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Analysis of Surface Roughness for Turning of Aluminium (6061) Using Regression Analysis

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Abstract— Surface Roughness and tolerance are among the most critical measures in many mechanical products as competition grows closer customers now have increasingly demanding for high quality; making surface roughness one of the most competitive dimension in today's manufacturing industries surface of mechanical product can be created with a number of manufacturing process. This works applies the frictional factorial experimentation approach to study the impact of turning parameters on the roughness turned surfaces analysis of variance is used to examine the impact of turning factors and factor interaction on surface roughness.

Keywords—Inserts, Regression Analysis, *Aluminium*, Surface Roughness.

I. Introduction

In machining of parts, surface quality is one of the most specified requirements of customer. Where major indication of surface quality of Tool geometry and parameters play an important role in determining the overall machining performance, including cutting forces, tool wear, surface finish, chip formation and chip breaking. Surface roughness is harder to Attain track then physical dimensions are, because, relatively many factors affects surface roughness some of these factors can be controlled and some are not. Controllable process parameters includes feed, cutting speed, tool geometry and tool setup. Other factors are such as tool, work piece and machine vibration, tool wear and degradation, and work piece and tool material variability cannot be controlled easily. The resultant roughness produced by machining process can be thought of as the combination of two independent quantities; ideal roughness and natural roughness.

Ideal roughness:

Ideal surface roughness is a function of feed and geometry of the tool. It represents the best possible finish which can be obtained for a given tool shape and feed. It can be achieved only if the built-up-edge, chatter and inaccuracies in the machine tool movements are eliminated completely. For a sharp tool without nose radius, the maximum height of unevenness is given by:

$$R_{max} = \frac{f}{\cot\phi + \cot\beta}$$

Here f is feed rate, φ is major cutting edge angle and β is the minor cutting edge angle.

The surface roughness value is given by, Ra = Rmax/4

Idealized model of surface roughness has been clearly shown in.

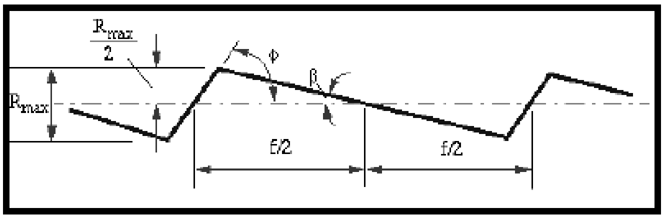

Fig-1 Idealized model of surface roughness

Natural roughness:

In practice, it is not usually possible to achieve conditions such as those described above, and normally the natural surface roughness forms a large proportion of the actual roughness. One of the main factors contributing to natural roughness is the occurrence of built-up edge and vibration of the machine tool. Thus, larger the built up edge, the rougher would be the surface produced, and factors tending to reduce chip-tool friction and to eliminate or reduce the built-up edge would give improved surface finish.

II. MATERIALS AND METHODS

A. CNC Turning Centre

Lakshmi Machine Works Limited make CNC turning centre of smarturn series with Fanuc / Siemens controller is used to carry out the experimentation.

TABLE I : SPECIFICATIONS OF CNC TURNING CENTER

Max. Turning diameter	200 mm
Max. Turning length	262 mm
Chuck Size	169 mm
Spindle Speed	45- 4500 rpm
Spindle motor power	5.5 kW/ 3.7 kW

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B. Selection of Cutting Tools

The cutting tool selected for present work is carbide inserts. The inserts (ISO coding) used in present work are CCGT120402-AL

The tool geometry of the inserts is as follows:

Insert CCGT120402-AL – diamond Shape, Clearance angle 7°, Inscribed Circle size- 4.4 mm, Thickness- 4.76 mm, Nose radius- 0.2mm.

C. Selection of Work piece Material

The work piece material used for current work is Aluminium (6061) HINDALCO.

TABLE II

CHEMICAL COMPOSITION OF ALUMINIUM (6061).

Elements	Weight%
Cu	0.15-0.4
Mg	0.7-0.4
Si	0.4-0.8
Fe	0.7 max
Mn	0.2-0.8
Other	0.4

C. Process Parameters and Levels used in the Experiment

The machining process on CNC lathe is programmed by cutting speed, feed and depth of cut. The parameters and levels used in the experiment are shown in Table II.

TABLE II : PROCESS PARAMETERS AND LEVELS

Levels	Variables		
	R.P.M.	Feed, mm/rev (B)	Depth of cut, mm (C)
Level 1	1900	0.100	0.20
Level 2	1700	0.125	0.30
Level 3	2100	0.150	0.40

C. Equations of Regression analysis

Regression analysis:

Regression analysis is one of the most widely used techniques for analyzing multifactor data. Its broad appeal and useful result from the conceptually logical process of using an equation to express the relationship between the variable of interest (The response) and a set of related predictor variables. So regression analysis was used to develop the parametric equations. The following factors are used in the present analysis.

Regression sum of squares:

$$SS_R = \sum_{i=1}^{n} (\hat{Y}i - Y)^2$$

Where Yi = sum of dependent variable

Ŷi =fitted value of ith dependent variable

Residual sum of squares:

$$SS_{Res} = \sum_{i=1}^{n} (\hat{Y}i - Y)^2$$

Ŷi =observed value of ith dependent variable.

Total sum of squares:

It is total variability in the observations of the data.

$$SS_T = SS_R + SS_{Res}$$

Predictor Variable:

$$K = SS_R / \sigma 2$$

This has a same number of degree of freedom as number of repressor and predictor variables in the model.

σ^2 = variance

Regression mean squares:

$$MS_R = \frac{SS_R}{K}$$

Residual mean squares:

$$MS_{RES} = \frac{SS_{RES}}{n-p}$$

P =k +1 = Parameter in the regression model.

N = no. of observations.

Test of statistics:

$$F = \frac{MS_R}{MS_{Res}}$$

Co efficient of determination

$$R^2 = \frac{SS_R}{SS_T} = 1 - \frac{SS_R}{SS_T}$$

Adjusted co- efficient of determination

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$$\text{Adjusted } R^2 = 1 - \frac{SS_{Res}\ /(n-p)}{SS_T\ /(n-1)}$$

Standard error of regression:

$$SE = \sqrt{MS_{Res}}$$

Mathematical models formulation of machining data:

The purpose to develop this mathematical model is to relate the machining responses and their machining factors to facilitate and optimize of the machining process.

Using these mathematical models, the objective function and constraints were formulated and optimization problem was then solved by using regression analysis. The mathematical models commonly used are represented by:

Y=Φ (V, f, d)

Where Y is the machining response,

Φ is the response function,

And V, f, d are the machining variables.

Y=C + αVβf +yd

The surface roughness model was formulated as:

Ra + C + αVβf +yd

Using these mathematical models, the objective function and process constraint were formulated and optimization problem was then solved by using regression analysis.

TABLE-III : DATA FOR DIFFERENT MACHINING VARAIBLES

S. No.	Dia. of Job	R.P.M	Depth of cut (mm)	Feed (MM/ Rev.)	Cutting speed (m/Min.)	Surface Roughness (μ)	Predicted Ra
1	19.1	1900	0.20	0.100	113.95	0.860	0.780
2	19.1	1900	0.20	0.125	113.95	1.040	1.048
3	19.1	1900	0.20	0.150	113.95	1.440	1.315
4	18.9	1900	0.30	0.100	112.75	0.920	1.315
5	18.9	1900	0.30	0.125	112.75	1.200	0.888
6	18.9	1900	0.30	0.150	112.75	1.600	1.155
7	18.7	1900	0.40	0.100	111.56	0.760	1.423
8	18.7	1900	0.40	0.125	111.56	1.100	0.996
9	18.7	1900	0.40	0.150	111.56	1.500	1.263
10	19.1	1700	0.20	0.100	101.95	0.820	1.531
11	19.1	1700	0.20	0.125	101.95	1.120	0.799
12	19.1	1700	0.20	0.150	101.95	1.440	1.066
13	18.9	1700	0.30	0.100	100.88	0.940	1.334
14	18.9	1700	0.30	0.125	100.88	1.060	0.780
15	18.9	1700	0.30	0.150	100.88	1.540	0.907
16	18.7	1700	0.40	0.100	99.82	0.960	1.174
17	18.7	1700	0.40	0.125	99.82	1.100	1.014
18	18.7	1700	0.40	0.150	99.82	1.500	1.282
19	19.1	2100	0.20	0.100	125.94	0.880	1.549
20	19.1	2100	0.20	0.125	125.94	1.080	0.761
21	19.1	2100	0.20	0.150	125.94	0.580	1.029
22	18.9	2100	0.30	0.100	124.62	0.780	1.296
23	18.9	2100	0.30	0.125	124.62	1.140	0.869
24	18.9	2100	0.30	0.150	124.62	1.420	1.137
25	18.7	2100	0.40	0.100	123.30	1.160	1.404
26	18.7	2100	0.40	0.125	123.30	1.260	0.977
27	18.7	2100	0.40	0.150	123.30	1.860	1.245

III. RESULTS AND DISCUSSIONS

A- Regression Analysis: Surface roughness versus Depth of cut, Feed (mm/rev),Cutting speed(m/min)

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The regression equation is

Surface roughness = - 0.323 + 1.06 Depth of cut
+ 10.7 Feed (mm/rev) - 0.00157 Cutting speed in
M/min

Predictor      Coef.   SE Coef.       T       P

Constant    -0.3231    0.5355   -0.60   0.552
Cutting    -0.00157  0.003946   -0.40   0.693
Feed         10.667     1.873    5.69   0.000
Depth of     1.0590    0.4707    2.25   0.034
cut

S= 0.1987   R-Sq = 62.2 %  R-Sq (Adj.) = 57.3%
PRESS =     1.37937        R-Sq(Pred.)= 42.61 %

Source       DF   SS        MS        F       P
Regression    3   1.4953    0.49846   12.62   0.000
Residual     23   0.9081    0.03948
error
Total        26   2.4035
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NO Replicates. Cannot do pure error test.

Durbin- Watson Statistic = 1.73

Lack of fit test
Possible interactions with variable CUTTING
(P-Value = 0.091) Possible lack of fit at
outer X- values (p-Values = 0.000)
Overall lack of fit test is significant at P
= 0.000
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B. *Surface Roughness (R_a)*

Roughness measurement has been done using a portable stylus-type profilometer, Mitutoyo- Surftest SJ- 201P/M. The evaluation length of 2.5 mm is used to measure response R_a value in µm.

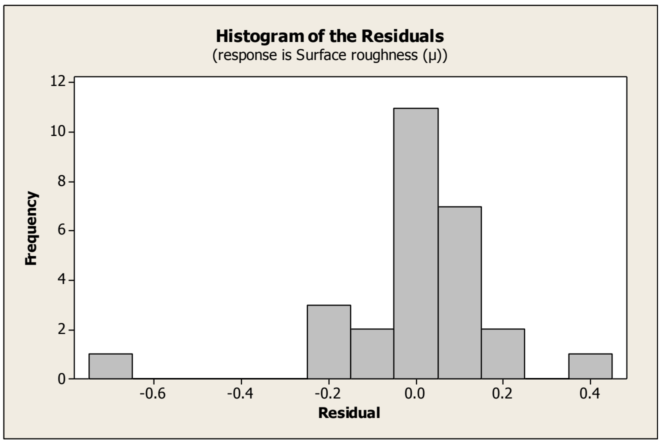

FIG-1: Histogram Surface Roughness (µ)

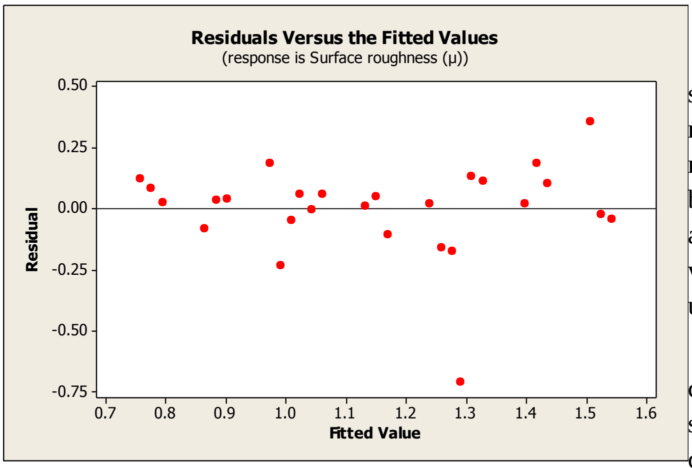

FIG-2: scatter diagram of surface roughness (µ)

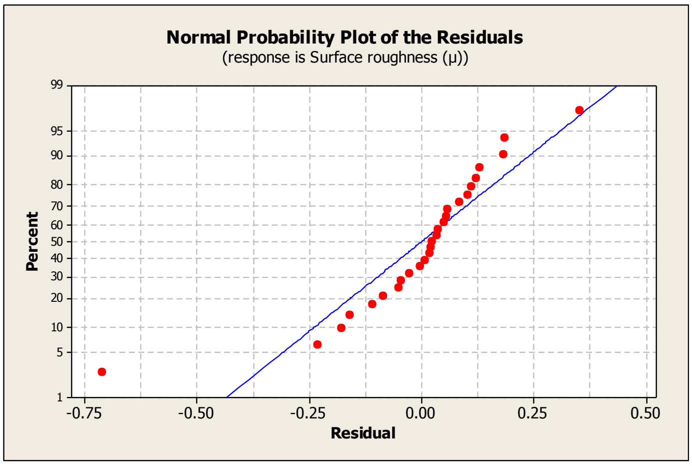

FIG-3: Probability graph of Surface Roughness (µ)

IV. CONCLUSIONS

Surface roughness equation for linear model

The data of analysis of variance of the roughness model for finish turning operation for Aluminium are shown in Table III the surfaces roughness model developed are:

$$Ra=-0.323-0.001157v+10.7f+1.06d$$

The R-square value of 0.622 indicated that 62.2%of the variability in the surface roughness was explained by the model with factors v, f and data based on the mathematical model, it can be concluded that the cutting speed is a dominant factor in the roughness model of finish turning in heavy machining operation.

V. RESULTS AND CONCLUSIONS

This work presented on the experimental approach to studying the impact of machining parameters on the surface roughness. Strong interactions were observed among the machining parameters. Most significant interaction was found between work materials feed and cutting speeds. A systematic approach was provided to design and analyze the experiments, which is able to reduce the cost and time of experiment to utilize the data obtained to the maximum extends.

From the data collection I have observed that the increase in cutting speeds tends to improve the finish, thus the average surface roughness value decreases, the increases in depth of cut influences the finish slightly but greater depth of cut marks the finish poor .feed rate is the most criticalparamet5r when finish is the criterion, finish gets poor as the feed increases, thus the average surfaces roughness value increases with increases in feed.

We have developed the regression of aluminium for both the linear as well as non- linear cases. Where the results are the relationship equations

For linear regression equation of aluminum relationship with the r- square value of 0.622 indicated that 62.2% of the variability in the surface roughness was explained by the model with factors V, f and d.

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