An Evaluation on Surface Texture of Aluminium Alloy A356 in Cylindrical Turning by Optimizing the Process Variables

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Abstract— In the present market circumstance quality and profitability of an item assumes huge part. All the assembling or generation units are extraordinarily worried about quality of the item. The benefit level and goodwill of any industry or association is additionally an imperative paradigm other than quality efficiency. Creation of a substantial number of items inside moderately least time is the target of each generation units, however diminishment underway and producing time may cause significant quality misfortunes. To adjust these two opposing criteria it is fundamental to check quality level of the thing. The intention is to fulfill the consumer loyalty's level. This prompts enhancement issue which distinguish best process condition or parametric mix for that assembling procedure. To take care of the multi-target streamlining issues, the present investigation connected Taguchi technique through a contextual analysis in turning of A356 Aluminum Alloy bar utilizing Carbide tip tool. The primary goal of this examination is to discover the best procedure conditions which satisfy the prerequisites of value and also efficiency at the same time. The anticipated ideal conditions guarantee the minimization of surface unpleasantness. In this postulation, to give the ideal setting, Taguchi technique is utilized. Confirmation tests are improved the situation check of ideal outcomes.

Key words: Productivity, Quality, Turning, Surface Roughness, MRR, Taguchi Approach

I. INTRODUCTION

The work is straight turned when it is made to rotate about the lathe axis, and the tool is fed analogous to the lathe axis. The plain turning produces a cylinder-shaped exterior by eliminating glut metal from the work piece. The method of turning is occupied by a single point cutting tool on lathe machine. The job is a part of pre-shaped matter that is mounted between the centres using lathe dog, which itself is fixed to the chuck of lathe machine, and allowed to revolve at high rapidity.
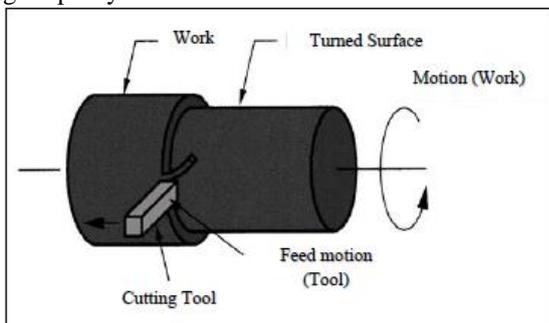

Fig. 1: Adjustable parameters in turning operation

A. Cutting variables in Turning

Speed, depth of cut and feed are three prime aspects which effects turning operation. There are also some other factors such as category of tool has an enormous impact, on the other hand three features are:

B. Cutting speed

While determining the cutting speed for any material, several factors are to be taken into account e.g., the type of job and tool, condition of machining, type of cut required, machinability of material, tool material etc.

Mathematically,

Cutting speed

$$v = \frac{\pi D N}{60} \text{ m/min} \qquad \text{Eq. 1.1}$$

Where,

v = cutting speed in metres/min,

D = Diameter of the specimen in mm, and

N = Speed of spindle in rpm.

C. Feed

The rate at which cutting tool is fed depends upon various factors such as finish required, depth of cut and rigidity of the machine. On maximum programmed lathes, the feed rate is completely associated to the speed of spindle and is articulated in mm (of tool advancement) per revolve of the spindle, or mm/rev. normally feed varies from 0.1 to 1.5 mm.

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

Here,

F_m = the feed rate in mm/minute;

f = the feed rate in mm/rev,

N = speed of spindle in rpm.

D. Depth of Cut

The diameter of the specimen is shrunken by two times the deepness o f cut since this stratum is being take away from both verges of the specimen.

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

Here,

D = initial diameter in mm of the specimen and

d = final diameter in mm of the specimen.

E. Tool Material:

Tool material chosen for the experimentation purpose is Carbide tip tool

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

II. GEOMETRY OF SINGLE POINT CUTTING TOOL

Geometry of cutting tool material plays a very significant role to achieve the effectiveness, efficiency and overall economy of machining. Cutting tools may be classified in two categories: Single point cutting tool and multi-point cutting tool. For single point tools, the utmost essential angles are the end, side relief and rake angles are shown in Fig. 2.
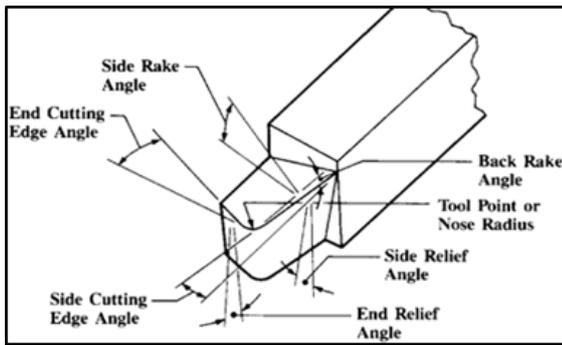
Fig. 2: Single point cutting tool geometry

A. Flank

During the course of plain spinning, the tool is fed into the specimen at the side flank surfaces, and the end edge passes over the recently machined peripheral.

B. Face

It is defined as that surface of the tool against which chips are formed.

C. Back rake angle

It is defined as the angle between the face of the tool and an edge parallel to the base of the tool, and measured in a flat through the cutting edge.

D. Side Rake Angle

It is defined as the angle amid the face of the tool and the centre of the sample, if observed forward the tool down the extent of the tool holder.

E. End Cutting Edge Angle

Increasing the extinction cutting edge angle slants the faraway end of the cutting verge away from the specimen.

F. Side Relief Angle

The angle that thwarts the intervention as the tool cross the threshold the material. Sometimes additional side clearance is also provided on the tool that is also acknowledged as side allowance angle.

G. 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. This word is used for the side cutting edge angle.

III. TURNING MACHINES

A. Turret Lathes

A longitudinally support hexagon turret replaces the tailstock in turret machine. The turret machine, contains six tools can be mounted, can be rotated about a vertical centre point to bring every tool into working position and the entire unit can be moved longitudinally either physically or by power, to offer sustain to the instruments. The turret indexes consequently to the end of its development when the turret get together is moved in an opposite direction from the shaft by methods for a capstan wheel, along these lines, bring each of the six devices into working position. Proceeding most turret machines, it can be moved transversely, by approaches for the cross slide, and longitudinally over the carriage. In maximum circumstances, an established tool frame similarly

is added to the back end of the cross slide for conveying a separating device.

Fig. 3: Turret lathe

IV. MATERIAL REMOVE RATE

The material removal rate (MRR) in turning operations is defined as the volume of material removed per unit time from the work piece in mm^3/min. Fig. shows various dimension of work piece to be turned. For each revolution of the work piece, a ring- shaped layer of material is removed.

$$MRR = (v.f.d \times 1000) \text{ in } mm^3/min \qquad Eq. 1.4$$

Let, v= cutting speed in m/min,
  f= feed, mm/rev., and
  d= depth of cut in, mm

$$mrr = \left(\frac{\pi D^2}{4} - \frac{\pi d^2}{4}\right) \times F \times rpm$$

where,
  D = diameter of workpiece before cutting
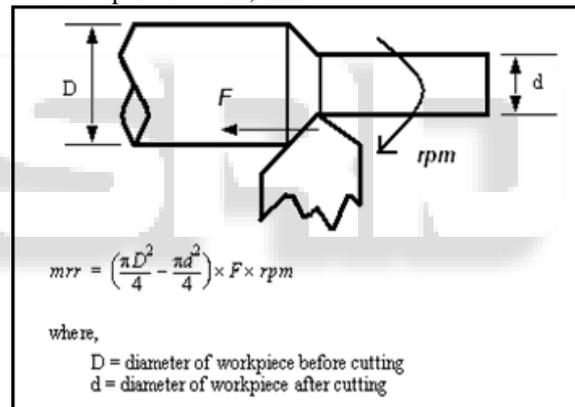 d = diameter of workpiece after cutting

Fig. 4: MRR in turning

V. SURFACE STRUCTURE AND PROPERTIES

Surface irregularity is an extent of product eminence since surface irregularity prominently influences the performance of mechanical measures and production cost. Mechanical characteristics like fatigue behaviour, oxidization confrontation, creep life span, etc., depend prominently on the surface irregularity. (Fig.5).
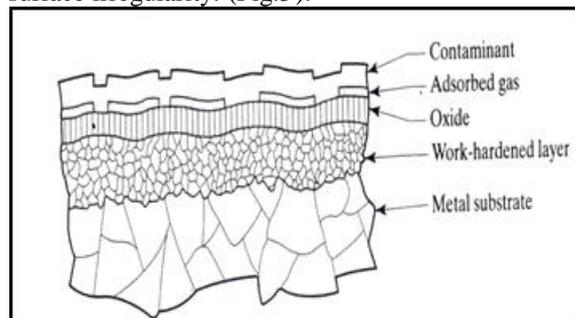

Fig. 5: Schematic of a cross-section of the surface structure of metal

The greater part of metal (substrate) has a structure that depends on the arrangement and dispensation of the metal.

Above the substrate, there is a stratum that regularly has been plastically warped and work-hardened during the manufacturing process.

An oxide layer forms above the work- hardened stratum, when the metal is processed and kept in an inert environment or is a gallant metal such as gold or platinum. Surface oxide stratums are normally protected with absorbed stratums of gas and humidity.

The farthest apparent of the material may be shielded with impurities for example dirt, dust, smear, lubricant scums cleaning-compound and contaminants from the atmosphere.

VI. SURFACE ROUGHNESS IN TURNING

The consequential jaggedness formed by a turning progression can be considered as the grouping of two extents:

− Ideal roughness
− Natural roughness.

A. Ideal Roughness:

It is the gathering of feed and tool geometry. It defines the paramount promising quality that can be acquired aimed at a particular tool contour and feed. Ideal roughness can be accomplished solitary if the built-up-edge, chatter and imprecisions in the machine tool travels are disinterested. For a high-pitched tool devoid of nose radius, the extreme elevation of patchiness is given by:

$$R_{max} = \frac{f}{\cot \phi + \cot \beta} \qquad \text{Eq. 1.5}$$

Where, f =feed rate,
ϕ =principal cutting edge angle and
β =minor cutting edge angle.
The surface roughness assessment is given by,

$$R_a = R_{max}/4 \qquad \text{Eq. 1.6}$$

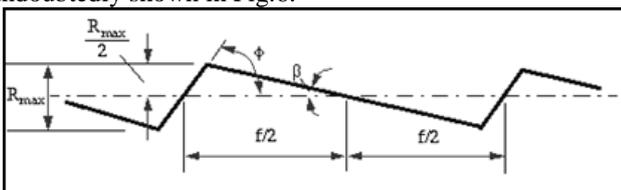Unrealistic prototype of surface unevenness has been undoubtedly shown in Fig.6.

Fig. 6: Idealized model of surface roughness

B. Natural roughness

Natural surface roughness actually forms a large proportion roughness. The foremost intention to natural roughness is the existence of a built-up edge and shuddering of the machine tool.

VII. CONSIDERATIONS OF SURFACE COARSENESS

Roughness constraints are designed using a formula. There are several diverse roughness constraints nevertheless R_a is the utmost common. Additional constraints comprises of R_z, R_q and R_{sk}.

The formulations recorded in the Table I assume that the roughness contour has been strained from the raw contour records and the mean line has been calculated.

Parameter	Description	Formula
R_a, R_{aa}, R_{yni},	Arithmetic average of absolute values	$R_a = \dfrac{1}{n}\sum\limits_{i=1}^{n} \lvert y_i \rvert$
R_q, R_{RMS}	Root mean square	$R_q = \sqrt{\dfrac{1}{n}\sum\limits_{i=1}^{n} y_i^{\,2}}$
R_v	Maximum valley depth	$R_v = \min_i\ y_i$
R_p	Maximum peak height	$R_p = \max_i\ y_i$
R_t	Maximum height of the profile	$R_t = R_p - R_v$
R_{sk}	Skewness	$R_{sk} = \dfrac{1}{n\,R_q^{\,3}}\sum\limits_{i=1}^{n} y_i^{\,3}$
R_{ku}	Kurtosis	$R_{ku} = \dfrac{1}{n\,R_q^{\,4}}\sum\limits_{i=1}^{n} y_i^{\,4}$

Table 1: Various Surface Roughness Parameters and Their Formulae

A. Approaches for Evaluation of Surface Roughness

Assessment and extent of surface coarseness of finished work pieces can be completed by means of diverse measurement approaches. 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

B. Applications

Commonly used in the manufacture of heavy-duty structures requiring good corrosion resistance, automatic weavings machine components, truck and marine components, railroad cars, furniture, tank fittings, general structural and high pressure applications, wire products, and in pipelines, automatic winding machines components.

VIII. LITERATURE REVIEW

Fnides B., Aouici H., Yallese M. A., X "Cutting forces and surface roughness in hard turning of hot work steel X38CrMoV5-1 using mixed ceramic", Mechanika, Volume 2, Number 70, pp. 73-78, (2008), considered on machining of slide-lathing grade X38CrMoV5-1 steel handled at 50 HRC by a merged ceramic tool (insertion CC650) to expose the effects of cutting constraints: flank wear, feed rate, cutting rapidity and depth of cut on cutting forces besides on surface coarseness. The author found that tangential cutting force was very sensitive to the variation of cutting depth. It has been examined that surface coarseness was very delicate to the deviation of feed rate and that flank wear had an excessive effect on the development of cutting force components and on the benchmarks of surface coarseness.

Mahmoud E. A. E. and Abdelkarim H. A., "Optimum Cutting Parameters in Turning Operations using HSS Cutting Tool with 45^0 Approach Angle", Sudan

Engineering Society Journal, Volume 53, Number 48, pp. 25-30, (2006), considered on turning process by High-Speed Steel (HSS) cutting tool with 45^0 slant angle. This tool indicated that it might execute cutting process at greater rapidity and longer tool life than customary tool with 90^0 slant angle.

Suresh P. V. S., Rao P. V. and Deshmukh S. G., "A genetic algorithmic approach for optimization of surface roughness prediction model", International Journal of Machine Tools and Manufacture, Volume 42, pp. 675–680, (2002), engrossed on turning mild steel by TiN-coated tungsten carbide (CNMG) cutting tools for emerging a surface coarseness forecast simulation by using Response Surface Methodology (RSM). Genetic Algorithms (GA) worked to optimize the impartial role and matched with RSM outcomes. It was detected that Genetic Algorithm program providing least and extreme standards of surface coarseness and their corresponding optimum machining circumstances.

A. Procedure

1) The existing research has been completed over the following proposal of investigation.
2) Inspection and organizing the CNC (Computer Numeric Control) Lathe machine prepared for achievement the turning procedure.
3) Cutting A356 bars by control hacksaw and execution of early handing activity over CNC Lathe to secure expected estimation of the work pieces.
4) The A356 bars are fitted in the jaw of the CNC machine.
5) Performing plain turning process on tests in several cutting settings including a few arrangements of control contemplations like: nourish, speed, encourage and infiltration of cut.
6) Measure surface coarseness and surface layout with the help of a moveable stylus-sort Profilometer, Taylor Hobson (Talysurf).

B. Process Variables Taken For Experimental Work

In this trial Taguchi L9 Orthogonal Array configuration have been chosen. In exhibit ponder, speed of spindle, feed rate and deepness of cut have been considered as process factors. These procedure factors are chosen keeping mind the modern information. The fundamental point is to advance these procedure factors without changing the hardware establishment inside the industry.

Sr.No.	Speed	Feed	DOC
1	600	0.4	0.3
2	1200	0.7	0.5
3	1800	0.9	0.7

Table 2: Process Parameters Used For Experimental Work

C. Experimentation Design

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 equipped by Taguchi, L9 Orthogonal Collection strategy of investigation has been found appropriate in the existing research. The Taguchi experimental design has been shown in Table 3.2. The different variables are obtained from the following transformation equations:
Spindle speed

$$A = (N-N_0)/\Delta N \qquad \text{Eq. 1.7}$$
Feed rate
$$B = (f-f_0)/\Delta f \qquad \text{Eq. 1.8}$$
Depth of cut
$$C = (d-d_0)/\Delta d \qquad \text{Eq. 1.9}$$

Here A, B and C are the coded values of the variables N, f and d respectively; N_0, f_0 and d_0 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.

Trial No.	Speed (rev./min.)	Feed (millimetre/rev.)	DOC (millimetres)
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

Table 3: Taguchi's L9 Orthogonal Selection

D. Equipments Used

1) Centre Lathe

The Centre Lathe is utilised to manufacturing cylinder-shaped from an array of materials comprising; plastics and steels. Several works that verve composed to create an engine work have been mass-produced by lathes. These may be manually operated lathes or computer controlled (i.e., NC or CNC) lathes that have been automated to convey out a specific task. Computer controlled lathe machine is used for current experiment.

Fig. 7: Experimental setup (CNC lathe)

2) Cutting Tool Used

Tool material specification-Carbide tip tool
STC (6/7" x 7") 16.88 x 152.70 mm

3) Work Piece Used

Aluminium (A356) rods of length 30 mm and diameter 25 mm.

IX. COARSENESS MEASUREMENT

Coarseness estimation has been finished by utilizing a transportable stylus-sort profilometer, Taylor Hobson (Talysurf) appeared in Fig.8. The parameters are assessed on chip premise. The results are exhibited on a LCD show and can be respect a copier or another PC for extra appraisal. This instrument is controlled by non-rechargeable soluble battery

(9V). This device is fitted out with a precious stone stylus taking a tip sweep 5 µm. The gaging stroke each time starts from the extraordinary external point and toward the fruition of the degree the pickup respects area prepared for the ensuing degree. Choice of cut-off length decides the navigate length of piece. Typically the cross length is five times the cut-off length however the amplification factor can be changed. The profilometer mechanical assembly has standard to an endpoint traverse of 0.9 mm, channel 3CR, and navigate speed 1 mm/sec and 4 mm cross separation. Coarseness degrees on the work pieces have been repeated 4 interims and run of the mill of 4 degrees of surface coarseness limitation esteems has been logged.
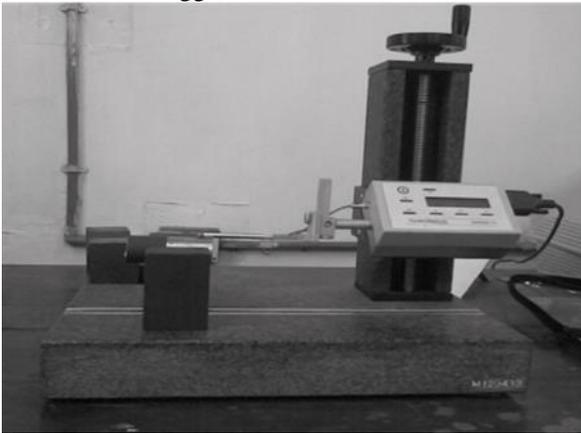

Fig. 8: Stylus-type profilometer, Talysurf (Taylor Hobson)

X. MATERIAL REMOVAL RATE MEASUREMENT

Material removal rate (MRR) has been calculated from the difference of weight of work piece before and after experiment.

$$MRR = (W_i - W_f)/\rho_a t \qquad mm^3/min \qquad Eq.1.10$$

W_i is the initial weight of work piece in g, W_f is the final weight of work piece in g, t is the machining time in min., ρ_a is the density of Al356 in g/ mm³ (2.67x10⁻³ g/ mm³). The weightiness of the work piece has been measured in a great accuracy digital weighing scale, which can measure up to the precision level of 10^{-4} *g* and therefore escaping the chance of great inaccuracy while computing material removal rate (MRR) in plain turning process.

A. Data Collection

First of all A356 bars (of diameter 25mm and length 60mm) necessary for accompanying the experimentation have been primed. Meanwhile L9 orthogonal optimization method is using for existing study thus nine specimens of identical material and identical proportions have been prepared. Applying diverse levels of the progression constraints nine samples have been turned in computer numerically control lathe consequently. Machining interval for apiece specimen has been intended.

After machining, surface coarseness and surface contour have been measured precisely by the assistance of a transportable stylus-type Profilometer, Taylor Hobson (Talysurf). The results of the experiments have been shown in Table VII. The analysis has been made based on those experimental data basis in the following chapter. Optimization of surface roughness has been made by Taguchi method. Confirmatory tests (by Minitab 15) have also been conducted finally to validate optimal results.

B. Data Analysis

1) Taguchi' Technique

The Taguchi technique comprises decreasing the deviation in a progression through simple strategy of experimentations. The global aim of the technique is to manufacture high value product at small cost to the producer. The typical Signal-to-Noise proportions commonly used are as follows: - Smaller the Better (SB) and Upper the Better (UB), Nominal is Best (NB). The optimal situation is the constraint arrangement, which has the maximum Signal/Noise proportion. Several Signal-Noise curvatures have been drawn to portray the performance on variable the diverse control constraints.
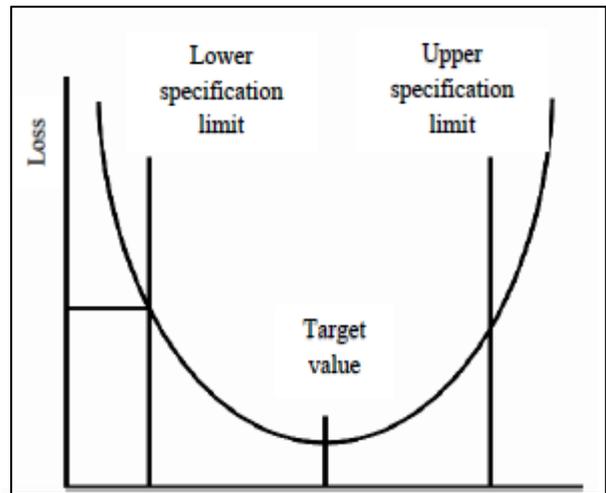

Fig. 9: Taguchi's quadratic loss function

1) Taguchi's Signal/Noise Proportion for (NB) Nominal-the-best

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

$$\eta = 10\log(1/n) \sum_{i=1}^{n}(\mu^2/\sigma^2) \qquad Eq.1.11$$

2) Taguchi's Signal/Noise Proportion for (SB) Smaller-the-better

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

$$\eta = -10\log(1/n) \sum_{i=1}^{n} y_i^2 \qquad Eq.1.12$$

3) Taguchi's S/N Ratio for (HB) Higher-the-better

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

$$\eta = -10\log(1/n) \sum_{i=1}^{n} (1/y_i^2) \qquad Eq. 1.13$$

C. 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.

1) Recognize the key meaning and its ill effects.
2) Recognize the analysis ailment and quality features.
3) Recognize the objective task to be enhanced.
4) Recognize the regulator aspects and their levels.
5) Choose an appropriate Orthogonal Array and paradigm the Matrix and Perform the matrix experiment.
6) Observe the facts; forecast the optimal regulator factor levels and its presentation.
7) Perform the confirmation experimentation.

Alloy	Elements by weight %					Balance
	Cu	Mg	Mn	Si	Fe	
Al 356	0.25	0.2-0.45	0.35	6.5-7.5	0.6	Al

Table 4: Chemical Composition of Aluminium 356 Alloy

Process Constraints	Constraint Designation	Levels		
		L1	L2	L3
Speed	A	600	1200	1800
Feed	B	0.4	0.7	0.8
DOC	C	0.3	0.5	0.7

Table 5: Process Constraints with Their Values at 3 Levels

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

Table 6: Standard L9 Orthogonal Array

D. Test Specimen

Figure.10 shows the real picture of test specimen A356 (Aluminium Alloy) about on which experiments have been done.

1) Dimension of specimen:
1) Length of the specimen: 30 mm
2) Diameter of the specimen: 25 mm

First of all, a test specimen is collected from the market of 850 mm length and 25 mm in diameter. Then cut it up to the required specifications (i.e. 30 mm in length). The greater length of specimen is so selected because some of the material is being removed when machining through cutting and turning. After obtaining the required specimen nine numbers of experiments with 3 levels each have been performed.

Fig. 10: Test Specimen A356

XI. RESULT AND CONCLUSION

A. 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. 11: Side view of specimen for roughness measurement after turning

Fig. 12: Roughness measurement by Talysurf

Calculations of S/N Ratios for Surface Roughness of Table No. VII

1) S/N Ratio (Experiment 1)

$$\eta_1 = -10\log(1/n)\sum_{i=1}^{n=3} y_i^2$$
$$\eta_1 = -10\log[(1/3)(0.81^2 + 0.96^2 + 0.86^2)]$$
$$\eta_1 = 1.12$$

2) S/N Ratio (Experiment 2)
$$\eta_2 = -10\log[(1/3)(2.53^2 + 2.41^2 + 2.17^2)]$$
$$\eta_2 = -7.49$$

3) S/N Ratio (Experiment 3)
$$\eta_3 = -10\log[(1/3)(0.54^2 + 0.68^2 + 0.72^2)]$$
$$\eta_3 = 3.74$$

4) S/N Ratio (Experiment 4)
$$\eta_4 = -10\log[(1/3)(3.42^2 + 3.55^2 + 3.35^2)]$$
$$\eta_4 = -10.73$$

5) S/N Ratio (Experiment 5)
$$\eta_5 = -10\log[(1/3)(3.97^2 + 3.02^2 + 3.17^2)]$$
$$\eta_5 = -10.60$$

6) S/N Ratio (Experiment 6)
$$\eta_6 = -10\log[(1/3)(3.11^2 + 2.67^2 + 2.53^2)]$$
$$\eta_6 = -8.84$$

7) S/N Ratio (Experiment 7)
$$\eta_7 = -10\log[(1/3)(3.48^2 + 3.68^2 + 3.44^2)]$$
$$\eta_7 = -10.95$$

8) S/N Ratio (Experiment 8)
$$\eta_8 = -10\log[(1/3)(3.96^2 + 3.86^2 + 3.54^2)]$$
$$\eta_8 = -11.57$$

9) S/N Ratio (Experiment 9)
$$\eta_9 = -10\log[(1/3)(1.34^2 + 1.31^2 + 1.55^2)]$$
$$\eta_9 = -2.92$$

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

Trial No.	Speed (rpm)	Feed (mm/rev)	DOC (mm)	Ra-1	Ra-2	Ra-3	Ra (Avg,)	S/N Ratio for rough
1	600	0.4	0.3	0.81	0.96	0.86	0.88	1.12
2	600	0.7	0.5	2.53	2.41	2.17	2.37	-7.49
3	600	0.8	0.7	0.54	0.68	0.72	0.65	3.74
4	1200	0.4	0.5	3.42	3.55	3.35	3.44	-10.73
5	1200	0.7	0.7	3.97	3.02	3.17	3.39	-10.6
6	1200	0.8	0.3	3.11	2.67	2.53	2.77	-8.84

7	180 0	0.4	0.7	3. 48	3. 68	3. 44	3.5 3	-10.95
8	180 0	0.7	0.3	3. 96	3. 86	3. 54	3.7 9	-11.57
9	180 0	0.8	0.5	1. 34	1. 31	1. 55	1.4	-2.92

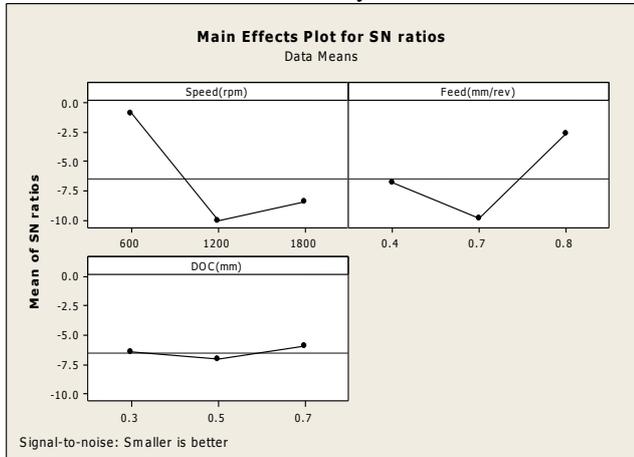Table 7: Standard L9 Array with Observations

Fig. 13: S/N ratio values for Surface Roughness

XII. 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:

1) 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.

2) The authentication experimentation established that the error arisen was not as much of as 2.0 % between calculation and real value.

3) The optimal settings of process parameters for optimal Surface Roughness are: Speed (600 rpm), Feed (0.8 mm/rev), and DOC (0.7 mm)

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