ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 5, Issue 9 , September 2018

Investigation of Cutting Parameters for Austenitic SS AISI 316 in Different Environment - Turning

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ABSTRACT: The austenitic stainless steel material has good corrosion resistant and heat resistant property. It is important to study machining of AISI 316 austenitic stainless steel due to its hardening property. The application of AISI 316 material is in sea-water, equipment for manufacturing dye, paper, acetic acid, fertilizer and chemicals, in the photo industry, food industry, the facilities constructed in the coastal area, bolts and nuts etc. AISI 316 austenitic stainless steel material becomes hard while machining in cryogenic cooling. This study was completed on the basis that, AISI 316 was used for different turning conditions to determine optimum machining parameters. The primary objective of the ensuing study was to find out optimal cutting parameters at three different environmental condition i.e. Dry, Wet and Cryogenic; 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 and the wear of the tool. The objective was to find the optimum machining parameters so as to minimize the surface roughness and tool wear for the selected tool and work materials in the chosen domain of the experiment. The present work concerned an experimental study of turning on Austenitic Stainless steel of grade AISI 316 by a PVD coated carbide insert tool. The design of experiment was done with the help of Taguchi's technique to find out optimal combinations of cutting parameters. Surface Roughness and tool wear was measured. The data was compiled into MINITAB 17 for analysis. The relationship between the machining parameters and the response variables (surface roughness and tool wear) were modelled and analyzed using the Taguchi Design. Response Surface Methodology was used to investigate the significance of these parameters on the response variables, and to determine a regression equation for the response variables with the machining parameters as the independent variables, with the help of a quadratic model. The top three optimum settings for carrying out the machining were obtained from Grasshopper Optimizer and are shown in the results section and then validation was carried out.

KEYWORDS: AISI 316 austenitic SS, Cryogenic, PVD coated carbide insert, Grasshopper Optimizer

I. INTRODUCTION

Stainless steel, are also known as corrosion-resistant steel, because it is an iron-based steel alloy, which contain minimum 11% chromium. When ordinary carbon steel is exposed to rain water, it corrodes easily due to formation of a brown iron oxide on the surface, which is commonly called as rust. Stainless Steel generally has high ductility, weld ability and cryogenic toughness properties. When exposed to air and moisture unprotected carbon steel rusts easily. Stainless steel have many applications based on architectural, transport, chemical or pharmaceutical, oil and gas subsea pipelines, food and drink, hot water tanks and springs, fasteners (bolts, nuts and washers), wire, etc.[1][2]As the machining of AISI 316 austenitic stainless material is required, then it is necessary to study the effect of machining on surface finish of work material and the machining effect on cutting tool.

Tool wear is an inherent occurrence in any machining process. Wear affects tool life and product quality. Hence, improvements have to be made in order to increase tool life. Surface finish is also an important aspect of a machined product. Among all Austenitic Stainless Steel, AISI 316 has more corrosion resistance property which can be used in sea-water, food industries, bolt and nuts etc. Hence AISI 316 Austenitic Stainless Steel material is selected as a

ISSN: 2350-0328

International Journal of AdvancedResearch in Science, Engineering and Technology

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workpiece material for studding a machining process (turning process) at different cutting environmental conditions i.e. dry, wet and cryogenic varying cutting parameters i.e. cutting speed, feed rate and depth of cut.

II. LITERATURE SURVEY

Literature consist of different studies related to AISI 316 Austenitic Stainless Steel material. Different experiments which contains study of turning effect on surface roughness, tool wear, thermal expansion due to machining, MRR (material removal rate),etc. Following are some literatures,

D. Philip Selvaraj (2010) [3] have proposed in his research about the effect of cutting parameters on surface roughness on austenitic stainless steel material in dry cutting. The experiment is based on Taguchi's technique which gives optimal cutting parameters to minimize surface roughness. M. Kaladhar (2012) [4] have proposed on the selection of proper cutting parameters using Taguchi method and find effect of parameters on surface finish and MRR (Material Removal Rate). Inserts of 0.4mm and 0.8mm nose radii are used. D.V.V. Krishan Prasad (2013) [5] proposed that in a turning process surface roughness depend on machining parameters and tool geometry. In this work considering three machining parameters and two tool geometrical parameters 243 experiments were conducted for full factorial design. Using ANOVA analysis the influence of these parameters on surface roughness was studied. Murat Sarikaya (2015) [6] have worked on different cooling i.e. dry, wet and cryogenic cooling with liquid nitrogen (LN2). After performing experiments at these different conditions, cryogenic cooling gives best results. Cryogenic cooling gives good surface quality of machined parts. The cutting tool used was PVD coated carbide inserts and experiment was performed under dry, wet and cryogenic cooling with liquid nitrogen. The S/N ratio was employed with smaller is better approach to obtain best combination. V.T.G. Naves (2013) [7] have suggested a systematic reduction of tool wear and reduce length between tool and chip with use of high pressure coolant. He found that flank wear was present in all types of conditions and crater wear was present on rake face. Kaldhone S.Y. (2015) [8] observed that depth of cut and spindle speed effect on material removal rate and feed rate. From S/N ratio graph and ANOVA it is conclude that the cutting speed and depth of cut are highly effect on MRR and as feed increases average cutting force also increases. Shahrzad Saremi (2017) [8] proposes an optimization algorithm called Grasshopper Optimization Algorithm (GOA) and applies it to challenging problems in structural optimization. The proposed algorithm mathematically models and mimics the behavior of grasshopper swarms in nature for solving optimization problems. The GOA algorithm is first benchmarked on a set of test problems including CEC2005 to test and verify its performance qualitatively and quantitatively

III. METHODOLOGY

The AISI 316 austenitic stainless steel material is selected after referring different literature. It is a chromium-nickel stainless steel containing molybdenum. Component selected is 36 mm dia., 130 mm long and round rolled shaped bars. Cutting tests were carried out on CNC lathe machine, SPEED LX-200 super of FANUC series, under dry, wet and cryogenic machining conditions. GRODAL CUTSOL A coolant used for wet turning which possess excellent lubricity, good protection of machinery and parts, increased tool life and water soluble, hence no fire hazards.

Cryogenic machining is a method of cooling the cutting tool and/or workpiece during material removal processes. The coolant is usually nitrogen fluid (LN), is liquefied by cooling to -196□ C. The cutting tool used for turning AISI 316 austenitic stainless steel is PVD coated carbide insert with ISO code MTJNL 25 25 12F. The range of cutting parameters is based on workpiece material and cutting tool used for machining. Factors i.e. cutting speed (Vc), feed (fd) and depth of cut (doc) are considered as control factors.

Table No.1: Factors and levels of Process Parameters

LEVELS	Vc (m/min)	fd (mm/rev)	d.o.c (mm)
1	160	0.1	0.5
2	180	0.2	1
3	200	0.3	1.5

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
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The design of experiment is done on the basis of Taguchi's design technique, as there are 3 processing parameters and 3 levels each, 3-leval design is selected. The L9 array is selected and optimal combinations are obtained.

For cryogenic machining the workpiece was deepen into liquid nitrogen for half an hour and then taken for machining first cutting condition was carried out and after completion the insert cutting point was changed and chip was collected. Then machine was cleaned and second cutting condition was obtained. Similarly all cutting conditions were carried out twice for dry, wet and cryogenic cutting environment respectively. Reading was noted for surface roughness and tool wear.

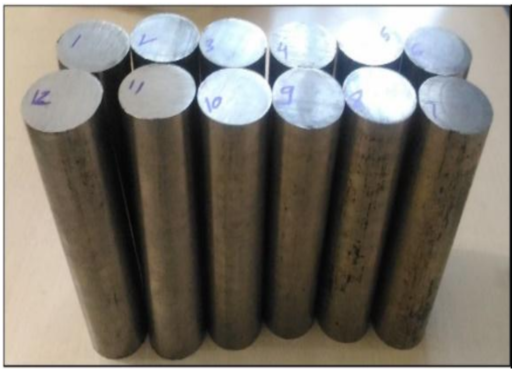


Figure No.1 - Workpiece Material AISI 316Figure No.2– Inserts used for turning

Table No.2: Flow of cutting conditions used for machining.

Sr. No.	Vc (m/min)	fd (mm/rev)	d.o.c. (mm)
1	160	0.2	1.5
2	160	0.1	1
3	160	0.3	0.5
4	180	0.3	1.5
5	180	0.2	1
6	180	0.1	0.5
7	200	0.1	1.5
8	200	0.3	1
9	200	0.2	0.5

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International Journal of AdvancedResearch in Science, Engineering and Technology
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Table No.3: Surface Roughness values for Dry, Wet and Cryogenic machining

Average Value of 3 location (µm)		
Ra (Dry)	Ra (Wet)	Ra (Cryogenic)
3.051	1.653	1.621
1.579	3.411	1.068
1.181	1.257	3.311
1.518	1.635	3.169
1.390	3.220	1.755
2.051	1.152	0.803
1.637	3.064	1.153
0.952	1.681	3.248
3.309	0.969	1.697

Table No.4: Tool wear values for Dry, Wet and Cryogenic machining

Tool wear (mm)		
Wear (Dry)	Wear (Wet)	Wear (Cryogenic)
0.010	0.005	0.005
0.030	0.005	0.010
0.025	0.045	0.050
0.020	0.015	0.005
0.015	0.005	0.025
0.035	0.035	0.030
0.085	0.025	0.015
0.045	0.010	0.005
0.025	0.020	0.005

IV. ANALYSIS OF WORK

The purpose of work is to obtain optimized value of surface roughness and tool wear. Taguchi Design Analyzer uses signal to noise (SN) ratio as a performance measure to choose control levels. In present work, as we have to minimize the values of surface roughness and tool wear, the SN ratio is used for minimization with smaller is better equation

$$\frac{S}{N}\text{ Ratio} = 10\times \log_{10}\left(\frac{\sum Y^2}{n}\right)$$

The mathematical modelling is based on Response Surface Methodology (RSM) which is used to find the relation in which an output response of interest is influence by several input variables and our objective is to optimize the response variables. The regression equations for surface roughness and tool wear at different cutting environment i.e. dry, wet and cryogenic respectively were obtained using RSM. On the basis of regression equation equations the optimal process parameters were obtained separately by Grasshopper Optimization Algorithm. The results obtained from the experiments were fed into MINITAB 17 for further analysis.

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International Journal of AdvancedResearch in Science, Engineering and Technology
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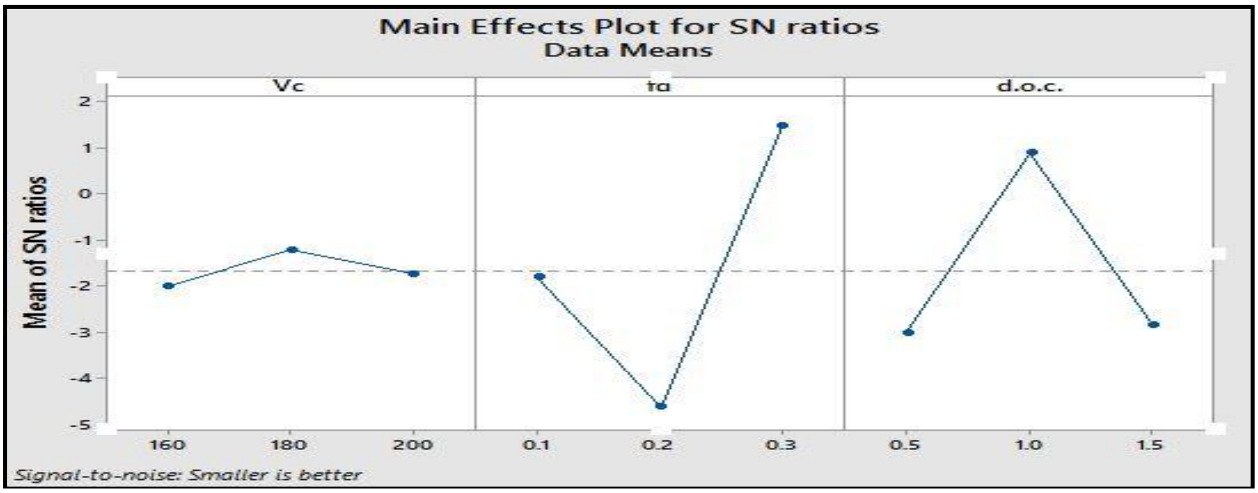
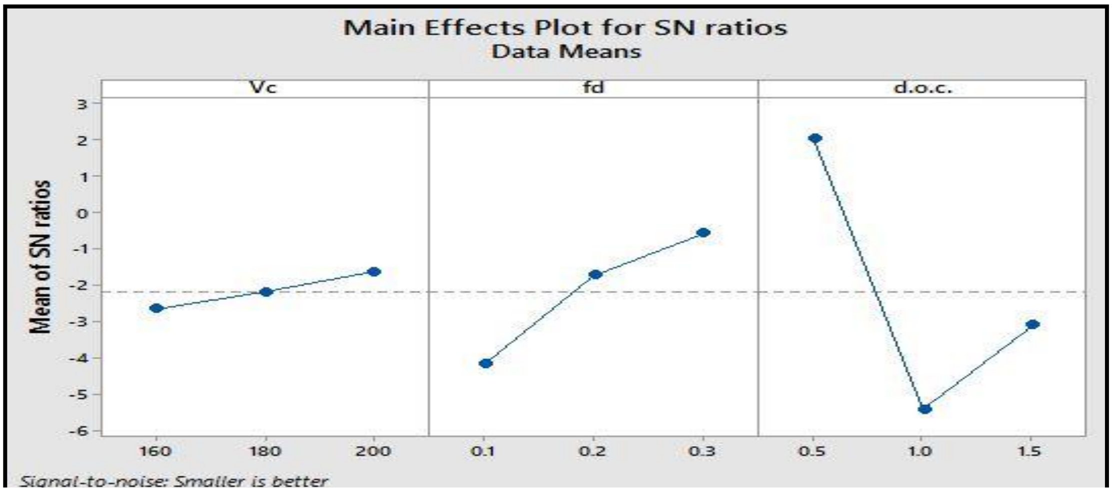


Graph No.1 - S/N Ratio for DRY



Graph No.2 - S/N Ratio for WET

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
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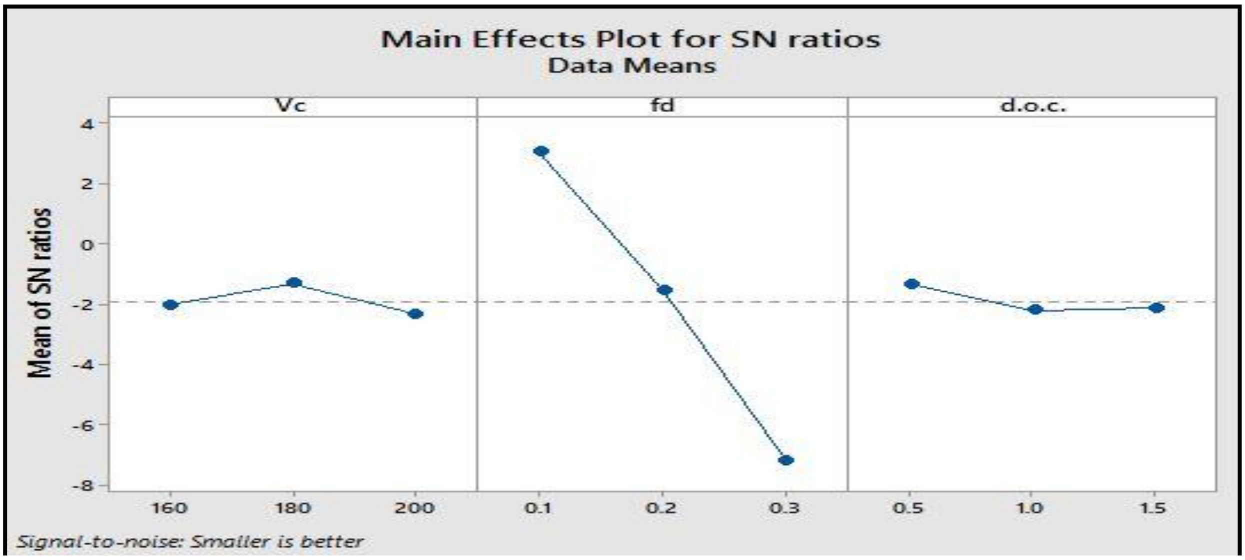


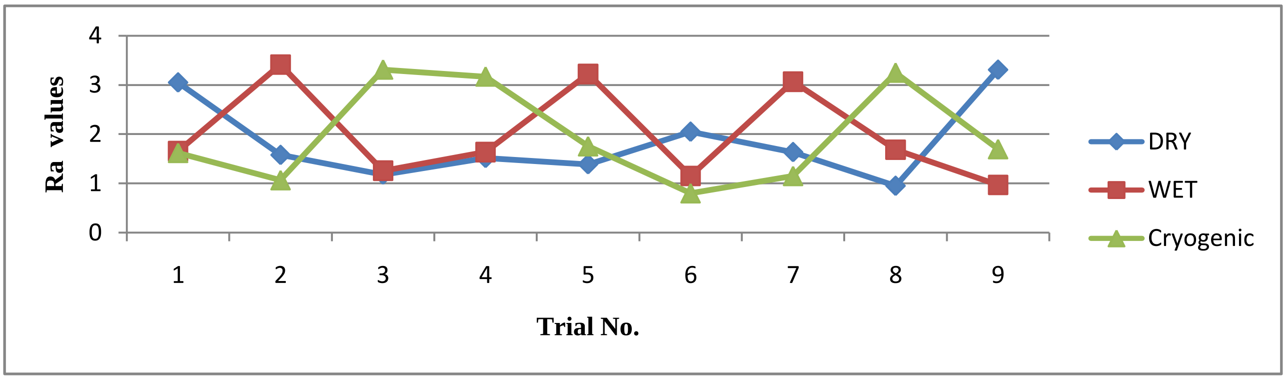
Graph No.3 - S/N Ratio for Cryogenic.

Summary: The AISI 316 material was selected on the basis of literature survey. The insert selected was PVD coated carbide insert and according to insert suitable tool holder was selected. The cutting parameters were also selected on the basis of literature survey. The DOE was done using Taguchi's Design and with the help of L9 array optimal combinations of cutting parameters were obtained. The experiment was carried on CNC machine using cutting parameters that were obtained with the help of DOE. Surface roughness was measured by using Surface Roughness Tester and tool wear was measured with the help of Tool Maker's microscope.
The combine optimal values were obtained using S/N ratio for surface roughness and tool wear at Dry, Wet and Cryogenic cutting environment condition

V. RESULT AND DISCUSSION

- Surface Roughness

The surface roughness values that are measured with the help of Surface roughness Tester after experimentation. The graph is plotted for different cutting condition i.e. dry, wet and cryogenic separately.



It is seen that the surface roughness values for dry machining are high as compare to wet machining and cryogenic machining. In wet machining the value of surface roughness is less as compare to dry machining and high as compared to cryogenic machining. In cryogenic machining the surface roughness values are less and better surface finish is obtained as compared to dry and wet machining.

- Tool Wear

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
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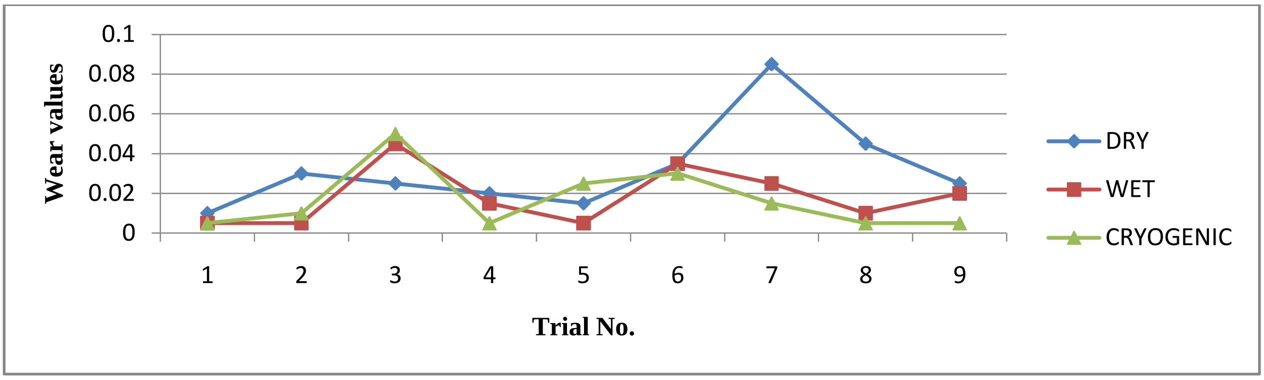
The Tool wear values that are measured with the help of Tool Makers Microscope after experimentation. The graph is plotted for different cutting condition i.e. dry, wet and cryogenic separately.



It is seen that the maximum wear of cutting tool has taken place in dry machining as it generates high temperature while machining. While in wet machining the tool wear is less compared to dry machining and high compared to cryogenic machining. In cryogenic machining the tool wear was very less as compared to dry and wet machining

VI.CONCLUSION AND FUTURE WORK

1. The optimal values obtained for surface roughness and tool wear with the help if S/N ratio was observed that, in dry condition the influencing factor was feed rate, in wet condition the influencing factor was depth of cut and in cryogenic condition the influencing factor was feed rate.
2. It was observed that in cryogenic condition the values of surface roughness and tool wear are very less as compared to dry and wet condition.
3. Cryogenic machining shows 34.48% better surface finish in dry machining and 4.65% in wet machining. The tool wear was also better i.e. 82.92% in dry machining and 58.82% in wet machining compared to cryogenic machining.
4. Cryogenic machining processing can provide significant improvement in both product quality and productivity and hence overall machining economy even after covering the additional cost of Cryogenic processing.
5. As there is more heat generation in dry cutting condition due to more friction we should use wet cutting condition or cryogenic condition to gain good surface finish and less tool wear.
6. Thus, it is possible to increase machine utilization and decrease production cost in an automated Manufacturing environment.

The experiment was originally planned to be conducted by direct flow of Liquid Nitrogen (LN2) through nozzle at tool-workpiece interface. Due to unavailability of the mist application device due to some constraints, the experiment was conducted by immersing workpiece into Liquid Nitrogen for half an hour.
Another improvement that can be made to the present study is that cutting forces could be added as an output response in addition to material removal rate and nose radius. The number of trials can be increase to get more optimal results. To inspect the structure of cutting tool, Scanning Electron Microscope (SEM) can be used and more accurate results can be obtained.

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