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APPLICATION OF TAGUCHI METHOD IN OPTIMIZING TURNING PARAMETERS OF ALUMINIUM ALLOY (H-15)

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Abstract
Every company seeks high production rate with high quality i.e., with low Surface roughness and dimensional accuracy have been the important factors to predict machining performances of any machining operation. Turning is used in variety of manufacturing industries including the aerospace and automotive sectors, where quality is an important factor in the prediction of rods, partings, boring moulds and dies. In this work a second order polynomial equation model is developed to predict the surface roughness. The Design of Experiments (DOE) technique was developed for three factors at three levels to conduct experiments. In this study, machining was performed on INTEX (GU1400) horizontal machining turning centre under dry condition. Experiments have been conducted considering cutting speed, feed rate and depth of cut as process parameters. Based on three-level full factorial design is used to generate a second order polynomial equation for surface roughness (R_a).The equation can be used for the analysis and prediction of the complex relationship between cutting parameters and the surface roughness on flat turning of aluminium alloy(H-15). The values of response obtained by both the models, i.e. factorial design are compared with the experimental values and average percentage deviation was found. Surface roughness, for that it is required to optimize the turning parameters. Taguchi method is one of the Optimization techniques for optimizing the cutting parameters. By using Taguchi method, optimizing the cutting parameters for the considered DOE

Keywords: Optimization, Taguchi method, Turning, surface roughness, Aluminium Alloy (H-15).

I. INTRODUCTION

In any modern industries the main objective is to manufacture the product with low cost and high quality in a short time. The most common method used for cutting metals and finishing of machined parts is “Turning”. It is broadly used in a variety of manufacturing units such as aerospace and automotive sectors. Surface roughness is commonly used for index of product quality and necessary for mechanical components. The great importance of the mechanical parts is to achieve the desired surface quality.

Surface roughness is used to determine the quality and factor of the product and it influences the manufacturing cost. It normally states that the lower desire surface roughness, the more manufacturing cost and vice versa. The surface roughness is mutual with the surface thickness, that is process dependant, can play a vital role on the operational characteristics of the part. It formulates an important design feature in many situations with respect to mechanical parts like fatigue loads, precision fits, fastener holes and aesthetic requirements. Besides tolerances surface roughness imposes one of the most critical constraints used for the selection of machines and cutting parameters in process planning.

The surface quality plays a vital role and improves fatigue strength, corrosion resistance and creep life. It also affects several functional parts like contact causing surface friction, wearing, light reflection, heat transmission, ability of distribution, holding a lubricant and coating. The final surface roughness should be considered as the sum of two independent effects.

The factors such as spindle speed, feed rate, and depth of cut that are used to control the cutting operation can be setup in progress. Nevertheless, factors such as geometry of cutting tool, tool wear, and joint material properties of both tool and work piece are out of control.

Other factors that are normally give to natural surface roughness in practice are the occurrence of chatter or vibrations of the machine tool, inaccuracies in machine tool movements such as the movements of the table, irregularities in the feed mechanism, defects in the structure of the work material, discontinuous chip formation when machining brittle materials, tearing of the work material when ductile metals are cut at low cutting speeds, surface damage caused by such factors as chip. One should develop techniques to predict the surface roughness of a product before machining in order to determine the required machining parameters such as feed rate or spindle speed for obtaining a desired surface roughness and product quality. It is also important technique the prediction should be accurate, reliable, low-cost, and non-destructive. Therefore, the purpose of this study is to develop surface prediction models.

One should able to obtain a functional relationship between process parameters viz. speed, feed and depth of cut and the surface roughness. Prediction strategy can be developed using the following method.

1.1 ALUMINIUM:

It is a metallic element and is used in several form such as forgings and bars, sheets plates etc either in pure form or as alloys. It is silvery white soft and ductile metal. It is an excellent conductor of heat and electricity. It is the most copious chemical element of all the metals by occupying third place. It is available in the earth's crust over 8% of its weight. The two common elements oxygen and silicon are more available in the atmosphere. Atomic number of Aluminum is 13 and atomic weight is 26.981(27).It belonged to third group in periodic table. It has about one third the density and stiffness of steel. Atoms of pure aluminum have a face centered cubic crystal structure (FCC).

Aluminium is broadly classified into two types they are

- *Wrought aluminium alloys*
- *Cast aluminium alloys.*

II. TAGUCHI METHOD:

Many research has been conducted for determing optimal process parameters. kwak presented the taguchi and response method to determine the robust condition for minimization of roundness error of workpieces. Yang and Trang employed Taguchi method and optimal cutting parameters of steel bars of turning operations.

The taguchi technique is a methodology for finding the optimum setting of the control factors to make product insensitive to the noise factor. This technique has been used in engineering design.

Taguchi Method is developed by Dr. Genichi Taguchi, a Japanese quality management consultant. The method explores the concept of quadratic quality loss function and uses a statistical measure of performance called Signal-to-Noise (SN) ratio. The SN ratio takes both the mean and the variability into account. The SN ratio is the ratio of the mean (Signal) to the standard deviation (Noise). The ratio depends on the quality characteristics of the product/process to be optimized. The standard SN ratios generally used are as follows: - Nominal is Best (NB), Lower the Better (LB) and Higher the Better (HB). The optimal setting is the parameter combination, which has the highest SN ratio.

Taguchi Method treats optimization problem in two categories:

1. Static problems:

Generally, a process to be optimized having several control factors which directly decide the output of the target or preferred value. The optimization can be involves significant the best control factor levels so then the output is the target value. Such a kind of problem is called as a "STATIC PROBLEM". These are finest explained by means of a P-Diagram which is as shown in below ("P" stands for Process or Product). Noise is shown to be present in this method but should have no effect on the output! This is the primary aim of the Taguchi experiments - to minimize variations in output even though noise is present in the procedure. Then that procedure is said to have become ROBUST.

There are three signal-to-noise ratios of general interest for optimization of static problems.

1. Taguchi's S/N Ratio for the (NB) Nominal-the-best

(Quality characteristic is usually a nominal output, say Diameter)

$$\eta = 10 ln_{10} \frac{1}{n} \sum_{i=1}^{n} \frac{\mu^2}{\sigma^2}$$

This is a generally the chosen S/N ratio for all undesirable distinctiveness like "Defects" etc. for which should be the ideal value is zero. moreover, when an ideal value is finite and its maximum or minimum value is defined (like maximum purity is 100% or maximum Tc is 92K or minimum time for making a telephone connection is 1 sec) then the difference between measured data and ideal value is estimated to be as undersized as possible. The ordinary form of S/N ratio then becomes,

2. Taguchi's S/N Ratio for the (LB) Lower-the-better

(Quality characteristics is usually a nominal output, say *Defects)*

$$\eta = -10 ln_{10} \frac{1}{n} \sum_{i=1}^{n} {y_i}^2$$

In this case it has been better to SMALLER-THE-BETTER by taking the reciprocals of measured data and then taking the S/N ratio as in the smaller-the-better case.

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

(Quality characteristics is usually for the nominal output, say *Current)*

$$\eta = -10 ln_{10} \frac{1}{n} \sum_{i=1}^{n} \frac{1}{{y_i}^2}$$

This case arises when a specified value is MOST desired, meaning that neither a smaller nor a larger value is desirable.

2.Dynamics problems:

If the product to be optimized has an input signal that openly decide the output signal, then the optimization involves influential the best control factor levels so that the "input signal / output" ratio is neighboring to the preferred relationship. Such a type of problem is called as a "DYNAMIC PROBLEM". This is best described by a P-Diagram which is shown below. Once more, the primary aim of the Taguchi experiments - to minimize variations in output even though noise is present in the process- is achieved by getting improved linearity in the input/output relationship.

In dynamic problems, we come across many applications where the output is supposed to follow input signal in a prearranged manner. Generally, a linear relationship between "inputs" "output" is desirable.

III. EXPERIMENTAL PROCEDURE:

The material usd for cutting was aiuminium alloy (h-15) can be turned on CNC machine.The mechanical properities of work piece material are shown below.The test specimen were in the form of a bar,25mm in diameter and 1350mm in length.

Table 1 Mechanical properties of Aluminium alloy AA24345 (H 15):

Direction	UTS Mpa (min)	0.2% PS Mpa(Min)	%Elongation 4D(Min)
Tangential	450	385	8
Axial	450	385	3
Radial	425	350	2

The machine used for the experiments was CNC machine "INTEX GU(1400) wth a 22.2KW power supply,speed range=3500 and cutting tool was carbide insert because aluminium is a soft material.

Figure 1 CNC Machine

3.1 EXPERIENTAL PLAN: In the present study three parameters namely cutting speed,feed rate and depth of cut were considered.
The cutting parameters ranges based on machine and provided by work piece and tool manufacture.after machining the surface roughness can be measured by using profilemeter surftest MITUTOYO SJ-301

3.2 CUTTING INSERT

A tipped tool normally refers for cutting any tool that has a cutting edge consists of a detached material piece that is either brazed or clamped on to a separate body. Polycrystallinediamond, Tungsten carbide, and cubic boron nitrite are the materials which are commonly used for tips. For tipped purpose we use tools namely milling cutters, tool bits and saw blades. The tool used for the turning operation is carbide.

Carbides:

Carbides are also known as cemented carbides or sintered carbides had been introduced in the year 1930. Carbides have high hardness over a maximum temperature range. It has high conductivity of thermal and lofty young's modulus which makes them as a effective tools and used as a die materials for a variety of Applications.

Tungsten carbide and titanium carbide are used for the purpose of machining and both these types shall be coated or uncoated.

The particles of tungsten carbide (1 to 5 micro meters) are mixed together by using cobalt matrix powder metallurgy. This powder can be hard-pressed and formed to the necessary insert shape. To communicate special properties titanium and niobium carbides are added.

For different applications uses a large grade range. A sintered carbide tip uses dominant material for the purpose of cutting the metal. The cobalt proportion (the usual matrix material) has an important consequence with the carbide tools properties. The 3-6% of cobalt matrix gives superior toughness and that decreases the stability, confrontation and potency. For the purpose of machining steels, cast irons and abrasive non-ferrous materials that uses tungsten carbide tools. Tungsten has lower wear resistance when compared to titanium carbide but it is not as soft. The nickel-molybdenum alloy used as a matrix (Tic) is appropriate for the purpose of machining at elevated speeds rather than tungsten Carbide. Based on coating the cutting speeds are typically used as 30 - 150 m/min or 100 – 250.

3.3 SPECIFICATIONS:

Figure 2 Carbide Insert

CNMG 12-04-04 cutting insert was used to perform Experiment

Table 2 : ISO Specification of carbide Insert

C	**N**	**M**	**G**	**12**	**04**	**04**
Rhomb ▱	Clearance angle 0°	Tolerance	Geometry	Length of the cutting edge	Thickness	Corner 0.4 radius

3.4 SURFACE ROUGHNESS TESTER:

The roughness can be measured by using a portable stylus-type profilometer, Talysurf. Based on the microprocessor the parameters are evaluated. The measured consequences are displayed on a screen (LCD) and used as an output to an optional printer or another system for auxiliary evaluation. The instrument is powered by non-rechargeable alkaline battery (9V) that consists a diamond stylus has a tip of radius 5μm. At the extreme outward position stroke is always measured. At the end the pickup measurements return to the position and ready for further measurement.

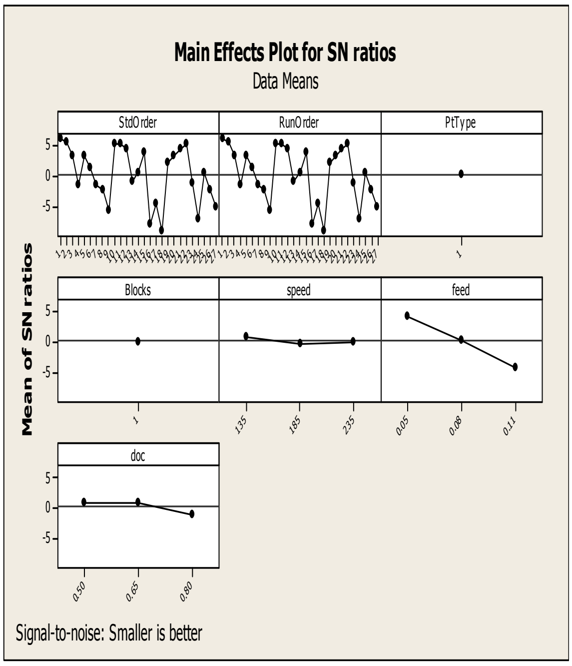
Figure 3 surface roughness

Table 3: Analyzed S/N ratios by Taguchi method

S.No	Speed	Feed	Depth	Ra	SN ratio
1	135	0.05	0.50	0.50	6.0205999
2	135	0.05	0.65	0.53	5.514482
3	135	0.05	0.80	0.69	3.223018
4	135	0.08	0.50	1.18	-1.43764
5	135	0.08	0.65	0.69	3.223018
6	135	0.08	0.80	0.87	1.209614
7	135	0.11	0.50	1.18	-1.43764
8	135	0.11	0.65	1.32	-2.41147
9	135	0.11	0.80	1.91	-5.62054
10	185	0.05	0.50	0.56	5.03623
11	185	0.05	0.65	0.55	5.1927
12	185	0.05	0.80	0.61	4.29340
13	185	0.08	0.50	1.11	-0.90645
14	185	0.08	0.65	0.94	0.53744
15	185	0.08	0.80	0.65	3.7417
16	185	0.11	0.50	2.47	-7.85393
17	185	0.11	0.65	1.71	-4.6599
18	185	0.11	0.80	2.82	-9.004982
19	235	0.05	0.50	0.79	2.0474
20	235	0.05	0.65	0.70	3.0980
21	235	0.05	0.80	0.61	4.2934
22	235	0.08	0.50	0.56	5.03623
23	235	0.08	0.65	1.16	-1.2891
24	235	0.08	0.80	2.25	-7.0436
25	235	0.11	0.50	0.97	0.2645
26	235	0.11	0.65	1.32	-2.41147
27	235	0.11	0.80	1.80	-5.1054

Main effects of cutting parameters of aluminium alloy (h-15):

Surface roughness values are measured by surface roughness tester and calculated by second order polynomial equation are plotted in the graph with the constant of each parameter (speed, feed, Doc, means, and s/n ratios).



IV. ANALYSIS OF VARIANCE:

The ANOVA analysis was carried at 95% confidence level. The analysis of variance was carried out for determining the influence of process parameters on the response variable.

Degrees of freedom

DOF is an important factor and useful concept that is difficult to define. It is a defined as to determine the amount of information that can be distinctively determined from a given set of data.

Sum of squares

The sum of squares is a measure of the deviation of the experimental data from the mean value of the data. Summing each squared deviation emphasized the total deviation.

Variance due to error

Error variance, generally termed as variance that is equal to the sum of squares divided by the degree of freedom error. Error variance is defined as a measurement of the variance due to all the uncontrolled parameter that includes measured error which involves in certain experiment.

F-test for comparison

Statistically there is a tool which provides a decision at some confident level as to whether the estimations of the variance based on the variance of averages and that based on the variation of individual are significantly different. This tool is called F-test. The F-test is simply a ratio of samples variances as shown in equation given below.

$$F=\frac{S_{y1}^2}{S_{y2}^2}$$

When this ratio become large enough, then the two sample variances are accepted as being unequal at some confidence level. To determine whether an F ratio of two sample variance is statistically large enough, three pieces information considered. One, the confidence level, other two are degree of freedom associated with the sample variance in the numerator and degree of freedom associated with the sample variance in the denominator.

The analysis of variance was called out for determining the influence of process parameters on the response variable

Table 4 ANOVA response

Source of	Sum of squares	DOF	Mean square	F_{cal}	F_{tab}	Inference
A	0.57394	2	0.2865	15.02	3.35	Significant
B	11.15813	2	5.60790	294.069	3.35	Significant
C	1.670572	2	0.83528	43.9624	3.35	Significant
AB	3.5031	4	1.75155	91.8484	2.73	Significant
AC	1.07035	4	0.2675	14.0318	2.73	Significant
BC	0.782588	4	0.19572	10.2633	2.73	Significant
ABC	38.92588	8	4.86573	255.151	2.31	Significant
Error	0.5151	27	0.01907			
Total	67.879	53				

From the table factors A (cutting speed), B (feed), C (depth of cut), interactions A×B, A×C has significant effect on the output parameter (surface roughness). The interactions B×C has effect on surface roughness.

The parameter cutting speed has greater influence, followed by feed, depth of cut and combined effect on cutting speed, feed.

3.1 SECOND ORDER POLYNOMIAL EQUATION:

To develop a second order polynomial equation the main effects were partitioned into linear and quadratic components, the two factor interaction may ever decomposed into linear*linear, linear*quadratic, quadratic*linear, quadratic*quadratic. The second order polynomial equation is used to calculate surface roughness for aluminum alloy (H-15) in turning process. The second order polynomial equation is shown in the equation (calculations are shown in appendix).

$$R_a = -102.9911 + 0.668788X_1 + 1827.8206X_2 + 164.031X_3 - 0.00231X_1^2 - 10360.22X_2^2 - 123.813X_3^2 - 16.0994X_1X_2 - 1615.877X_2X_3 - 0.3022X_1X + 0.0426301X_1^2X_{2_3} + 103.599X_1X_2^2 + 1333.19X_3X_2^2 + 1105.3421X_2X_3^2 - 0.27999X_1^2X_2^2$$

1. X_1- Cutting speed (rpm)
2. X_2- Feed (mm/rev)
3. X_3- Depth of cut
4. R_a- Surface roughness

4.2 SURFACE ROUGHNESS VALUES BY USING SECOND ORDER POLYNOMIAL EQUATION

A second order polynomial equation was developed to predict the surface roughness for aluminum alloy (h-15) in order to substitute the valves of speed, feed and depth of cut. And we have calculate the percentage deviation between the predicated and experimental valves and it was compared with the measured value and average percentage deviation was found to be 5.8227%.

V. OPTIMUM VALUE:

The following table shows the Optimized cutting conditions obtained by Taguchi Method.

Table 5 Optimized cutting conditions obtained by Taguchi Method

Speed	Feed	Depth of cut	Surface Roughness	SN ratio	Mean
135	0.05	0.50	0.50	6.020599	0.50

VI. Conclusion:

Aluminum alloy (H-15) was machined by turning using carbide insert based on full factorial design by varying cutting speed, feed and depth of cut. ANOVA analysis was conducted and second order polynomial equation is generated to predict surface roughness. The surface roughness measured from the second order polynomial equation has been compared with the actual measured values. The following conclusion can be drawn from this work.

- Among the cutting parameters speed has the great influence, followed by the combined effect of speed and feed, feed, depth of cut, feed and depth of cut and speed and depth of cut.
- Second order polynomial equation is generated based on the experimental values and predicted the surface roughness values.
- Then compared the predicted surface roughness values with the experimental values and found that generated equation has better capability for predicting the surface roughness values.
- In order to observe that as the feed rate increases the surface roughness valves also increases.
- Optimal machining condition for achieving minimum surface roughness 0.50µm of was obtained at a cutting speed of 135rpm, feed of 0.05mm/rev and depth of cut of 0.50mm by using Taguchi method.

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