NOVATEUR PUBLICATIONS
INTERNATIONAL JOURNAL OF INNOVATIONS IN ENGINEERING RESEARCH AND TECHNOLOGY [IJIERT]
ISSN: 2394-3696
VOLUME 2, ISSUE 9, SEP.-2015

OPTIMIZATION OF CUTTING PARAMETERS FOR CUTTING FORCE IN TURNING OF AISI 904L STAINLESS STEEL MATERIAL USING TAGUCHI METHOD

V. V. Potdar
Department of Mechanical Engineering,
A. G. Patil Institute of Technology,
Solapur University, Solapur, India

Umashankar Rawat
Department of Mechanical Engineering,
A. G. Patil Institute of Technology,
Solapur University, Solapur, India

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. Chromium, Nickel, Copper and Molybdenum gives 904L better corrosion resistance properties in sulphuric and phosphoric acid environment. It has excellent forming and welding characteristics.
The present work is concentrated on dry turning of 904L. In this study the effect of cutting parameters on cutting force is studied by experimentation. 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.

KEY WORDS: Cutting force, Taguchi method, S/N ratio, turning

INTRODUCTION

Austenitic stainless steel is one of the highly consumed steel worldwide and it is commonly used to fabricate chemical and food processing equipment, as well as machinery parts requiring high corrosion resistance. It is also amongst the "difficult to cut" material and the difficulties such as poor surface finish and high tool wear are common. The work hardening and low thermal conductivity is recognized to be responsible for the poor machinability of AISI304, AISI 904L austenitic stainless steels. In addition, they bond very strongly to cutting tool during cutting and when chip is broken away, it may bring with it a fragment of cutting tool. Little work has been reported on the determination of optimum machining parameters during dry turning of austenitic stainless steels. [6] The need for selecting and implementing optimal machining conditions and the most suitable cutting tool has been felt over the last few decades. [5]
In turning operation, it is an important task to select cutting parameters for achieving high cutting performance. Usually, the desired cutting parameters are determined based on experience or by use of a handbook. However, this does not ensure that the selected cutting

parameters have optimal or near optimal cutting performance for a particular machine and environment. [7]
Different procedures have been used by researchers from time to time for the process of optimization. Taguchi method is an experimental method. It is effective methodology to find out the effective performance and machining conditions. Taguchi parameter design offers a simple, systematic approach and can reduce number of experiment to optimize design for performance, quality and manufacturing cost. Signal to noise ratio and orthogonal array are two major tools used in robust design. [11]

PROBLEM DEFINITION & PROPOSED METHODOLOGY

Problem Definition

As we know the stainless steel material AISI 904L 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 AISI 904L on cutting force by using Taguchi method.

Proposed Methodology

Considering the problem occurring while selecting parameters for machining of AISI 904L. Here firstly we selected the tool insert for machining of AISI 904L, tool holder PCLNR 2525M12. After the selection of tool insert, and tool holder we selected the Taguchi technique for performance of dry turning of AISI 904L 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.

Steps in methodology

1. Selection of Taguchi method
2. Selection of machining conditions
3. Selection of work material
4. Machining using different parameters
5. Analysis and optimization of machining parameters
6. Result and discussion

EXPERIMENTATION

In this study, AISI 904L with Brinnel hardness of 187 (HBW is used as the work piece material. Dimensions of the work piece are diameter Ø40 mm × length 200 mm. Lathe (Maxcut PRH175) of maximum power 2 HP is used for experiments. The maximum RPM of the lathe machine is 1535 rpm, photograph of the machine is shown in Fig 1. Machining operations are performed with Coated carbide, CNMG 120408-5, TN4000 grade. Tool Holder PCLNR 25*25-M12 (Korlay Make) is used for holding the insert.

Figure 1: Lathe Maxcut PRH175

Table 1: Experimental Condition

Work piece material	AISI 904L
Insert used	Coated Carbide tool insert
Insert Designation	CNMG 120408-5 TN4000
Spindle Speed (rpm)	202, 303, 455
Feed (mm/rev)	0.133, 0.167, 0.267
Depth of cut (mm)	0.15, 0.2, 0.25
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.

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 1. Experimental plan is organized according to the Taguchi method for the three factors and three level design (L27 orthogonal array). 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.

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.

Table 2: Responses of Experiments for Cutting force

Sr No.	SPEED (rpm)	Feed (mm/rev)	DOC (mm)	Cutting force (Fc), Kg.
1	202	0.133	0.15	13
2	202	0.133	0.2	08
3	202	0.133	0.25	21
4	202	0.167	0.15	12
5	202	0.167	0.2	16
6	202	0.167	0.25	18
7	202	0.267	0.15	12
8	202	0.267	0.2	20
9	202	0.267	0.25	21
10	303	0.133	0.15	08
11	303	0.133	0.2	12
12	303	0.133	0.25	14
13	303	0.167	0.15	10
14	303	0.167	0.2	13
15	303	0.167	0.25	15
16	303	0.267	0.15	10
17	303	0.267	0.2	15
18	303	0.267	0.25	19
19	455	0.133	0.15	04
20	455	0.133	0.2	08
21	455	0.133	0.25	08
22	455	0.167	0.15	05
23	455	0.167	0.2	10
24	455	0.167	0.25	10
25	455	0.267	0.15	06
26	455	0.267	0.2	12
27	455	0.267	0.25	18

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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.
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 shows values of S/N ratios for observations of the cutting force.

Table 3:- Corresponding S/N (dB) ratio

Sr. No.	SPEED (rpm)	Feed (mm/rev)	DOC (mm)	Cutting force (Fc), Kg.	SN for Fc
1	202	0.133	0.15	13	-22.2789
2	202	0.133	0.2	08	-18.0618
3	202	0.133	0.25	21	-26.4444
4	202	0.167	0.15	12	-21.5836
5	202	0.167	0.2	16	-24.0824
6	202	0.167	0.25	18	-25.1055
7	202	0.267	0.15	12	-21.5836
8	202	0.267	0.2	20	-26.0206
9	202	0.267	0.25	21	-26.4444
10	303	0.133	0.15	08	-18.0618
11	303	0.133	0.2	12	-21.5836
12	303	0.133	0.25	14	-22.9226
13	303	0.167	0.15	10	-20.0000
14	303	0.167	0.2	13	-22.2789
15	303	0.167	0.25	15	-23.5218
16	303	0.267	0.15	10	-20.0000
17	303	0.267	0.2	15	-23.5218
18	303	0.267	0.25	19	-25.5751
19	455	0.133	0.15	04	-12.0412
20	455	0.133	0.2	08	-18.0618
21	455	0.133	0.25	08	-18.0618
22	455	0.167	0.15	05	-13.9794
23	455	0.167	0.2	10	-20.0000
24	455	0.167	0.25	10	-20.0000
25	455	0.267	0.15	06	-15.563
26	455	0.267	0.2	12	-21.5836
27	455	0.267	0.25	18	-25.1055

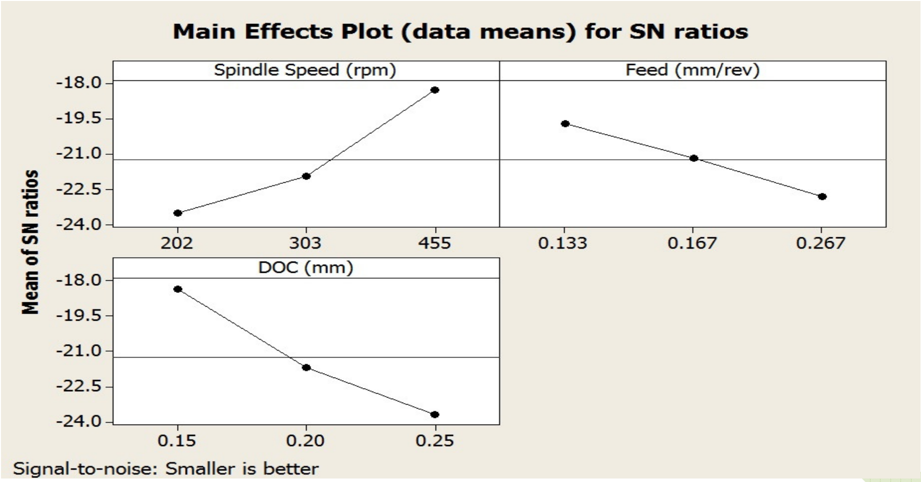

Figure 2: shows main effect plot for the optimal turning parameters for the cutting forces

CONCLUSIONS

1) As spindle speed increases cutting force decreases and lowest value of cutting force is observed at spindle speed 455 rpm.

2) As the feed rate increases cutting force increases and lowest value of cutting force is observed at the feed rate 0.133 mm/rev

3) As the depth of cut increases cutting force increases and lowest value of cutting is observed at depth of cut 0.15 mm.

ACKNOWLEDGEMENT

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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