International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2163
Volume 1 Issue 8 (September 2014) www.ijirae.com

Experimental Study of Effect of Cutting Parameters on Cutting Force in Dry Turning of SS316L Using Taguchi Method

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***Abstract*— Austenitic stainless steel is one of the most important engineering materials with wide variety of applications. Superior resistance to corrosion and compatibility in high temperature and high vacuum has particularly made it an attractive choice. However, the machinability of austenitic stainless steel is not very promising owing to lower thermal conductivity, higher degree of ductility and work harden ability**

Grade 316 is the standard molybdenum-bearing grade. Molybdenum gives 316 better corrosion resistance properties than crevice corrosion in chloride environment. It has excellent forming and welding characteristics.

The present work is concentrated on dry turning of SS316L. In this study the effect of cutting parameters on cutting force. A plan of experiments is done by Taguchi design of experiments to acquire data. The obtained data is validated by calculating S/N ratio and plotting a graph.

***Keywords*— Cutting force, Taguchi method, S/N ratio, Turning, SS316L**

I. INTRODUCTION

Austenitic stainless steels

Most commonly used austenitic stainless steel contain 18% chromium and 8% nickel. They have an excellent corrosion resistance, weldability, formability fabricability, ductility, cleanability and hygiene characteristics. Along with good high and excellent low temperature properties, these are non magnetic (if annealed) and are hardenable by cold work only.

Challenges In Machining Stainless Steel

Austenitic Stainless Steel is distinguished by their suitable applicative nature due to their good combination of high chemical properties. These properties are dependent and influenced by quantity and nature of their alloying elements. They are also dependent on the heat treatment used. The major challenges while machining are expressed in high adhesion affinity up to high cutting speed ranges, high thermal loads as well as in a hardening of the material. Further the high toughness leads to an unpropitious chip breakage and increased burr formation. In turning stainless steel, burr formation is of great importance because it influences not only the quality and handling of work piece but also the tool wear.

To study the influence of machining parameters on various aspects of machinability of austenitic stainless steel, still there exits some gap which need to be studied in more detail. There is no report of systematic study of influence of machining parameters on cutting force of SS316L grade austenitic stainless steel. Keeping them in mind, the objective of the present work has been as follows:

To study the effect of cutting speed, depth of cut and feed rate on cutting force on dry turning of SS316L stainless steel.

II. PROBLEM DEFINITION & PROPOSED METHODOLOGY

Problem Definition

As we know the stainless steel material SS316L is very difficult to machining due to reasons such as having low thermal conductivity, high built up edge tendency and high corrosive resistance. So study the effect of cutting parameters of SS316L on cutting force by using Taguchi method.

Proposed Methodology

Considering the problem occurring while selecting parameters for machining of SS316L. Here firstly we selected the tool insert for machining of SS316L, tool holder PCLNR 2525M12. After the selection of tool insert, and tool holder we selected the Taguchi technique for performance of dry turning of SS316L in Taguchi method. Firstly we select the orthogonal array and cutting parameters like cutting velocity, feed and depth of cut and the reading are to be taken as per the orthogonal array selected. After taking the reading we calculate the S/N ratios for cutting forces.

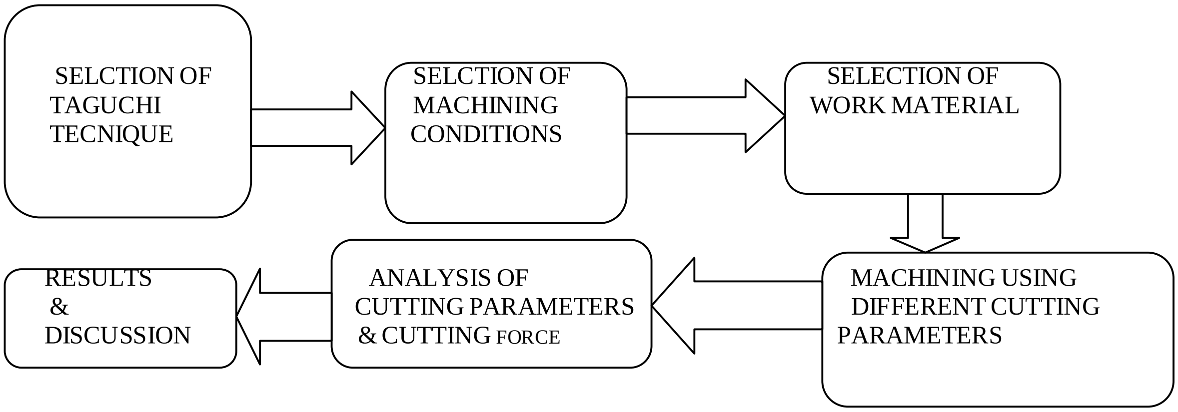


Fig. 1 FLOW CHART OF PROPOSED METHODLOGY

III. EXPERIMENTATION

Work piece material SS316L

Table 1:- Typical values of chemical compositions of SS316L

C	Mg	P	S	Si	Cr	Ni	Mo	N	I
0.03 max	2.00 max	0.045 max	0.03 max	0.75 max	16.00-18.00	10.00-14.00	2.00-3.00	0.10 max	Balan ce

Table 2:- Mechanical properties of 316L

Tensile strength (MPa) (min)	***Yield Stress 0.2% of (MPa) (min)***	***Stress Elongation Proof (%50mm) (min)***	***Hardness in Rockwell B (HR B) (max)***	***Brinell Hardness (max)***
515	***205***	***40***	***95***	***217***

Cutting Insert: CNMG 120408 Cemented carbide (K25M Grade)
Tool Holder: PCLNR 2525M12
Tool Dynamometer: THREE COMPONENT LATHE TOOL DYNAMOMETER
Lathe: Maxcut PRH175, Max Power 2HP

Experimental Setup:

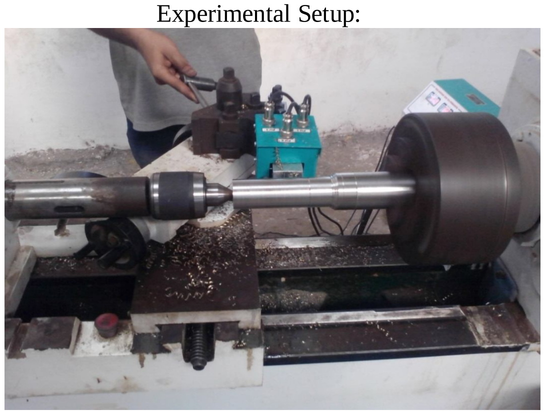


Fig: 2 Experimental Conditions for Turning

Table 3:

Work piece material	AISI316L
Insert used	Cemented Carbide tool insert
Insert Designation	CNMG 120408
Cutting velocity (m/min)	48,77,107
Feed (mm/rev)	0.067,0.111,0.133
Depth of cut (mm)	0.25, 0.5, 0.75
Environment	Dry

Selection of Machinability Characteristics

The effectiveness, efficiency and overall economy of machining of any work material by given tools depend largely on the machinability characteristics of the tool-work materials under the recommended condition. Machinability is usually judged by (i) cutting temperature, which affects product quality, and cutting tool performance (ii) pattern and mode of chip formation (iii) magnitude of the cutting forces, which affects power requirement, dimensional accuracy and vibration and (iv) tool wear and tool life. In the present work, cutting force, chip pattern, tool wear are considered for studying.

Cutting Force

It was necessary to design a fixture to mount a force dynamometer on the lathe in such a way that tool tip will lie at the exact center of lathe axis. The cutting forces were measured using piezoelectric dynamometer mounted on specially designed fixture. PCLNR 2525M12 tool holder was used for holding the 25×25 shank size cutting tool. The input sensitivities of the three-charge amplifiers were set corresponding to the output sensitivity of the force dynamometer in the *x*, *y* and *z* directions. The output sensitivity was set for 100 N/V for cutting force (Fz), and 50 N/V for feed force (Fx) and thrust force (Fy) on the respective charge amplifier. and stored in computer using Minitab software for further analysis.

Turning Conditions and Experimental Design

Type of cutting velocity, feed rate and depth of cut are considered as turning parameters. The ranges of turning parameters are selected as recommended from the tool manufacturer. The turning factors and their levels are shown in Table 4. Experimental plan is organized according to the Taguchi method for the three factors and three level design(L09 orthogonal array). Minitab 17 version is used for multiple regressions. Reducing the large numbers of experiments by Taguchi method is important for robust design in experimental investigations. This method designs certain standard orthogonal arrays by which the simultaneous and independent evaluation of two or more parameters for their ability to affect the variability of a particular product or process characteristics could be done in a minimum number of tests Loss function is the main analysis parameter and calculated for the deviations between the experimental and desired values. This function relocate to S/N (dB) has a ratio of the wanted signal to unwanted random noise; it represents quality characteristics for the observed data.

Table 4: Responses of experiments

Sr.No.	Vc(m/min)	D(mm)	F(mm/rev)	Fc(N)
1.	48	0.75	0.067	117.72
2.	48	0.25	0.133	29.43
3.	48	0.5	0.111	88.29
4.	77	0.5	0.067	49.05
5.	77	0.25	0.111	19.62
6.	77	0.75	0.133	115.58
7.	107	0.75	0.067	115.58
8.	107	0.25	0.111	9.81
9.	107	0.5	0.133	88.29

In optimizing process, there are three S/N ratios characteristics; the lower -- the better, the higher--the better and the nominal--the better. In this work, cutting force for obtaining of optimal conditions are investigated and the lower-the better is selected in experimental plan since the objective of project is minimization of cutting forces.

IV. RESULTS & DISCUSSION

Statistical Analysis of Experimental Results

Analyses of S/N are applied for statistical analyses of experimental results. An analysis of S/N is important for optimum points.

5.2.1 Analysis of S/N

The performances of new optimal cutting conditions are analyzed by Taguchi's the lower the better quality characteristic (S/N ratio) for cutting force. S/N (dB) ratio is calculated using the following equation:

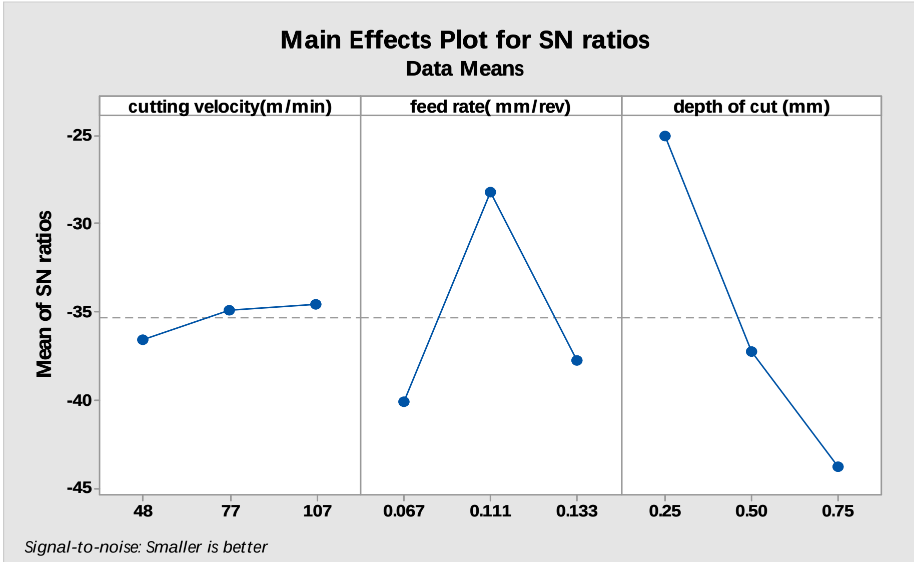
$$S/N = -10\log[1/n(\sum yi^2)]$$

Where n is number of measurements in a trial/row and *yi* is the ith measured value in a run/row. Table 5.2shows values of S/N ratios for observations of the cutting force.

Fig. shows main effect plot for the optimal turning parameters for the, cutting forces

Table 5:- Corresponding S/N (dB) ratio

Sr.no	Fc	S/N for Fc
1.	117.72	-31.89
2.	29.43	-19.83
3.	88.29	-29.375
4.	49.05	-24.27
5.	19.62	-16.31
6.	115.58	-31.72
7.	115.58	-31.72
8.	9.81	-10.297
9.	88.29	-29.27



V. CONCLUSIONS

1) Cutting velocity: - The effect of parameter cutting velocity on the cutting force values is shown above figure for S/N ratio. Its effect is increasing with increase in spindle speed from 48 m/min. So the optimum spindle speed is level 1 i.e. 48m/min
2) Feed Rate: - The effect of parameter feed rate on the cutting force values is shown above figure S/N ratio. Its effect is increasing with increase in feed rate. So the optimum feed rate is level 1 i.e. 0.067 mm/rev.
3) Depth of Cut: - The effect of parameters depth of cut on the metal cutting force values is shown above figure for S/N ratio. Its effect is decreasing with increase in depth of cut. So the optimum depth of cut is level 3 i.e. 0.75mm.
4) From the cutting force S/N ratio results the optimum value, is at cutting velocity 48 m/min, 0.067 mm/rev and depth of cut 0.75

ACKNOWLEDGMENT

This paper bears impart of many people. It is joyful occasion for all of us to publish our paper. I would like to express my deep sense of gratitude to my guide, teachers and friends for giving valuable time, precious guidance which helped us in completion of paper successfully.

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