International Journal of Engineering Sciences Paradigms and Researches (IJESPR)
Vol. 48, Special Issue, (TAME-2019, April 4-5, 2019)
(An Indexed, Referred and Impact Factor Journal approved by UGC- Journal No. 42581)
ISSN (Online): 2319-6564
www.ijesonline.com

STUDY THE EFFECT OF MACHINING PARAMETERS ON SURFACE ROUGHNESS DURING TURNING OF AUTENITIC STEEL SS304 USING TAGUCHI METHOD

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Abstract

The study aims at investigating the influence of different machining parameters such as cutting speed (v), feed (f) and depth of cut (d) on different performance measures during turning of SS304 stainless steel (18%Cr,8%Ni,0.08%C). Sintered carbide coated insert tool was used a cutting tool for the turning purpose.The primary objective of the study was to use the ANOVA in order to determine the effect of machining parameters viz. cutting speed, feed, and depth of cut, on the surface roughness of the machined material.The objective was to find the optimum machining parameters so as to minimize the surface roughness.The experiment was conducted in an experiment matrix of 9 runs designed using an orthogonal array L9. Surface Roughness was measured using a Talysurf. MINITAB ® 17 was used for analysis of the compiled data.
The significance of the parameters on the response variables was investigated using Analysis of Variance (ANOVA).Results showed that feed is the most significant factor affecting the surface roughness, closely followed by cutting speed and depth of cut.The recommended parametric combination based on the studied performance criteria (i.e. Feed, Cutting Speed, Depth of Cut) was found. A confirmatory test was also carried out to support the analysis and an improvement was observed in Taguchi method.

Keywords – Optimization, Parameters, Turning, Taguchi's Method, ANOVA, Stainless Steel, L9 Orthogonal Array

1. Introduction

Machining is the manufacturing process (generally a secondary process) the parts formed either by casting generally go through Machining as well. It consists of forcing a cutting tool of harder material through the excess material on the work-piece. The surplus material of work-piece is removed in the form of chips because of the relative motion between the tool and work-piece material. The operation finally results in a transformed product of desire dimension and surface finish. The turning operation is a basic metal machining operation that is used widely in industries dealing with metal cutting. In a turning operation, high precision single point cutting tool is rigidly held in a tool post and is feed past a rotating work piece in a direction parallel to the axis of rotation of the work piece, at a constant rate, and unwanted material is removed in the form of chips giving rise desired profile.

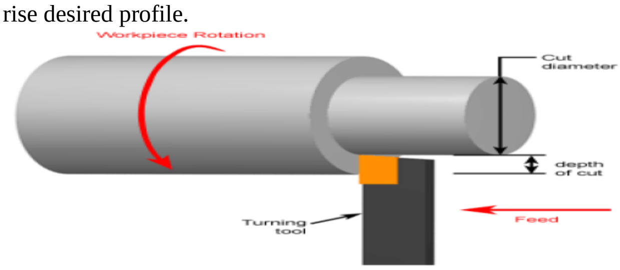

Figure1. Turning of job with single point cutting tool

2.Literature Review

The ensuing detail covers published work of researchers pertaining to the turning process in order to optimize parameters. The scope of the review also extends to various optimization techniques that are used to obtain optimal solution mainly focusing on the ANOVA.

Philips et al [1] studied dry turning using TiC and TiCN on AISI 304 Austenitic Stainless Steel(ASS). He revealed the influence of cutting parameters like cutting speed, feed rate and depth of cut on the surface roughness of austenitic stainless steel during dry turning.A plan of experiments based on Taguchi's technique had been used by Philips to acquire the data. The cutting characteristics of AISI 304 austenitic stainless steel bars using TiC and TiCN coated tungsten carbide cutting tool was investigated using orthogonal array, the signal to noise (S/N) ratio and the analysis of variance (ANOVA).

Shamnad M, and Thulaseedharan Raman et al [2] found that in order to minimize all theproblems of health hazards, non-economy and temperature in case flood cooling; the Minimum Quantity Lubrication (MQL) has to be applied.

The result concluded the effect of flow rate, frequency of pulsed jet, standoff distance of nozzle and composition of cutting fluid to find out the best result in terms of cutting temperature and surface finish. The experimentation had been conducted during turning of AISI 304 alloy steel with minimum quantity lubrication with a pressure of 100bar having vegetable based cutting fluid. The temperature had been measured by infra red thermometer and surface finish by SJ-210 surf test. ANOVA result showed the most significant parameter which affects temperature and surface finish.The result showed that MQL provides better performance than other fluid application while measuring temperature and surface finish.

Ravi Patel et al [3] conducted the experiment under different machining parameters by Taguchimethod to improve the surface roughness (quality) of the product which decreases the machining time, increases the production rate and alongside decreasing the product manufacturing cost.Taguchi optimization methodology had been applied to optimize cutting parameters in turning of mild steel with carbide tool under dry cutting condition. Theminimum surface roughness was found using orthogonal array, signal to noise ratio (S/N) and Taguchi method.From the Experimental result of Taguchi method it was found that Depth of cut is most significant, spindle speed is significant and feed rate is least significant factor effecting surface roughness.

Ch. Maheswara Rao et al [4] studied that Surface Finish is the main challenge in the metal cuttingindustry during turning processes. He investigated the effect of cutting parameters (speed, feed and depth of cut) in CNC (Computer Numerical Control) turning of AA7075 to achieve low Surface Roughness using tungsten carbide insert. The experiments were designed as per the Taguchi's L_9 (3 levels * 3 parameters) Orthogonal array technique.Significance of the cutting parameters on the Surface roughness was found using Analysis of variance (ANOVA).

The most important parameters influencing the surface roughness were feed and cutting speed. The minimum surface roughness were found at cutting speed of 1000 rpm (Level 1), feed of 0.2 mm/rev (Level 1) and depth of cut of 0.5 mm (Level 1) using Taguchi analysis, respectively. Thereafter, optimal range of value of surface roughness was predicted. Finally, relationship was foundby using the MINITAB-16 softwarebetween cutting parameters and response was developed and regression analysis was done. The predicted values were compared with the experimental values and it was observed that both the values were very nearer and hence the models prepared were more accurate and adequate.

Jasvir Singh et al [5] observed the effects of various machining parameters suchas feed rate, cutting speed, and depth of cut on surface roughness during dry turning process.Aluminium 6061 alloy was machined using sintered carbide 120408 EN-TM (H20TI) CNC turning inserts. To obtain regression equation and for optimization of the input parameters Response Surface Methodology (RSM) was used to design the experiment. For checking the interaction of input parameters on the surface roughness of the componentsurface plots and contour plots were generated using RSM. The analysis of the result established that the feed rate has maximum effect on surface roughness and cutting speed and depth of cut has minimum effect on surface roughness. The span of machining parameters were found to be 0.1-0.2 mm/rev124- 207 m/min, and 0.05-0.8 mm for feed rate, cutting speed and depth of cut respectively. Best values of parameters are 0.1 mm/rev, 165.5m/min and 0.85mm for feed rate, cutting speed and depth of cut respectively.

M. Kaladhar et al [6]from his study foundthatprocess parameters selection is essential in order to produce any product with desired quality bymachining. This can be accomplished by Taguchi approach.He aimed to investigate the effects of process parameters on surface finish and material removal rate (MRR) to obtain the optimal setting of these process parameters. And the Analysis Of Variance (ANOVA) was also used to analyze the influence of cutting parameters during machining. In his work M. Kalandhar studied AISI 304 austenitic stainless steel work pieces by turning on computer numerical controlled (CNC) lathe by using Physical Vapour Deposition (PVD) coated cermet insert (TiCN- TiN) of 0.4 and 0.8 mm nose radii. The result revealed that the most significant process parameters on work piece surface roughness is feed and nose radius. Depth of cut and feed are also the significant factors on MRR.

SudhansuRanjan Das et al [7] studied that turning of hardened steels using a single point cuttingtool has replaced the cylindrical grinding since it offers advantage in terms of lowering the cost of equipment, providing shorter set up time, reduced process setups, higher material removal rate, improvedsurface quality and removal of cutting fluids compared to cylindrical grinding. His work was related to investigate the effect of machining parameters such as cutting speed, feed and depth of cut on surface roughness during dry turning of hardened AISI 4340 steel with CVD (TiN+TiCN+Al2O3+ZrCN) multilayer coated carbide inserts. A full factorial design of experiment was selected for experimental planning and the analysis of variance (ANOVA) has been employed to analyze the significant machining parameters on surface roughness during turning. The results showed that feed (60.85%) was the most influencing parameter followed by cutting speed (24.6%) at 95% confidence level. And the two-level interactions of feed-cutting speed (F*V), depth of cut-feed (D*F) and depth of cut-cutting speed (D*V) was found to have significant effects on surface roughness in this turning process. Multiple regression analysis was used to model the relationship between the machining parameters and performance measure i.e. surface roughness.

Kumar Amit Akash et al [8] made an attempt to investigate the effect of cutting parameters(cutting speed, feed and depth of cut) on the performance characteristics (cutting force and surface roughness) for finish hard turning of AISI 52100 bearing steel using CBN tool. The combined effects of the process parameters on two performance characteristics were investigated employing Taguchi's L_9 orthogonal array and analysis of variance (ANOVA).

The results showed that feed rate and cutting speed strongly influence surface roughness. However, the depth of cut was the principal factor affecting cutting force, followed by feed.

3.1 Material Used

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The cutting test is performed by carbide tool on SS 304 commercially known as 18/8 stainless steel. The main non-iron constituentsarechromiumbetween 18–20% and nickel between 8–10.5%. It is an austenitic stainless steel. It is non-magnetic and less electrically and thermally conductive as compared tocarbon steel.

C	Mn	Si	P	S	Cr	Mo	Ni	N	Co
0.08	1.8	0.70	0.045	0.03	18	0.03	8	0.10	0.003

Table1. Composition of SS-304

3.2 Experimental setup and preparation

A centre lathe has been used to carry out the machining. The insert was mounted on the tool post and clamped in the tool holder. The job was held rigidly by the chuck of the lathe. Turning has been done and the job was held at the other end by the tail stock and a skin pass was carried out. The setup is hence complete.

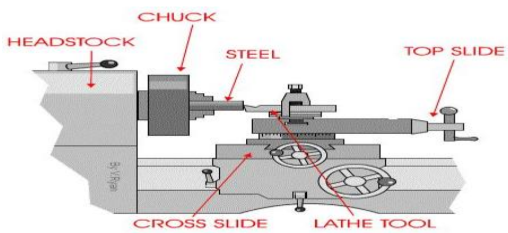

Figure2. Setup for machining

3.3Cutting Condition

To carry the experiment dry cutting environment was used. In dry cutting process no coolant is used during machining. Use of dry cutting, costs of cutting fluid was reduced. Cutting fluids have corrosive effects and non-environment-friendly. Dry is environment friendly. Also, during dry cutting inserts perform better because of higher cutting temperatures.

3.4 Measurement of Surface Roughness

Surface roughness was precisely measured using a portable stylus-type profilometer, talysurf (Taylor Hobson, Surtronic 3+, UK).Measurements were taken at different locations and the average was reported for each run.

3.5 Process Parameters

The cutting parameters and levels chosen are mentioned in the following table.

Cutting parameter	Levels		
Cutting Speed(rpm)	30	60	90
Feed(mm/revolution)	0.2	0.3	0.4
Depth of Cut(mm)	0.1	0.2	0.3

Table 2. Process Parameters

3.6Orthogonal Arrays

Taguchi has developed a system of tabulated design (arrays) that allow for the maximum number of main effects to be estimated in an unbiased (orthogonal) manner, with a minimum number of runs in the experiments.Orthogonal arrays are used to systematically vary and test the different levels of each of the control

EXPERIMENT NUMBER	A	B	C
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	3
5	2	2	1
6	2	3	2
7	3	1	2
8	3	2	3
9	3	3	1

factors commonly used OAs include the L_4, L_9, L_{12}, L_{18}, L_{27}.The columns in the OA indicate the factor and its corresponding levels, and each row in the OA constitutes an experimental run which is performed at the given factor setting .

Table3. L9 Orthogonal Array

3.7 Signal to Noise (S/N) Ratio

The S/N ratio developed by Taguchi is a performance measure to obtain chooses control levels that best cope with noise. In its simplest form, the S/N ratio is the ratio of mean (signal) to the standard deviation (noise). The S/N equation is determined by the criterion for the quality characteristic to be optimized. There are many different possible S/N ratios, threeone those which are considered standard and most commonly applicable across any situation have been mentioned below:

Smallest-is-best quality characteristic (contamination)

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- Nominal-is-best quality characteristic (dimension)
- Biggest-is-best quality characteristic (strength, yield)

Smaller the better (to make the systems response as much small as possible)

$$SNS = -10 \log \left\{\frac{1}{n}\sum_{i=1}^{n} y_i^2\right\} \quad ....1$$

Nominal the best (toreduce variability of a target)

$$SNT = 10 \log \left\{\sum \frac{\overline{y^2}}{s^2}\right\} \quad ....2$$

Larger the better (to make the systems response larger)

$$SNL = -10 \log \left\{\frac{1}{n}\sum_{i=1}^{n} \frac{1}{y_i^2}\right\} \quad ....3$$

These S/N ratios are derived from the quadratic loss function and are expressed in a decibel scale. Once all of S/N ratio has been computed for each run of an experiment, Taguchi advocates a graphical approach to analyze the data. In the graphical approach, the S/N ratios are plotted for each factor against each of its levels. Finally, confirmation tests should be run the "optimal" product setting to verify that the predicted performance is actually realized.

4. Result and Discussion

In order to assess influence of various factors means and signal to noise ratio for each control factor are to be calculated. Levels of input parameters (i.e. cutting speed, feed rate, depth of cut) are selected as per orthogonal array selector and results of surface roughness test specimen for each trial are tabulated in table 4.

4.1 Analysis for surface roughness

All the response variables for 9 experiments are shown below.

Experiment Number	A Feed	B Depth of Cut	C Cutting Speed	Surface Roughness(µm)
1	0.2	0.1	30	R_a=1.62
				R_z=7.10
2	0.2	0.2	60	R_a=0.82
				R_z=4.05
3	0.2	0.3	90	R_a=0.79
				R_z=4.02
4	0.3	0.1	60	R_a =0.81
				R_z=3.98
5	03	0.2	90	R_a=0.80
				R_z=4.00
6	0.3	0.3	30	R_a=0.39
				R_z=2.48
7	0.4	0.1	90	R_a=3.20
				R_z=2.20
8	0.4	0.2	30	R_a=1.60
				R_z=6.90
9	0.4	0.3	60	R_a=1.60
				R_z=7.00

Table4. Experimental results and corresponding S/N ratio

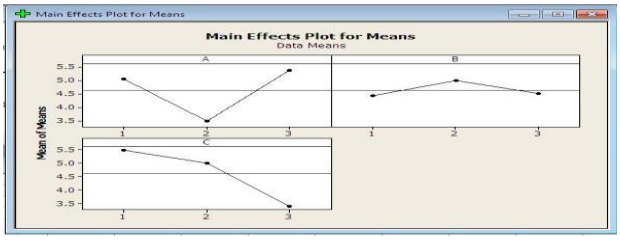
4.2 Optimization of surface roughness

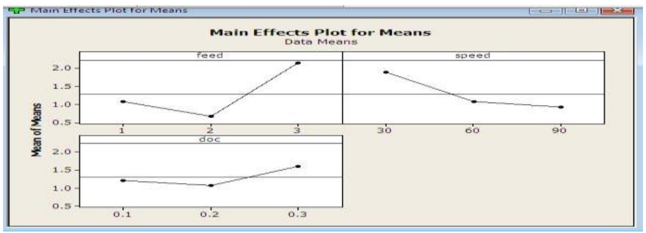
Initially the experimental results were used to obtain the following graphs using MINITAB. It can be seen from Graph1 that within the range of investigated input parameters, the optimal combination of the parameters surface roughness for $\mathbf{R_a}$ values comes out at **7th** trail which is$\mathbf{A_3B_1C_3}$.

Graph1. Optimal combination for R_a

The following Graph2 shows that within the range of investigated input parameters, the optimal combination of the parameters surface roughness for $\mathbf{R_z}$ values comes out at **8th** trail which is**A3B2C1.**

Graph2. Optimal combination for R_z





4.3 Result of Analysis of Variance
Using ANOVA we get the following table

R_a	**SS** (Sum of Squares)	**DOF** (Degree of Freedom)	**MS** (Mean of Squares)	**F** (Variance Ratio)	**%Contribution**
A	0.1186	2	0.0593	15.6540	57.07
B	0.0812	2	0.0406	10.7195	39.08
C	0.0004	2	0.0002	0.0557	0.20
Error	0.0076	2	0.0038	1.0000	3.65
Total	0.2079	8			100.00

Table5. Percentage contribution for R_a

Based on the ANOVA results in above table the percentage contribution of various factors to surface roughness can be identified. Here, **Feed** is the most influencing factor followed by **DOC** and **Cutting Speed** for R_a values.

R_z	**SS** (Sum of Squares)	**DOF** (Degree of Freedom)	**MS** (Mean of Squares)	**F** (Variance Ratio)	**%Contribution**
A	0.0458	2	0.0229	0.6634	16.06
B	0.1279	2	0.0639	1.8517	44.83
C	0.0425	2	0.0212	0.6152	14.89
Error	0.0691	2	0.0345	1.0000	24.21
Total	0.2853	8			100.00

Table6. Percentage contribution for R_z

Based on the ANOVA results in above table the percentage contribution of various factors to surface roughness can be identified. Here, **DOC** is the most influencing factor followed by **Feed** and **Cutting Speed** for R_z values.

4.4 Conclusion

This work presents an experimental study in which turning operations are performed on Austenitic Steel. The effect of three machining parameters namely cutting, feed and depth of cut are studied.Subsequently cutting at three level, feed rate at three levels and depth of cut at three levels are considered and 9 experiments as per the experimental plan of Taguchi's experimental design i.e. L_9 Orthogonal Array are conducted . Surface roughness is measured.Subsequently, analysis of variance is used to obtain the percentage distribution of the parameters. The analysis of mean is performed to obtain optimum level of the machining parameters for multi performance characteristics. Analysis of variance is used to determine which machining parameters is significantly affected the multi performance characteristics and also to obtain the percentage distribution of each machining parameters towards the objective.

From the result of the present study following conclusion are drawn

- The optimum combination of machining parameters and their levels for decreasing deviation in surface roughness is $\mathbf{A_3B_1C_3}$ which comes at 7th trail for $\mathbf{R_a}$ and $\mathbf{A_3B_2C_1}$ which comes at 8th trail for $\mathbf{R_z}$.
- **Speed**, **feed** and **depth of cut**forms0.20%, 57.07% and 39.08% for $\mathbf{R_a}$ and 14.89%, 16.06% and 44.83% for $\mathbf{R_z}$ respectively.

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