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"OPTIMIZATION OF CUTTING PARAMETERS FOR TURNING OPERATION IN CNC LATHE FOR AISI 1045 MATERIAL USING TAGUCHI METHOD AND ANOVA METHOD BY EXCEL 2007 SOFTWARE"

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ABSTRACT

The main purpose of today's manufacturing industries is to produce low cost, high quality products in short time. They mainly focused on achieving high quality, in term of part accuracy, surface finish, high production rate etc. So, the selection of optimal cutting parameters is a very important issue for every machining process in order to reduce the machining costs and increase the quality of machining products. In this project the cutting of AISI 1045 steel material under wet and dry condition is carried out using CNC lathe machine. Taguchi method is used to formulate the experimental layout. The effect of cutting condition (spindle speed, feed rate and depth of cut) on surface roughness were studied and analysed. The CNC turning machine is used to conduct experiments based on the Taguchi design of experiments (DOE) with orthogonal L9 array and Anova method used by Excel 2007 software. Optimal cutting parameters for each performance measure were obtained employing Taguchi techniques. The orthogonal array, signal to noise ratio and analysis of variance were employed to find minimum surface roughness. Optimum results are finally verified with the help of confirmation experiments.

Keywords: *CNC, Surface roughness, Dry, Wet, Taguchi, Anova, Excel 2007*

I. INTRODUCTION

Manufacturing means transformation of raw materials into finished goods for the satisfaction of human needs. To transform the raw material different manufacturing processes are applied because of which the shape, size and physical properties of given material are altered. Different types of manufacturing process for metals are: -

Metal casting:-Casting is a manufacturing process where a solid is melted and heated to certain temperature, then poured into a cavity or mould, the molten metal solidifies in the mould and the desired shape is formed. Metal forming and shaping:-A simple metallic geometry is transformed into a complex one through plastic deformation. Tools or dies impart pressure on the material to transfer the desired geometry through the tool/material interface. It includes rolling, forging, extrusion, drawing, sheet forming, powder metallurgy, molding etc.

Joining:-Temporary or permanent joining of same or different materials. It includes welding, brazing, soldering, diffusion bonding, adhesive bonding, mechanical joining etc.

Machining:-It is the metal removing process. It includes turning, boring, drilling, milling, planning, shaping, broaching, grinding etc.

Finishing operations:-It means improving the surface finish of the material. This includes honing, lapping, polishing, burnishing, deburring, coating, plating processes etc.

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Material property modification process:-This process involves changing the property of materials to achieve desirable characteristics. This includes hardening, quenching, annealing, case carburizing etc.

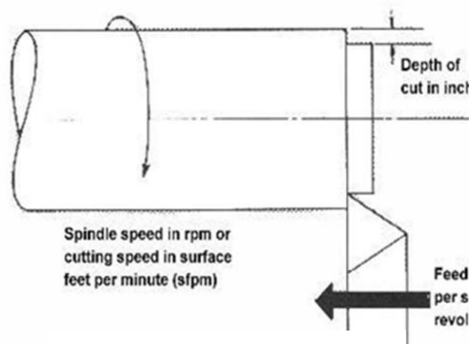

Fig 1.1 .1 Turning Processes

1.1 CUTTING TOOL MATERIALS AND TOOLS

The Ideal cutting tool material should have all of the following characteristics:

- Harder than the work it is cutting
- High temperature stability
- Resists wear and thermal shock
- Impact resistant
- Chemically inert to the work material and cutting fluid

1.2 TAGUCHI METHOD

Taguchi method is statistical method developed by Genichi Taguchi to improve the performance and quality of the products. According to Taguchi, the most important thing prior to analysis is establishment of the experiment. Only by this approach, it is possible to improve the quality of the process. This approach could achieve the final output value and minimized the variability around the output value by minimum cost.

1.3 EXCEL SOFTWARE

Excel Data Analysis is a statistics package.. This software is used for Data and File Management- spreadsheet for better data analysis; Analysis of Variance; Regression Analysis; Power and Sample Size; Tables and Graphs; Multivariate Analysis - includes factor analysis; cluster analysis; correspondence analysis; etc., Nonparametric tests including sing test, runs test, friedman test, etc., Time Series and Forecasting tools that help show trends in data as well as predicting future values. In this work, the Excel is used for obtaining ANOVA.

Fig.1.2 Cutting Tools

II. OBJECTIVEOF PRESENT WORK

The objective of the present work is to investigate the effect of the spindle speed, feed rate and depth of cut on surface roughness in dry and wet conventional turning of AISI 1045 steel using TiN coated cutting tool in dry condition.

III. METHODOLOGY AND EXPERIMENTATION

Accordingly the present study has been done through the following plan of experiment.

- Checking and preparing the Lathe ready for performing the machining operation.
- Cutting steel bars by power saw and performing initial turning operation in Lathe to get desired dimension (of diameter 50mm and length 140 mm) of the work pieces.
- Performing straight turning operation under dry and wet conditions on specimens in various combinations of process control parameters like: spindle speed, feed and depth of cut.
- Length of cut was kept constant at 50 mm for both dry and wet turning.
- Measuring surface roughness and surface profile with the help of a portable stylus-type profilometer, *Talysurf*(Taylor Hobson, Surtronic 3+, UK).

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3.1 MATERIAL AISI 1045 AND ITS APPLICATIONS

The material selected was AISI 1045 MS bars (of diameter 50 mm and length 140 mm) on the basis that it was suitable for most engineering and construction applications. AISI 1045 is a low-cost alloy, medium-carbon steel with adequate strength and toughness characteristics, AISI 1045 is valuable for induction- or flame-hardened components. The hardness of bar is 187 HB Automotive type applications. Axle and spline shaft are two examples of automotive components produced using this material where the turning is the prominent machining process used.

Fig. 3.1 Work piece before machining

Fig. 3.2 Work piece after machining

3.2 MACHINE USED

Side Base CNC Lathe machine with coated cemented carbide cutting tool was used in the experiments. Cutting speed, feed rate and depth of cut were selected as the machining parameters to analyze their effect on surface roughness.

Technical Specifications

Travel in X-axis- 1000mm
Travel in Z-axis-3000 mm
Swing over bed-760 mm
Spindle Nose –MT-5
Turret-12 Tools
System-Sinumaric-3T4B
Siemens-802D

Fig3.3 CNC Lathe

3.3 COATED CARBIDE TOOL INSERT DESCRIPTION

Coated carbide tools have been known to perform better than uncoated carbide tools when turning steel. For this reason, commercially available CVD coated carbide insert was used in this investigation. The cutting inserts used were multi layer coated cemented carbide by (TiN-Al2O3-TiCN) from WIDIA with a standard notation of CNMG 120408 of nose radius 0.8 mm. The selected cutting tool was based on the cutting tool manufacturer's manual.

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3.4 SURFACE ROUGHNESS MEASUREMENT

The surface roughness test was done by using Mitutoyo surface roughness tester 'Surftest SJ 201'. The probe was adjusted to measure the R_a value. The probe was moved a distance of 3mm.

Fig. 3.4 Surface roughness tester

IV. EXPERIMENTS RESULTS

Table 4.1 Experimental Data Related to Surface Roughness Characteristics for Dry Turning

Experiment no.	Spindle speed (rpm), N	Feed rate (mm/rev), f	Depth of cut (mm), d	Surface roughness, Ra (µm)	S/N ratio of surfaces roughness
1	160	0.3	0.7	2.24	-7
2	160	0.4	0.8	5.67	-15.07
3	160	0.5	0.9	5.93	-15.46
4	320	0.3	0.8	5.34	-14.55
5	320	0.4	0.9	4.87	-13.75
6	320	0.5	0.7	6.07	-15.66
7	620	0.3	0.9	2.91	-9.27
8	620	0.4	0.7	3.78	-11.54
9	620	0.5	0.8	5.05	-14.06

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Table 4.2 Experimental Data Related to Surface Roughness Characteristics for Wet Turning

Experiment no.	Spindle speed (rpm), N	Feed rate (mm/rev), f	Depth of cut (mm), d	Surface roughness, Ra (µm)	S/N ratio of surfaces roughness
1	160	0.3	0.7	2.12	-6.52
2	160	0.4	0.8	3.40	-10.62
3	160	0.5	0.9	3.62	-11.17
4	320	0.3	0.8	2.37	-7.49
5	320	0.4	0.9	3.69	-11.34
6	320	0.5	0.7	2.8	-8.94
7	620	0.3	0.9	2.11	-6.48
8	620	0.4	0.7	3.78	-11.54
9	620	0.5	0.8	2.80	-8.94

4.1 CALCULATIONS OF S/N RATIOS FOR SURFACE ROUGHNESS FOR DRY TURNING AND WET TURNING

Calculation for Dry Turning

- S/N Ratio (Experiment 1) = η_1= -10log [($\sum Yi^2$)/n] =-10 log [1/ $(2.24)^2$] = -7
- 2. S/N Ratio (Experiment 2) = η_2= -10 log [1/ $(5.67)^2$] = -15.07
- 3. S/N Ratio (Experiment 3) = η_3= -10 log [1/ $(5.93)^2$] = -15.46
- 4. S/N Ratio (Experiment 4) = η_4= -10 log [1/ $(5.34)^2$] = -14.55
- 5. S/N Ratio (Experiment 5) =η_5 = -10 log [1/ $(4.87)^2$] = -13.75
- 6. S/N Ratio (Experiment 6) =η_6= -10 log [1/ $(6.07)^2$] = -15.66
- 7. S/N Ratio (Experiment 7) =η_7= -10 log [1/ $(2.91)^2$] = -9.27
- 8. S/N Ratio (Experiment 8) = η_8= -10 log [1/ $(3.78)^2$] = -11.54
- 9. S/N Ratio (Experiment 9) =η_9= -10 log [1 /$(5.05)^2$] = -14.06

Calculation for Wet Turning

- S/N Ratio (Experiment 1) = η_1= -10log [($\sum Yi^2$)/n] =-10 log [1/ $(2.12)^2$] = -6.52
- 2. S/N Ratio (Experiment 2) = η_2= -10 log [1/$(3.40)^2$] = -10.62
- 3. S/N Ratio (Experiment 3) = η_3= -10 log [1/$(3.62)^2$] = -11.17
- 4. S/N Ratio (Experiment 4) = η_4= -10 log [(1/$2.37)^2$] = -7.49
- 5. S/N Ratio (Experiment 5) = η_5 = -10 log [1/$(3.69)^2$] = -11.34
- 6. S/N Ratio (Experiment 6) = η_6= -10 log [1/$(2.80)^2$] = -8.94
- 7. S/N Ratio (Experiment 7) = η_7 = -10 log [1/$(2.11)^2$] = -6.48
- 8. S/N Ratio (Experiment 8) = η_8 = -10 log [1/$(3.78)^2$] = -11.54
- 8. S/N Ratio (Experiment 9) = η_9 = -10 log [1/ $(2.8)^2$] = -8.94

4.2 ANOVA METHOD

ANOVA is a statistical tool which determines the contribution of individual factors to control the final response. It calculates the parameters like sum of squares (SS_S), degree of freedom, variance, f value. p value for each factor. The ANOVA calculations were done using the help of the MS OFFICE 2007 software Excel. In ANOVA test we found that most important parameter like SS, DOF, Variance, Mean, f value and p value.

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- In below figure we can see that all parameter value have found by ANOVA method. Fishers F 29.48 value and p value is $3.43x10^{-7}$ is very less from Alpha (0.05). So our result is good.

Anova: Single Factor

Groups	Count	Sum	Average	Variance
a	9	3300	366.6667	40900
b	9	3.6	0.4	0.0075
c	9	7.2	0.8	0.0075

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	804029.5	2	402014.8	29.48763	3.43E-07	3.402826
Within Groups	327200.1	24	13633.34			

Fig. 4.1 Anova method

4.3 DISCUSSION

4.3.1 ANALYSIS OF VARIANCE

The results obtained from the experiment were checked with the help of ANOVA, which predicts the significance of input parameter for any desired response function. It shows the most significant parameter which influences the results.

4.3.2 ANOVA FOR SURFACE ROUGHNESS IN DRY AND WET TURNING

Results obtained for the surface roughness in dry and wet turning experimental results analyzed with ANOVA The F value calculated through Excel 2007 software is shown in the second last column of ANOVA table which suggests the significance of the factors on the desired characteristics.

4.4 CONFIRMATION TEST

The last step of Taguchi parameter design is to verify and predict the improvement of surface roughness (response) using optimum combination of cutting parameters.

4.4.1 CONFIRMATION TEST FOR SURFACE ROUGHNESS IN DRY TURNING

For Spindle speed, factor effects are mA_1, mA_2 and mA_3.
As from Table 3.7, A_1 occurs in experiment 1, 2, 3, A_2 in 4, 5, 6 and A_3 in 7, 8, 9 respectively.
So, mA_3= = = -11. 62 dB
Now, Factor effect of B (i.e. Feed Rate), from table 6, B_1 occurs in 1, 4, 7 experiment and B_2 occurs in 2, 5, 8, B_3 in 3, 6 and 9 respectively).
So, mB_1 = = = -10.27 dB
Lastly factor effect of C (i.e. Depth of Cut) Again from table 6, C_1 occurs in 1, 6, 8 experiments,

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C_2 occurs in 2, 4, 9 and C_3 in 3, 5 and 7 respectively.

Therefore, mC_1 = = = - 11.4 dB

And, m = = -12.928 dB

η_{opt} =m + (mA_3 – m) + (mB_3 – m) + (mC_1 – m)

= -12.928 + (-11.62 + 12.928) + (-10.27 + 12.928) + (-11.4 + 12.928)

= -12.928 + 1.308 + 2.658 + 1.528

= -7.434 dB

Now the value of Surface Roughness is,

R_a = = 2.34 μm

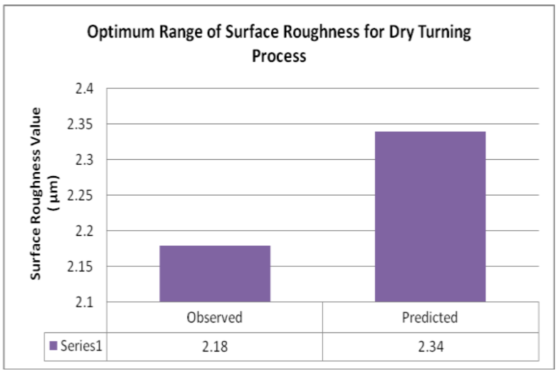

Fig. 4.2 Optimum range of surface roughness for Dry turning process

4.4.2 CONFIRMATION TEST FOR SURFACE ROUGHNESS IN WET TURNING

For Spindle speed, factor effects are mA_1, mA_2 and mA_3.

As from Table 3.7, A_1 occurs in experiment 1, 2, 3, A_2 in 4, 5, 6 and A_3 in 7, 8, 9 respectively.

So, mA_3= = = -8.99 dB

Now, Factor effect of B (i.e. Feed Rate), from table 6, B_1 occurs in 1, 4, 7 experiment and B_2 occurs in 2, 5, 8, B_3 in 3, 6 and 9 respectively).

So, mB3 = = = -9.68 dB

Lastly factor effect of C (i.e. Depth of Cut) Again from table 6, C_1 occurs in 1, 6, 8 experiments,

C_2 occurs in 2, 4, 9 and C_3 in 3, 5 and 7 respectively.

Therefore, mC3 = = = - 6.83 dB

And, m = = -9.23 dB

η_{opt} =m + (mA_3 – m) + (mB_3 – m) + (mC_1 – m)

= -9.23+ (-8.99+ 9.23) + (-9.68+ 9.23) + (-6.83+ 9.23)

= -9.23 + 0.24-0.45 +2.4

= -7.05 dB

Now the value of Surface Roughness is,

R_a = = 2.25 μm

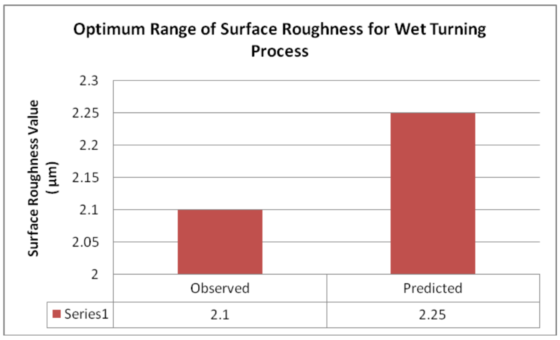

Fig. 4.3 Optimum range of surface roughness for wet turning process

V. CALCULATIONS FOR SURFACE ROUGHNESS

The following conclusions are done from the study:

It has been found that feed rate is found to be the most significant factor & its contribution to surface roughness is 48.44 %. The best results for surface roughness (lower is better) would be achieved when AISI 1045 work piece is machined at spindle speed of 620 rpm, feed rate of 0.3 mm/rev and depth of cut of 0.7 mm. With 95% confidence interval, the feed rate effects the surface roughness most significantly. The Surface roughness is mainly affected by feed rate, depth of cut and spindle speed. With the increase in feed rate the surface roughness also increases, as the depth of cut increases the surface roughness first increase and decrease and as the spindle speed increase surface roughness decreases.

- From ANOVA analysis, parameters making significant effect on surface roughness are feed rate and depth of cut.
- Optimal machining parameters for minimum surface roughness were determined. The percentage error between experimental and predicted result is 6.83 %.
- The parameters taken in the experiments are optimized to obtain the minimum surface roughness possible. The optimum setting of cutting parameters for high quality turned parts is as :-
- Spindle speed = 620 rpm
- Feed rate = 0.3 mm/ rev
- Depth of cut = 0.7 mm

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VI. FUTURE SCOPE

In this present study only three parameters have been studied in accordance with their effects. Other factors like Nose radius, Types of Inserts, cutting conditions (dry or wet) etc. can also be studied. Also, the other outputs like power consumption, tool life, cutting forces etc. Can also be added.

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