organization is also a very important criterion besides quality productivity. Production of a large number of products within relatively minimum time is the objective of every production units, but reduction in production & manufacturing time may cause major quality losses. To balance these two contradictory criteria it is essential to check quality level of the item. The purpose is to satisfy the customer's satisfaction level. Various qualitative or quantitative attributes describe the quality of the production. This leads to optimization problem which identify best process condition or parametric combination for that manufacturing process. The present study applied Taguchi method through a case study in turning of A356 Aluminium Alloy rod using Carbide tip tool. The main objective of this study is to find out the best process conditions which fulfill the requirements of quality as well as productivity simultaneously. The predicted optimal conditions ensure the minimization of surface roughness. Verification tests are done for verification of optimal results.

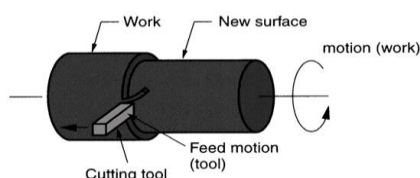
**Key words:** production, eminence, turning, surface coarseness, Material Removal Rate, Taguchi technique

## 1. INTRODUCTION

Turning in a lathe is defined as to remove excess material from work piece to produce a cone-shaped or cylindrical surface in the form of chips from the outer diameter.

Turning is used for the machining of a peripheral surface:

- i) By the work piece revolving.
- ii) By a single point cutting tool,
- iii) By the cutting tool feeding analogous to the axis of the specimen and at a space that will remove the peripheral surface of the specimen.



**Fig -1:** Adjustable parameters in turning operation  
**1.1 Cutting Aspects in Turning**

Speed, deepness of cut and feed are three principal facets which distresses turning operation. There are also some additional features such as category of substantial and sort of tool has an enormous impact, on the other hand these three features are key that an operative can amend at the time of machining.

### Cutting speed

In lathe, cutting speed defined as the number of metres measured on the perimeter of cylindrical job that passes the cutting verge of the tool in single minute.

Cutting speed

$$v = \frac{\pi DN}{1000} \text{ m/min} \tag{Eq. 1.1}$$

Where,

v=cutting speed in metres/min.,

D= Diameter of the specimen in mm, and

N= Speed of spindle in rpm.

### Feed

It is the amount of tool advancement per revolution of job parallel to surfaces being machined. It is given in mm per revolution of the job.

$$F_m = f \cdot N \text{ mm/min} \tag{Eq. 1.2}$$

Here,

F<sub>m</sub> = the feed rate in mm/minute;

f = the feed rate in mm/rev,

N= speed of spindle in rpm.

### Depth of Cut

It is the advancement of tool in the job in a direction perpendicular to the surface being finished. Depth of cut depends upon cutting speed, rigidity of machine tool and tool material etc.

$$d_{cut} = \frac{D - d}{2} \text{ mm} \tag{Eq. 1.3}$$

Here,

D= initial diameter in mm of the specimen and

$d$  = final diameter in mm of the specimen.

**Tool material:** Tool material used for the experiment purpose is

Tool material-Carbide tip tool

STS (5/8" x 6") 15.88 x 152.80 mm

## 1.2 Single Point Cutting Tool Geometry

### Flank

It is the end exterior of a cutting tool that is neighbouring to the cutting verge and beneath it, while the single point cutting tool is in the horizontal position. During the course of plain spinning, the tool is fed into the specimen at the side flank surfaces, and the end verge passes over the recently machined peripheral.

### Face

It is defined as that part against which chips are beared.

### Back rake angle

It is well-defined as the angle between the facade of the tool and an edge analogous to the base of the tool, and measured in a flat through the cutting edge.

### Side rake angle

It is defined as the angle amongst the facade of the tool and the centreline of the specimen, if beheld ahead the tool down the span of the tool holder.

### Side cutting edge angle

It is defined as the angle among the adjacent cutting verge and adjacent of the tool shank.

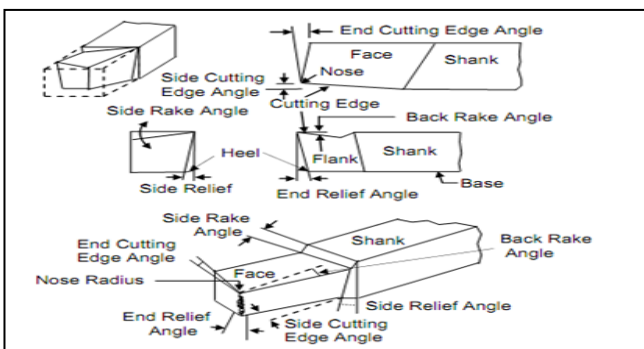


Fig -2: Single point cutting tool geometry

### End cutting edge angle

It is defined as the angle among the extinction flank and a contour of the shank, if observed from above eyeing on the cutting tool.

### Side relief angle

It is defined as the angle among the side flank of the tool and an upright line miserable to the base, if observed behind the tool the extent of the tool edge.

### End relief angle

It is defined as the angle made by the end flank of the tool and vertical to the base of the tool.

### Nose radius

It is point where side cutting verge and end cutting verge crisscrosses. It possesses minor radius which is accountable for producing surface texture on the work-piece

### Lead angle

If a tool frame is manufactured with measurements which move the angle of an insertion, the lead angle receipts this alteration into consideration.

## 1.3 Turning Machines

There are various types of lathe machines used for turning operation. Such as:

- i. Manual Lathe
- ii. Automatic Lathe

**Automatic Lathe:** CNC lathes comes in this category. PC Numerical Controlled (CNC) is one in which the utilities and signals of a machine are synchronized by methods for a PC program containing coded alpha numeric data. CNC can control the developments of the work piece or instrument, the investment limitations like speed, encourage and profundity of cut errands like coolant on/off, turning shaft on/off. PC Numerical Controlled (CNC) machines are being utilized as a part of every sort of assembling and generation techniques. In machine device arrangement, CNC is broadly utilized for machine sheet metal press working machine, tube bowing machine, processing machine, granulating unit.



Fig -3: CNC lathe

## 1.4 Approaches for Evaluation of Surface Coarseness (roughness)

These approaches can be categorized into the subsequent classes:

1. Direct measurement approaches
2. Comparable based approaches

3. Non-contact approaches
4. On-process quantity

## 2. LITERATURE REVIEW

**Srikanth T., and Kamala V.**, “A Real Coded Genetic Algorithm for Optimization of Cutting Parameters in Turning IJCSNS”, International Journal of Computer Science and Network Security, Volume 8 Number 6, pp. 189-193, (2008), assessed optimal solution of cutting constraints by a Real Coded Genetic Algorithm (RCGA) and described several problems of RCGA and its compensations over the prevailing methodology of Binary Coded Genetic Algorithm (BCGA). This study established that RCGA was trustworthy and precise for resolving the cutting parameter optimization and create optimization problem with various assessment variables.

**Doniavi A., Eskanderzade M. and Tahmsebian M.**, “Empirical Modeling of Surface Roughness in Turning Process of 1060 steel using Factorial Design Methodology”, Journal of Applied Sciences, Volume 7, Number17, pp. 2509-2513, (2007), treated response surface methodology (RSM) in directive to improve experimental model for the estimate of surface coarseness by determining the optimal cutting circumstance in turning. The authors disclosed that the feed rate prejudiced surface coarseness bizarrely.

**Thamizhmanii S., Saparudin S. and Hasan S.**, “Analysis of Surface Roughness by Using Taguchi Method”, Attainments in Materials and Production Engineering, Volume 20, Issue 1-2, pp. 503-505, (2007), used Taguchi technique for obtaining the optimum assessment of surface coarseness under optimal cutting circumstance in turning SCM 440 alloy steel. The testing was planned by applying Taguchi technique and trials were led and consequences thereof were examined with the assistance of ANOVA (Analysis of Variance) technique. The reasons of poor surface texture as spotted were machine tool pulsations, tool chattering whose effects were snubbed for investigates. The researchers decided that the outcomes attained by this technique would be suitable to other investigates for analogous form of study on tool pulsations, cutting forces etc.

## 3. METHODOLOGY

The existing research has been completed over the following proposal of investigation.

- a) Inspection and arranging the CNC (Computer Numeric Control) Lathe machine ready for accomplishment the turning process.
- b) Cutting A356 rods by power hacksaw and execution of early turning action in CNC Lathe to acquire anticipated measurement of the work pieces.
- c) The A356 rods are fitted in the jaw of the CNC lathe.

- d) Performing plain turning process on samples in several cutting settings including several sets of control considerations like: feed, speed, feed and penetration of cut.
- e) Now process for checking the roughness.
- f) Measure surface coarseness and surface outline with the assistance of a moveable stylus-type Profilometer, Taylor Hobson (Talysurf).

### 3.1 Process Parameters used for Experimental Work

In this experiment Taguchi L9 Orthogonal Array design have been selected. In present study, spindle speed, feed rate and depth of cut have been considered as process variables. These process variables are selected keeping mind the industrial data. The main aim is to optimize these process variables without changing the machinery installation within the industry.

Table 1 Process parameters used for experimental work

Values in coded form	Spindle Speed (N) (RPM)	Feed (f) (mm/rev)	Depth of cut (d) (mm)
1	600	0.4	0.3
2	1200	0.7	0.5
3	1800	0.9	0.7

### 3.2 Design of Experiment

Experimentations have been conceded out with the help of Taguchi’s L9 Orthogonal Collection. Investigational strategy which comprises of nine arrangements of depth of cut, spindle speed and feed rate. Rendering to the index [Peace, G., S., (1993)] equipped by Taguchi, L9 Orthogonal Collection strategy of investigation has been found appropriate in the existing research. In this study 3 process constraints are measured to be varied in three distinct stages. The Taguchi experimental design has been shown in Table 1 (all factors are in coded form). The different variables are obtained from the following transformation equations:

Spindle speed

$$A = (N - N_0) / \Delta N \quad \text{Eq. 3.1}$$

Feed rate

$$B = (f - f_0) / \Delta f \quad \text{Eq. 3.2}$$

Depth of cut

$$C = (d - d_0) / \Delta d \quad \text{Eq. 3.3}$$

Here A, B and C are the coded values of the variables N, f and d respectively; N<sub>0</sub>, f<sub>0</sub> and d<sub>0</sub> are the values of spindle speed, feed rate and depth of cut at zero level; ΔN, Δf and Δd are the entities or recesses of deviation in speed (N), feed (f) and depth of cut (d) correspondingly.

Table 2 Taguchi's L9 orthogonal selection

Trial No.	Speed (rev./min.)	Feed (millimetre/rev.)	DOC (mm)
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

### 3.3 Coarseness Measurement

Coarseness measurement has been completed by using a transportable stylus-type profilometer, Taylor Hobson (*Talysurf*) shown in Fig. 4. The *Talysurf* apparatus is a handy, independent apparatus for the measurement of surface roughness (primary roughness & secondary roughness). The parameters are evaluated on microprocessor basis. The outcomes are demonstrated on an LCD display and can be yield to a copier or another computer for additional assessment. This instrument is powered by non-rechargeable alkaline battery (9V). This apparatus is fitted out with a diamond stylus taking a tip radius 5  $\mu\text{m}$ . The gauging stroke each time initiates from the extreme outer point and at the completion of the extent the pickup yields to location ready for the subsequent extent. Selection of cut-off length determines the traverse length of piece. Usually the traverse length is five times the cut-off length though the magnification factor can be changed. The profilometer apparatus has customary to an endpoint span of 0.9 mm, filter 3CR, and traverse rapidity 1 mm/sec and 4 mm traverse distance. Coarseness extents on the work pieces have been reiterated 4 intervals and typical of 4 extents of surface coarseness constraint values has been logged. The measured contour has been digitized and handled by the devoted progressive surface texture examination software *Talysurf* for extent of the coarseness constraints.

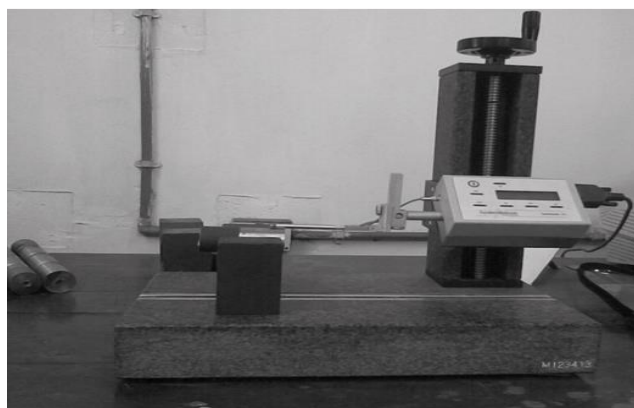


Fig. 4. Stylus-type profilometer, Talysurf (Taylor Hobson)

### 4 Taguchi' Technique

The Taguchi technique was established by a Japanese engineer Dr. Genichi Taguchi who continued that deviation. Taguchi has established together procedure and philosophy for the development or product value enhancement that be contingent predominantly on statistical perceptions and tools, specifically statistically designed experimentations. He was an Engineer who has been working in the enhancement of engineering item for consumption and procedures since 1940s. Many industries get success by applying these methods. Taguchi method reduces the number of tests to achieve the required optimum conditions. The main involvement is that Taguchi has pooled manufacturing and statistical methods to accomplish quick enhancements in decreasing the cost and increasing the quality level by enhancing product strategy and engineering procedures. The anticipated cutting constraints are controlled based on experience or by hand book. Several cutting constraints are revealed on surface coarseness, surface quality and dimensional abnormality turned product. Taguchi methodology to draft of experimentations is very simple to use for operators with no abundant of information of measurements, therefore increased extensive admiration in the manufacturing and scientific society. In entire engineering procedure it is very significant to accomplish a consistence tolerance and surface quality. The degree of surface finish sometimes plays a most important role, when greater accuracy is required. It is very appropriate for manufacturing and engineering purpose, however can also be applied for scientific investigation. The technique discovers the perception of quadratic eminence deficiency function (Fig. 5) and customs a statistical degree of presentation called Signal-to-Noise (S/N) proportion. The Signal-to-Noise proportion receipts together the average and the inconsistency into deliberation. It is demarcated as the proportion of the average (Signal) to the normal deviance (Noise). The proportion be contingent on the quality features of the produce, procedure or amenities to be enhanced.

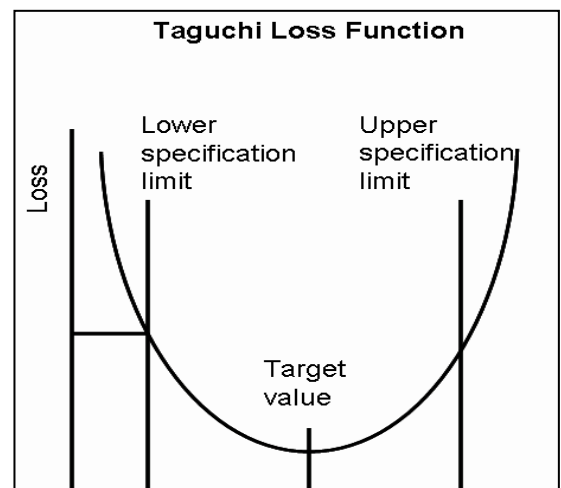


Fig. 5. Taguchi's quadratic loss function



**1. Taguchi’s Signal/Noise Proportion for (NB) Nominal-the-best**

(Quality features is typically a small output, say Diameter)

$$\eta = 10\log(1/n) \sum_{i=1}^n (\mu^2/\sigma^2)$$

Eq. 4.1

**2. Taguchi’s Signal/Noise Proportion for (SB) Smaller-the-better**

(Quality features is typically a small output, say Defects)

$$\eta = -10\log(1/n) \sum_{i=1}^n y_i^2$$

Eq. 4.2

**3. Taguchi’s S/N Ratio for (HB) Higher-the-better**

(Quality features is typically a small output, say Current)

$$\eta = -10\log(1/n) \sum_{i=1}^n (1/y_i^2)$$

Eq. 4.3

(All notations carry their usual meanings)

**4.1 Technique Reformed for Optimization**

The optimization method is the Taguchi technique centred on certain Taguchi’s Orthogonal Array (OA) Strategy of experimentation. The usage of Taguchi’s constraint design comprises the following steps.

- a) Recognize the key meaning and its ill effects.
- b) Recognize the analysis ailment and quality features.
- c) Recognize the objective task to be enhanced.
- d) Recognize the regulator aspects and their levels.
- e) Choose an appropriate Orthogonal Array and paradigm the Matrix and Perform the matrix experiment.
- f) Observe the facts; forecast the optimal regulator factor levels and its presentation.
- g) Perform the confirmation experimentation.

**4.2 Data Examination**

The procedure constraints that are disturbing the features of turned portions are:

1. **Cutting Tool constraints**-Geometry of tool and material of tool.
2. **Work member associated constraints** -Stiffness, Toughness.
3. **Cutting constraints**- Feed, Cutting Speed and Deepness of Cut.
4. **Ecological constraints**- Dry and Wet cutting.

**Typical uses of A356:** It is mostly use in aircraft pump parts, automotive transmission cases, aircraft fittings and control parts, water-cooled cylinder blocks. Other applications where excellent castability and good weldability, pressure tightness, and good resistance to corrosion are

required. A356: aircraft structures and engine controls, nuclear energy installations

Table 3 Chemical Composition of Aluminium 356 ALLOY

Alloy	Elements					Balance
	Cu	Mg	Mn	Si	Fe	
Al 356	0.25	0.4	0.3	6.5	0.5	Al

Table 4 Mechanical properties of A356 alloy

Sr.	Mechanical Properties
1	Brinell Hardness (70), 500 kg load/10 mm ball
2	Ultimate Tensile Strength, minimum is 241
3	Yield Tensile Strength is 165 N/mm <sup>2</sup>
4	Elongation at Break, minimum is 7.5%
5	Modulus of Elasticity in compression is usually about 2% greater than Elastic Modulus in Tension
6	Shear Strength is 180 N/mm <sup>2</sup>

Table 5 Experimental conditions

Specimen Material	A356 Aluminium Alloy
Span of the specimen	60 mm
Diameter of the specimen	25 mm
Lathe machine Used	XLTURN CNC Lathe
Tools Used	Uncoated Carbide Tools
Gauging Apparatus	Profilometer (Talysurf-Taylor Hobson)
Ecology	DRY

Table 6 Process constraints with their values at 3 levels

Process Constraints	Constraint Designation	Levels		
		L1	L2	L3
Speed (rev. /min.)	A	600	1200	1800
Feed (mm/rev.)	B	0.4	0.7	0.8
Depth of Cut (mm)	C	0.3	0.5	0.7

Table 7 Standard L9 orthogonal array

Sr. No.	Speed (rpm)	Feed (mm/rev)	DOC (mm)
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

### 4.3 Test specimen

Figure 5 shows the real picture of test specimen A356 (Aluminium Alloy) about on which experiments have been done.

Dimension of specimen:

- i. Length of the specimen: 60 mm
- ii. Diameter of the specimen: 25 mm

First of all, a test specimen is collected from the market. Then cut it up to the required specifications because some of the material is being removed when machining through turning. After obtaining the required specimen nine numbers of experiments with 3 levels each have been performed.



Fig. 5. Test Specimen A356

**5 Result Analysis:** As discussed earlier, various parameters are chosen for the turning operation. After turning with taking various parameters on lathe machine. These specimen were tested on the Taylor Hobson Talysurf, various surface roughness values were obtained.



Fig. 6 Specimen for roughness measurement after turning



Fig.7 Roughness measurement by Talysurf

Table 8 shows the L9 OA with observed values for each parameter.

Table 8 Standard L9 array with observations

Trial No.	Speed (rpm)	Feed (mm/rev)	DOC (mm)	Ra-1	Ra-2	Ra-3	Ra (Avg, $\mu\text{m}$ )
1	600	0.4	0.3	0.81	0.96	0.86	0.88
2	600	0.7	0.5	2.53	2.41	2.17	2.37
3	600	0.8	0.7	0.54	0.68	0.72	0.65
4	1200	0.4	0.5	3.42	3.55	3.35	3.44
5	1200	0.7	0.7	3.97	3.02	3.17	3.39
6	1200	0.8	0.3	3.11	2.67	2.53	2.77
7	1800	0.4	0.7	3.48	3.68	3.44	3.53
8	1800	0.7	0.3	3.96	3.86	3.54	3.79
9	1800	0.8	0.5	1.34	1.31	1.55	1.4

Table 5.2 General linear model for surface roughness ra

Factor	Type	Levels	Values
Speed	Fixed	3	600, 1200, 1800
Feed	Fixed	3	0.4, 0.7, 0.8
DOC	Fixed	3	0.3, 0.5, 0.7

As well as the experimental data have input in Minitab 15, the various curves are formed as shown in Fig. 8, Fig. 9, Fig. 10.

Fig. 8 Shows S/N (Signal-to-Noise ratio) the variation of parameters chosen and smaller is better.

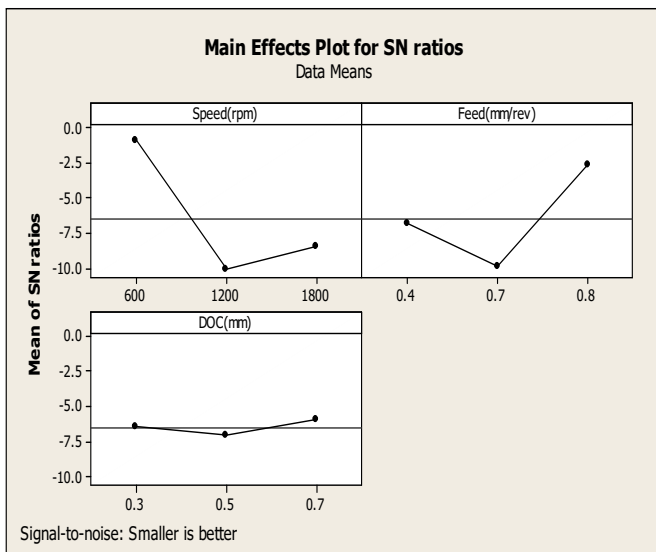


Fig.8 S/N ratio values for Surface Roughness

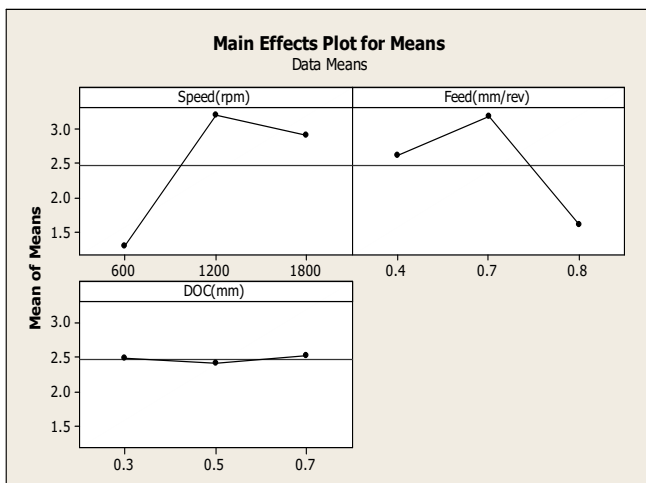


Fig. 9 Main effects plot for mean

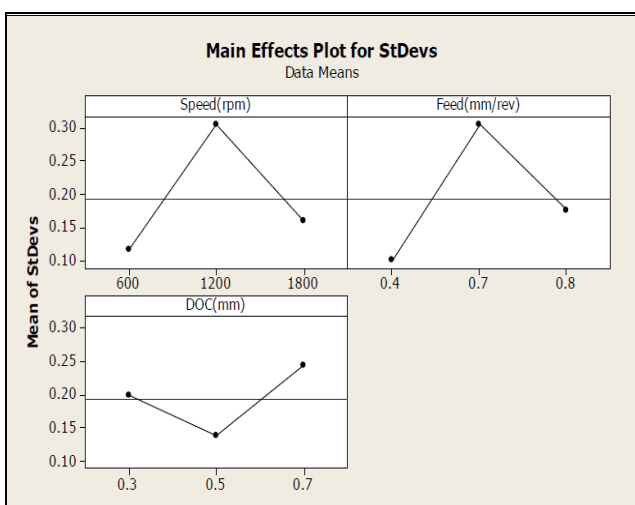


Fig. 10 Main effects plot for Standard Deviation

## 6 Conclusion

The study suggested an optimization approach using Taguchi's optimization methodology. This research deals with optimization of several surface coarseness constraints in examination of an optimum parametric mishmash capable of creating desired surface eminence of the turned product in a moderately smaller interval. Various conclusions drawn based on the test conducted on Aluminium A356 alloy during turning operation with Uncoated Carbide Insert are given below:

- i) From the results obtained a Model has been developed for Surface Roughness. From this model we can predict the optimum value of Surface Roughness if the values of Cutting Speed, Feed and Depth of Cut are known.
- ii) The authentication experimentation established that the error arisen was not as much of as 2.0 % between calculation and real value.
- iii) The optimal settings of process parameters for optimal Surface Roughness are: Speed (600 rpm), Feed (0.8 mm/rev), and DOC (0.7 mm)

This foregoing research provides the way to use Taguchi's method to obtain optimum condition with minimum number of experiments and at lowest cost. The investigation can be comprehensive for other materials by Tool Nose Radius, Lubricant, Material Hardness etc. as process constraints.

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