MACHINABILITY STUDIES OF AISI 304 STAINLESS STEEL IN CNC TURNING OPERATION

A Project Submitted by

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Under the supervision of

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DEPARTMENT OF MECHANICAL ENGINEERING

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BONAFIDE CERTIFICATE

Certified that this project report "**MACHINABILITY STUDIES OF AISI 304 STAINLESS STEEL IN CNC TURNING OPERATION"** is the bonafide work of "**SAMUELSON G (PRK21ME5002)"** who carried out the project work under my supervision during the academic year 2021-2022.

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ABSTRACT

In this project, the CNC turning process parameters are optimized by employing the Taguchi method under dry and wet machining conditions of AISI 304 stainless steel. The dry and wet turning operations are conducted at three levels of cutting velocity, feed and depth of cut. The test results are evaluated by employing Mean and ANOVA. It is revealed that the cutting speed, feed, and depth of cut are the important input variables affecting the quality of the machined surface. The optimum surface finish is attained at the combination of lower depth of cut, medium higher feed rate and lower cutting speed during dry turning process. Surface roughness, temperature, and tool wear plays a significant role in machining for proper planning and control of machining parameters and optimization of cutting conditions.

Keywords

Austenitic stainless steel, Machining conditions, Surface roughness, Tool wear, Taguchi's method

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CHAPTER 1

INTRODUCTION

1.1 General introduction

Stainless steels (SSs) contain at least 10.5% chromium (Cr) by weight in order to have corrosion resistance. Generally, austenitic stainless steels (ASSs) have at least 16% chromium and small amount of nickel and/or manganese. The usage of ASS alloy is higher compared with other stainless steel alloys. They possess face-centered cubic (FCC) microstructure. They have good formability, weldability, and higher toughness. ASS is employed for making cooking utensils, architectural applications, containers, equipment for food industries, heat exchangers, and surgical implants [1].

Surface finish is an important factor needed by the production engineers to the effective working of the machine elements. It is required for production engineers to obtain required surface roughness on the machine components. Ra is widely employed parameter for surface roughness evaluation in machine tool industries. Various reasons for surface roughness are machine tool vibration, tool feed marks, and formation of built up edges. In the past few decades, CNC machines are replacing conventional machine tools in the industries due to more productivity, better accuracy, and reduction in rejection rate [2, 3].

The Taguchi method is commonly employed for optimizing the machining operations. Several researchers used the Taguchi techniques for optimizing the surface finish of various materials in different cutting processes. Dry turning process is the method of turning without employing cutting fluids. And wet turning process is the method of turning with employing cutting fluids. So, in the current work, the influences of turning process variables on surface finish of 304 ASS during dry and wet turning process in CNC lathe are analyzed by applying the Taguchi technique.

1.2 Objective of the project

To carry out turning experiments under dry and wet machining conditions in the AISI 304 SS.

To find out the influence of cutting parameters such as cutting speed, feed rate and depth of cut on output parameters like surface roughness, cutting temperature and tool wear in turning operation.

To optimize the cutting parameters for minimizing the surface roughness, cutting temperature and tool wear during the turning operations under dry and wet cutting conditions using Taguchi method.

To compare the performance of AISI 304 SS under dry and wet cutting conditions with respect to surface roughness, cutting temperature and tool wear.

1.2 Motivation for the project

Stainless steels are difficult to machine material due to its high toughness, low thermal conductivity, high degree of work hardening rate and tendency to the built up edge formation. Currently the manufacturing industries are facing difficulties in machining of SS components. In the present work an attempt has been made to find the optimum machining parameters to improve surface quality and productivity during CNC turning of AISI 304 SS.

CHAPTER 2
LITERATURE REVIEW

Philip Selvaraj, D., & Richard Philip, P. (2021). Some studies on surface roughness of AISI 304 austenitic stainless steel in dry turning operation. Trends in Mechanical and Biomedical Design, 869-877.

In this paper, the input variables of the turning process of AISI 304 stainless steel are optimized by employing the Taguchi method under dry machining conditions. The dry turning operations are conducted at three levels of depth of cut, cutting velocity, and feed. The test results are evaluated by employing S/N ratio and ANOVA. It is revealed that the depth, cutting speed, and feed are the important input variables affecting the quality of the machined surface. The optimum surface finish is attained at the combination of lower depth, lower feed, and higher cutting speed.

O'sullivan, D., & Cotterell, M. (2002). Machinability of austenitic stainless steel SS303. Journal of Materials Processing Technology, 124(1-2), 153-159.

Stainless steel SS303 is a grade of material widely used in the manufacture of proprietary inserts for the electronics and automotive industry. Users have often reported machining difficulties with this material and very little information on its machinability can be found. Problems such as poor surface finish and high tool wear are common. Optimum setting of machining parameters, such as cutting speeds and feed rates, is critical with this material, especially in today's high volume production environment. Machining data from machine tool manufactures, material suppliers and cutting tool suppliers is not consistent and does not give reliable results when tested in practice. Third party data, from engineering handbooks, is out of date and is not representative of modern grades of material and tooling. Many of the current problems are attributed to work hardening of the material during machining, and a trial and error approach is adopted on the shop floor to avoid the conditions that lead to this phenomenon.

Better scientific understanding of the mechanisms that contribute to workpiece surface integrity and to tool wear when working with this material is desirable. As a result, research was undertaken to develop some fundamental guidelines on the machinability of this grade of stainless steel. In the interest of reducing manufacturing and production costs, an on-line technique will be developed for the detection of work hardening of austenitic stainless steel SS303 in unmanned machining operations. A review of current on-line work hardening detection techniques is presented.

Kumar, M. V., Kumar, B. K., & Rudresha, N. (2018). Optimization of machining parameters in CNC turning of stainless steel (EN19) by Taguchi's orthogonal array experiments. Materials Today: Proceedings, 5(5), 11395-11407.

The objective of this work is to machine EN 19 stainless steel material by using CNC Turning operation and to investigate the affecting parameters while machining materials are surface roughness and MRR. The CNC Turning process parameters are feed rate, depth of cut and spindle speed/ rotational speed, lubricant, have been analyzed on MRR and Surface roughness. Carbide tip tool used as a cutting tool for the experiments. Taguchi's L18 mixed type orthogonal array experimental design have been selected for investigation, and optimization is done through Taguchi's approach, and also the analysis of variance (ANOVA) is applied to know the significance of process parameters on response variable.

Patel, U., Rawal, S., Bose, B., Arif, A. F. M., & Veldhuis, S. (2022). Performance evaluations of Ti-based PVD coatings deposited on cermet tools for high-speed dry finish turning of AISI 304 stainless steel. Wear, 492, 204214.

The aim of this research work is to develop and compare in-house Ti-based coatings with commercial coatings for cermet tools, specifically for the high-speed dry turning of Austenitic stainless steel (AISI 304). In the present study, commercial Ti-based coated cermet tools from different manufacturers are used to evaluate and compare the performance of commercial coatings. This research focuses on the investigation of the performance for the various commercial coatings on cermet tools based on the mico-mechanical properties, tool performance and surface roughness.

The results are used to develop a range of in-house Ti-based PVD coatings with different compositions and compare their performance with similar commercial coatings. Coating surface topography and structure were investigated using Atomic Force Microscopy (AFM). The compositions of coating materials and tribo films were determined using Energy-Dispersive X-ray Spectrometry (EDS) and X-ray photoelectron spectroscopy. The results of this research demonstrate that the compositions of various coatings affect the micromechanical properties and significantly influence the tool life and wear morphology. The performance of inhouse Ti-based coatings with a similar composition to commercial coatings were better than the latter, depending upon their micro-mechanical properties.

He, Q., DePaiva, J. M., Kohlscheen, J., & Veldhuis, S. C. (2022), Analysis of the performance of PVD AlTiN coating with five different Al/Ti ratios during the high-speed turning of stainless steel 304 under dry and wet cooling conditions

High-speed machining of austenitic stainless steel normally causes significant tool damage and generates reduced tool life. In this paper, five AlTiN PVD coatings with different Al/Ti atomic ratios (50/50, 60/40, 67/33, 70/30 and 73/27) which deposited on cemented carbide inserts were used to conduct high-speed of 370 m/min finish turning tests. The experiments were carried out under different cooling conditions (dry and wet) on SS304 to study the tribological behavior of the AlTiN coatings with different Al/Ti ratios and the effect of the coolant under such aggressive cutting conditions. During the experiments, tool life, cutting force, wear mechanism, friction condition and surface integrity of machined workpiece were investigated. Crater wear was found to be the predominant wear mode during the cutting test, while the complex combination of oxidation, abrasion/ attrition, adhesion, and chipping contributed to the tool failure. Given the machining conditions proposed in this study, the results revealed that all coated inserts possessed an improved friction behavior in the wet cutting condition. Compared to the dry machining, all five coatings had exhibited 2–3 times longer tool life. The AlTiN coated insert (Al/Ti = 60/40), in particular, exhibited a cutting length of almost 7000 m, compared to 1000 m for the AlTiN coated insert (Al/Ti = 73/27)

CHAPTER 3
EXPERIMENTAL DETAILS

3.1 Introduction

In this section, experimental methodology, the details of equipment facilities, machine tools used, cutting tool, workpiece material, machining parameters and experimental set-up have been described.

3.2 Workpiece material

Type 304 stainless steel (containing 18%-20% chromium and 8%-10.5% nickel) is the most common stainless steel. It is also known as "18/8" stainless steel because of its composition, which includes 18% chromium and 8% nickel. This alloy resists most types of corrosion. It is an austenitic stainless steel and it has also excellent cryogenic properties, and good high-temperature strength as well as good forming and welding properties. It is less electrically and thermally conductive than carbon steel and is essentially non-magnetic.

Element	wt%
C	0.067
Si	0.64
Mn	1.60
S	0.023
P	0.025
Cr	19.12
Ni	9.06
Fe	Balance

Table 3.1 Chemical composition of AUSTENITIC STAINLESS STEEL 304

Fig 3.1 AISI 304 SS Workpiece material

3.3 CNC Turning center

A CNC Turning Center is a complex machine, capable of lathe and milling processes. It is computer controlled with designs starting on CAD software, which are exported as CAM files. These files are used to drive the motors of the turret tool post, chuck and machine bed, allowing for manufacturing complexity as well as precision engineering.

This CNC Centre (below) is being set up for a series of machining processes. The Turret Tooling System, is clearly seen in the Centre of the photograph.

Fig 3.2 CNC Turning Center

CNC Centers are controlled by a programme, normally produced after a CAD drawing has been converted / processed, during the design stage. The programme is a series of coordinates (numbers) that control the movement of the cutting tools.
CNC Centers are supplied in a range of sizes. Two typical CNC Centers are seen. The photograph is of a desktop / school / college version. Notice the doors / sliding guards, which enclose the machining area. This is an essential safety feature, as the machines will not work unless the safety doors are in a closed position.

3.4 Profilometer

A profilometer is an instrument used to measure the profile and surface finish of a surface. On a small scale, surfaces can be composed of a series of peaks and valleys with varying height, depth, and spacing. Subtle differences in these features determine if the surface feels smooth or rough, looks matte or glossy, can form a seal, or is suitable for a wear surface. In industries where mechanical parts are produced, surface roughness or surface finish requirements are commonly specified on technical drawings, and profilometers are used to verify that the requirements have been met.

Fig 3.3 Profilometer

Types of profilometers

Profilometers come in many shapes and sizes, but they can be divided into two basic types – contact and optical. Contact profilometers measure surface profile by physically tracing the surface with a stylus. In contrast, optical profilometers use reflections of various types of light to measure surface features in a line or area.

Contact Profilometer

Contact profilometers measure surface profile by lightly dragging a stylus across the surface. The tip of the stylus rides in a line across the surface, moving vertically over the peaks and valleys. Changes in the stylus' height are registered electrically and tracked against position as the stylus moves, creating a measured profile. Stylus tips are conical, with a spherical radius on the bottom. The cone angle and tip radius determine the smallest features that a stylus can trace. Stylus tips are typically made of hard, wear-resistant materials such as diamond or sapphire.

Optical Profilometers

Optical profilometers include 1-D, 2-D, and 3-D profiling devices. These devices use light to measure features on a surface, and their operation can be based on a number of different principles, including optical interference, use of confocal apertures, focus detection, and pattern projection. Despite the breadth of this group of instruments, they share points of commonality. Optical profilometers are relatively large instruments that consist of a light source, optical lenses, and image sensors. They require the surface to reflect the light being used, so many of these instruments will have trouble measuring translucent or highly reflective surfaces. Also, for the reflection to accurately characterize the surface, it must be free of debris and contaminants such as dirt, water, and oil. Since light travels very quickly, measurements can be taken faster than with contact profilometers. With some instruments, millions of readings can be collected in seconds, making it practical to model a relatively large area's surface topography

3.5 Pyrometer

A pyrometer, also known as an Infrared thermometer, detects the surface temperature of an object, which depends on the radiation (infrared or visible) emitted from the object. The basic principle of the pyrometer is to measure the temperature by sensing the heat/radiation emitted from the object without making contact. The pyrometer has two components, optical systems, and detectors. Pyrometers possess the property of absorbing energy and measuring EM wave intensity at any wavelength. These devices can measure the temperature accurately, precisely, visually, and quickly. Pyrometers are available in different spectral ranges (since metals – short wave ranges and nonmetals-long wave ranges).

Fig 3.4 Pyrometer

3.6 Tungsten carbide cutting tool

Tungsten carbide (chemical formula: WC) is a chemical compound (specifically, a carbide) containing equal parts of tungsten and carbon atoms. In its most basic form, tungsten carbide is a fine gray powder, but it can be pressed and formed into shapes through sintering for use in industrial machinery, cutting tools, chisels, abrasives, armor-piercing shells and jewelry.

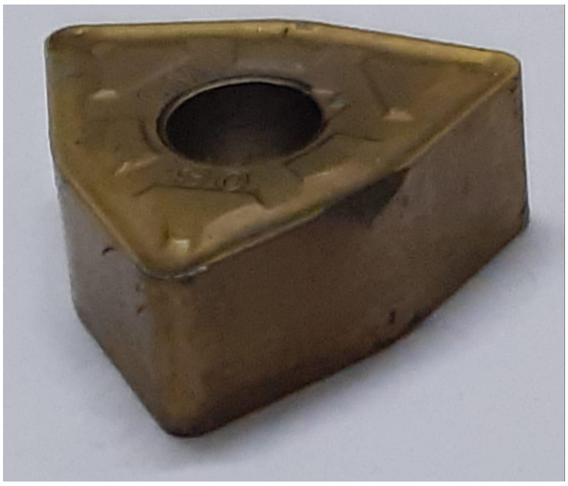


Fig 3.5 Tungsten Carbide cutting tool insert

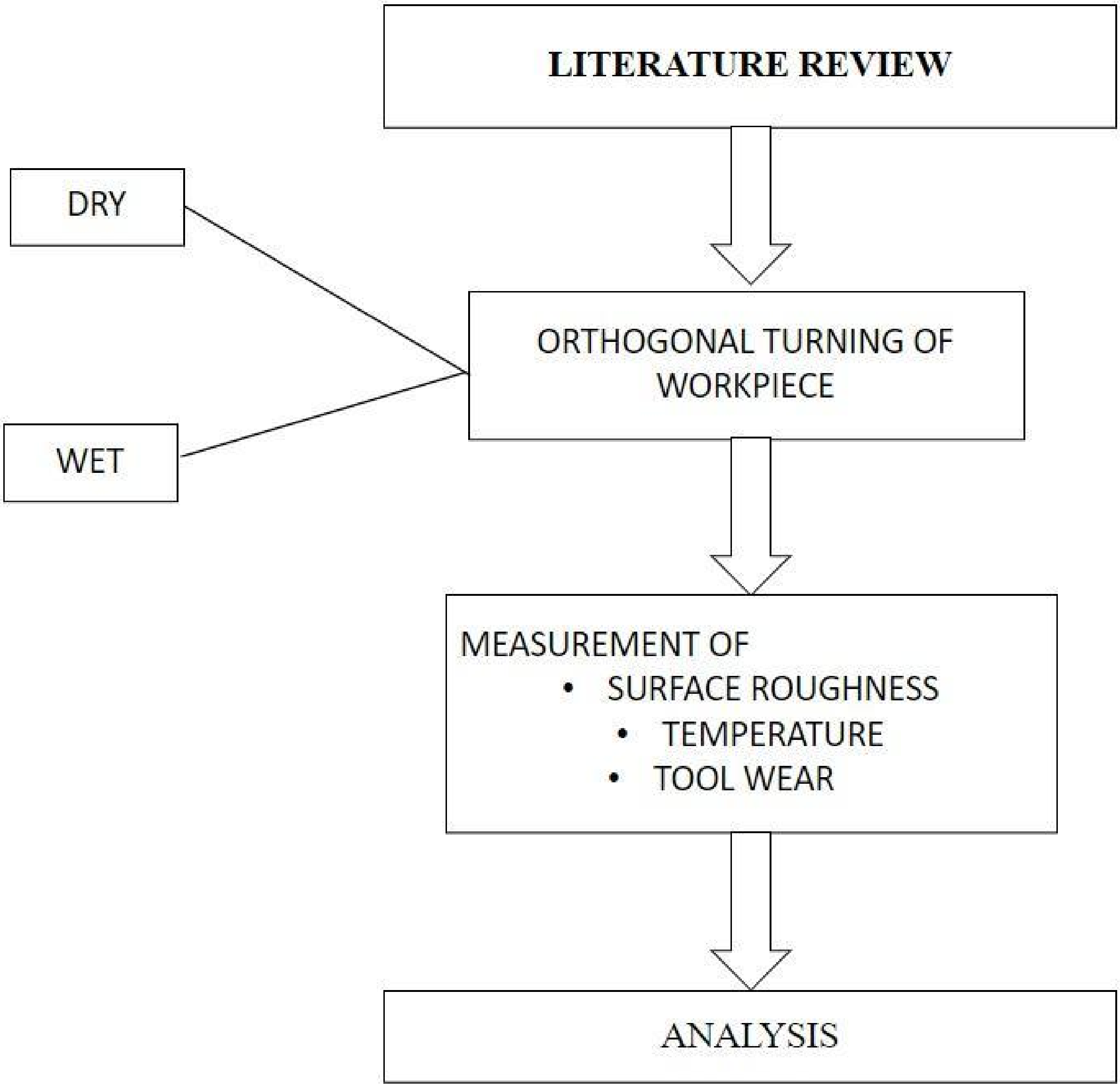
Tungsten carbide is approximately twice as stiff as steel, with a Young's modulus of approximately 530–700 GPa and is double the density of steel nearly midway between that of lead and gold. It is comparable with corundum (α-Al_2O_3) in hardness and can be polished and finished only with abrasives of superior hardness such as cubic boron nitride and diamond powder, wheels and compounds. Tungsten carbide cutting tools have the characteristics of high hardness, high strength, high wear resistance and high modulus of elasticity, as well as good impact toughness and corrosion resistance. The main component is WC and Co. The general carbide cutter has solid carbide type and welding edge type.

3.7 Profile projector

Fig 3.6 Profile projector

Profile projectors (optical comparators) are a type of optical measuring instrument. The measurement principle is similar to that of optical microscopes. A light is shined on the target (measurand) from underneath. It causes the target's profile, or shadow, to be projected on the screen. A tele centric optical system can enable accurate measurements. Some sizable profile projectors have screen diameters that exceed 1 m. Profile projectors are also commonly known as optical comparators or shadowgraphs.

3.8 Methodology



3.9 First stage of experiment

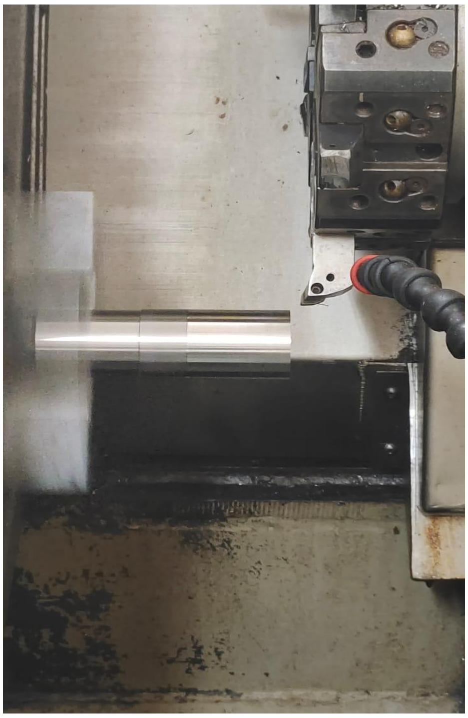


Fig 3.7 Machining at Dry condition

In the first stage of the experiment, stainless steel machined under dry conditions. Tungsten carbide tools are used for this machining process. Cutting parameters are similar for all the conditions. After machining cycle, surface roughness and temperature of the component is measured. Experimental condition is provided in Table 3.2

Cutting tools	TUNGSTEN CARBIDE
Cutting velocity(m/min)	100, 150, 200
Feed (f)	0.05, 0.10, 0.15
Depth of cut (ap), mm	0.4, 0.7, 1.0
CONDITION	DRY

Table 3.2 Parameters of dry machining

3.10 Second stage of experiment

Fig 3.8 Machining at Wet condition

Second stage of the experiment, stainless steel machined under Wet conditions .Tungsten carbide tools are used for this machining process. Cutting parameters are similar for the entire conditions. After machining cycle, surface roughness and temperature of the component is measured. Experimental condition is provided in Table 3.3

Cutting tools	TUNGSTEN CARBIDE
Cutting velocity(m/min)	100, 150, 200
Feed (f)	0.05, 0.10, 0.15
Depth of cut (ap), mm	0.4, 0.7, 1.0
CONDITION	WET

Table 3.3 Parameters of wet machining

Maximum temperature and roughness attained during dry and wet turning

CONDITION	TEMP	Ra
DRY	58 deg.C	2.310 µm
WET	48.5 deg.C	1.180 µm

Table 3.4 Maximum Temperature and Surface roughness attained during dry and wet turning

Measurement of tool wear and surface roughness

The surface roughness of the component is measured after each machining cycle. To measure the surface roughness, the machined component is placed on a V-block. Then, the probe of the profilometer is made to slide over the surface. The Ra, Rq, and Rz values are recorded and analyzed for different machining conditions.

A specific tip is chosen for the tool wear analysis. The tool wear is observed after being subjected to 5 minutes of continuous machining. The machined tip of the tool is placed in the base of the profile projector and focused on the screen. The ratchet of the projector is adjusted to place the origin at the tip of the tool. Further, the deviation in the tip (Flank wear) is measured by calculating the difference between the position of the original tip and the worn region.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Calculation of spindle speed from cutting velocity

Cutting velocity = 100, 150, 200 m/min

Feed rate = 0.05, 0.10, 0.15 mm/rev

Depth of cut = 0.4, 0.7, 1.0mm

Spindle speed at 100m/min for a diameter of 40mm

V=3.14*D*N/1000

100=3.14*40*N/1000

N=**796.17rpm**

Spindle speed at 150m/min for a diameter of 40mm

V=3.14*D*N/1000

150=3.14*40*N/1000

N=**1193rpm**

Spindle speed at 200m/min for a diameter of 40mm

V=3.14*D*N/1000

200=3.14*40*N/1000

N=**1592rpm**

4.2 Outcomes of machining in dry condition

sl.no	v	f	d	surface roughness	temp	tool wear
1	100	0.05	0.4	0.731	42	0.260
2	100	0.10	0.7	0.764	46	0.290
3	100	0.15	1.0	1.140	53	0.320
4	150	0.05	0.7	0.870	49	1.340
5	150	0.10	1.0	1.639	45	1.390
6	150	0.15	0.4	0.739	42.5	1.300
7	200	0.05	1.0	2.310	55	0.320
8	200	0.10	0.4	0.418	48	0.230
9	200	0.15	0.7	0.519	58	0.270

Table 4.1 Experimental results in dry condition

From the obtained results, the influence of machining parameters and surface roughness are studied

4.2.1 Surface roughness vs velocity, feed and depth of cut - dry turning

Response Table for Means

Level	v	F	D
1	0.8783	1.3037	0.6293
2	1.0827	0.9403	0.7177
3	1.0823	0.7993	1.6963
Delta	0.2043	0.5043	1.0670
Rank	3	2	1

Table 4.2 Response table for Ra - dry turning

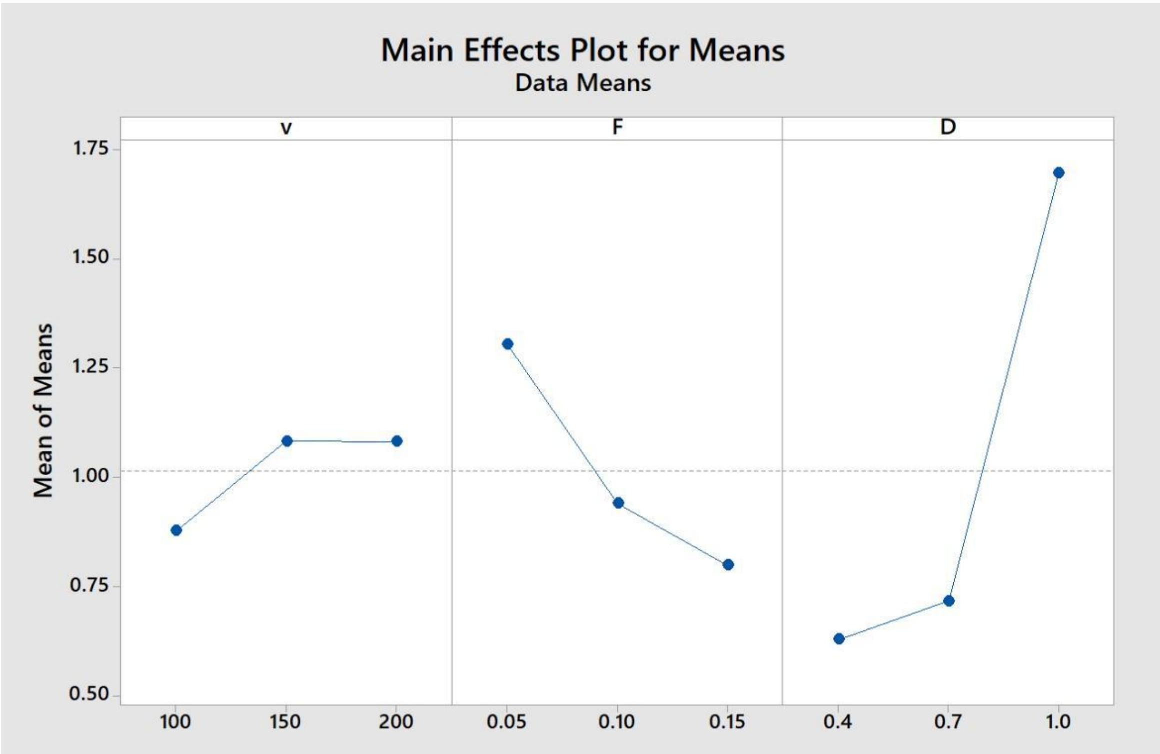


Fig 4.1 Surface roughness vs velocity, feed and depth of cut (dry)

The above graph shows the influence of cutting velocity, feed, and depth of cut on surface roughness under different machining conditions. This graph shows that in dry condition, surface roughness increases with cutting speed

Regression Analysis: RA versus v, F, D

Analysis of Variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Regression	3	2.15169	73.55%	2.15169	0.71723	4.64	0.066
v	1	0.06242	2.13%	0.06242	0.06242	0.40	0.553
F	1	0.38153	13.04%	0.38153	0.38153	2.47	0.177
D	1	1.70773	58.38%	1.70773	1.70773	11.04	0.021
Error	5	0.77362	26.45%	0.77362	0.15472		
Total	8	2.92531	100.00%				

Table 4.3 Results of ANOVA for Ra - dry turning

From Table 4.3, it is revealed that the most influential variable for surface finish is cutting velocity. The cutting variables influencing the surface finish are in the order of depth of cut followed by feed rate and then cutting speed. The ANOVA table indicated that depth, feed, and cutting velocity are influencing the surface finish of AISI 304 ASS by approximately 58 %, 13 %, and 2 %, respectively. It is revealed that the cutting velocity is the most important variable and the depth of cut is the least dominant variable in controlling the surface finish for dry condition.

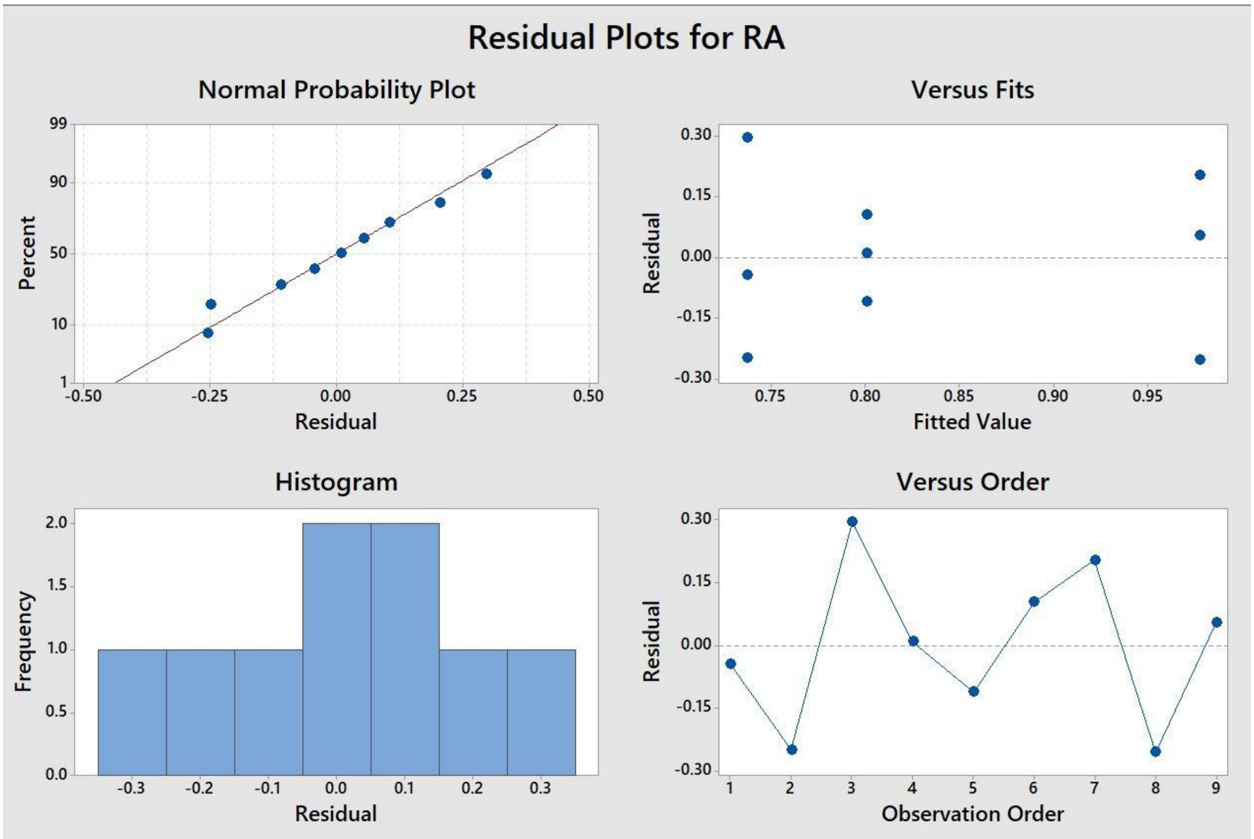


Fig 4.2 Residual plots for Ra - dry turning

In order to investigate the surface geometry of the workpiece, surface Roughness (Ra) was measured using a contact stylus probe. During cutting, feed has a larger impact when compared to the cutting speed and depth of cut on surface finish. In dry condition, workpiece machining under 796 rpm spindle speed it is seen that the surface roughness decreased with increase in feed rate up to 0.10 mm/rev. So, after 0.10 mm/rev the surface roughness significantly increased with feed rate. In 1193 rpm condition surface roughness decreased with increase in feed rate so the best machining condition between 0.10 to 0.15 mm/min. At 1592 rpm, it is seen that the surface roughness increased with increase in feed rate up to 0.10mm/rev. So, after 0.10mm/rev the surface roughness significantly decreased with feed rate

4.3 Outcomes of machining in wet condition

sl.no	v	f	d	surface roughness	temp	tool wear
1	100	0.05	0.4	0.692	32	0.670
2	100	0.10	0.7	0.488	40	0.640
3	100	0.15	1.0	1.031	41	0.610
4	150	0.05	0.7	0.809	39	0.460
5	150	0.10	1.0	0.689	44	0.490
6	150	0.15	0.4	0.904	37	0.420
7	200	0.05	1.0	1.180	44	1.390
8	200	0.10	0.4	0.722	47	1.320
9	200	0.15	0.7	1.031	48.5	1.370

Table 4.4 Experimental results in wet condition

4.3.1 Surface roughness vs velocity, feed, and depth of cut – wet turning

Response Table for Means

Level	V	F	D
1	0.7370	0.8937	0.7727
2	0.8007	0.6330	0.7760
3	0.9777	0.9887	0.9667
Delta	0.2407	0.3557	0.1940
Rank	2	1	3

Table 4.5 Response table for Ra - wet turning

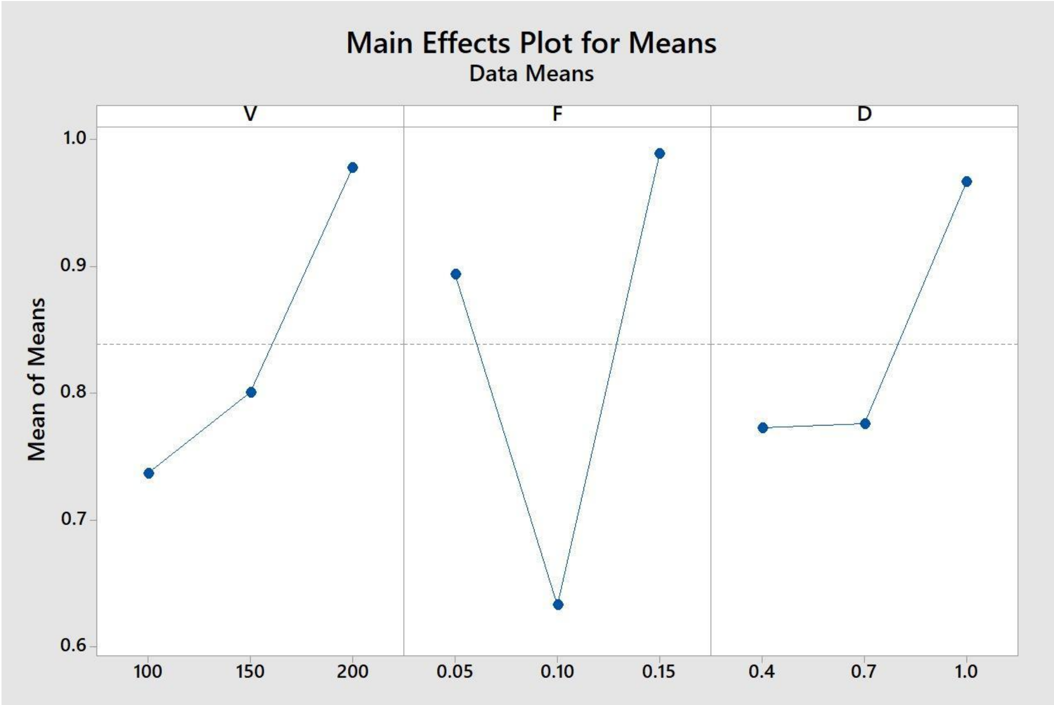


Fig 4.3 Surface roughness vs velocity, feed and depth of cut (wet)

The above graph shows the influence of cutting velocity, feed, and depth of cut on surface roughness under different machining conditions. This graph shows that in wet condition, surface roughness increases with cutting speed

Regression Analysis: RA versus V, F, D

Analysis of Variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Regression	3	0.15687	41.71%	0.15687	0.05229	1.19	0.402
V	1	0.08688	23.10%	0.08688	0.08688	1.98	0.218
F	1	0.01354	3.60%	0.01354	0.01354	0.31	0.602
D	1	0.05645	15.01%	0.05645	0.05645	1.29	0.308
Error	5	0.21926	58.29%	0.21926	0.04385		
Total	8	0.37613	100.00%				

Table 4.6 Results of ANOVA for Ra - wet turning

From Table 4.6, it is revealed that the most influential variable for surface finish is cutting velocity. The cutting variables influencing the surface finish are in the order of cutting velocity followed by depth of cut and then feed rate. The ANOVA table indicated that depth, feed, and cutting velocity are influencing the surface finish of AISI 304 ASS by approximately 15 %, 4 %, and 23 %, respectively. It is revealed that the cutting velocity is the most important variable and the depth of cut is the least dominant variable in controlling the surface finish for wet condition.

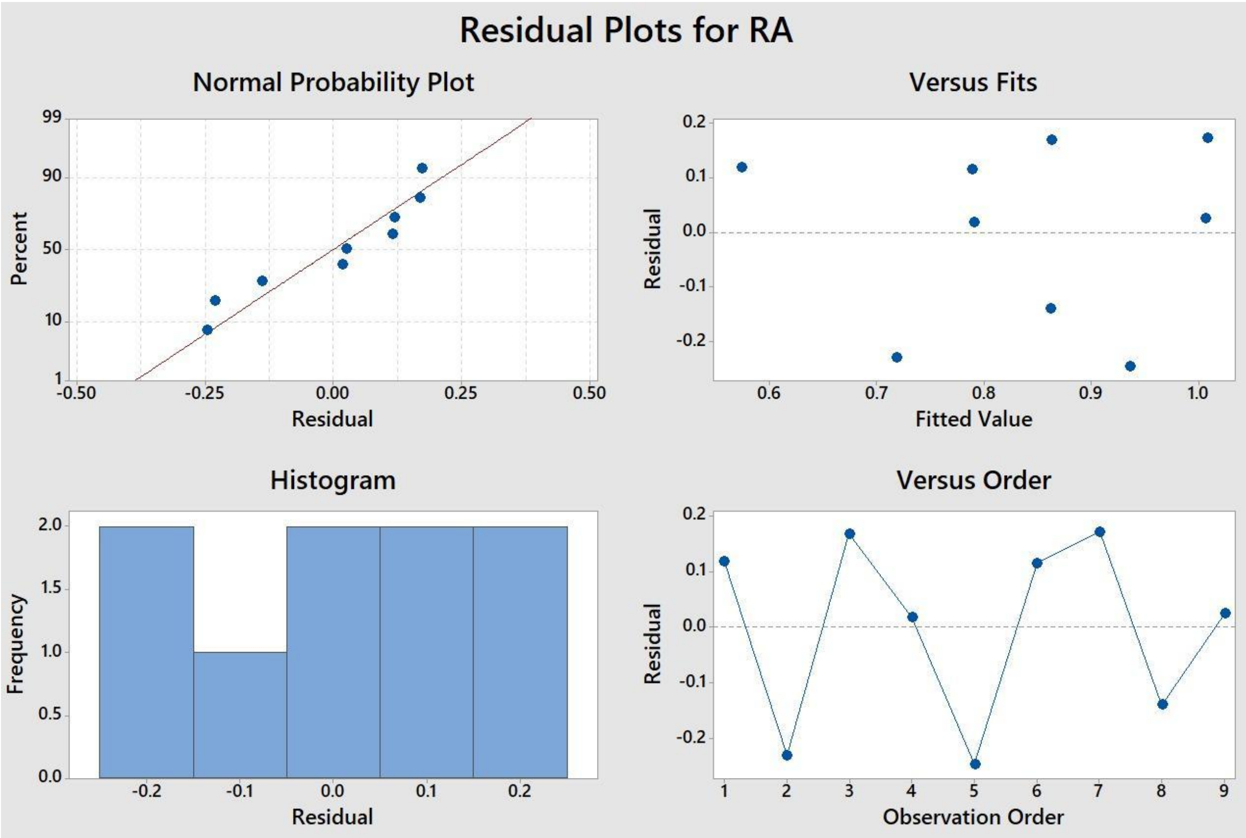


Fig 4.4 Residual plots for Ra - wet turning

To investigate the surface geometry of the workpiece, surface Roughness (Ra) was measured using a contact stylus probe. During cutting, the feed has a larger impact when compared to the cutting speed and depth of cut on surface finish. In wet conditions, workpiece machining under 796 rpm spindle speed, it is seen that the surface roughness increases with an increase in feed rate. At 1193 rpm the surface roughness increased with feed rate. At the initial time surface roughness is low because the feed rate is 0.05 mm/min after that feed rate increases then surface roughness also increases. At 1592 rpm, graphs show that the surface roughness increased with an increase in feed rate up to 0.10 mm/rev. So after 0.10mm/rev the surface roughness significantly decreased with the feed rate.

4.4 Tool wear

Response Table for Means

Level	V	F	D
1	0.2900	0.6400	0.5967
2	1.3433	0.6367	0.6333
3	0.2733	0.6300	0.6767
Delta	1.0700	0.0100	0.0800
Rank	1	3	2

Table 4.7 Response table for Ra - dry turning

Fig 4.5 Surface roughness vs velocity, feed and depth of cut (dry)

Regression Analysis: TOOL WEAR versus V, F, D

Analysis of Variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Regression	3	0.01017	0.45%	0.01017	0.003389	0.01	0.999
V	1	0.00042	0.02%	0.00042	0.000417	0.00	0.977
F	1	0.00015	0.01%	0.00015	0.000150	0.00	0.986
D	1	0.00960	0.42%	0.00960	0.009600	0.02	0.890
Error	5	2.25446	99.55%	2.25446	0.450891		
Total	8	2.26462	100.00%				

Table 4.8 Results of ANOVA for Ra - dry turning

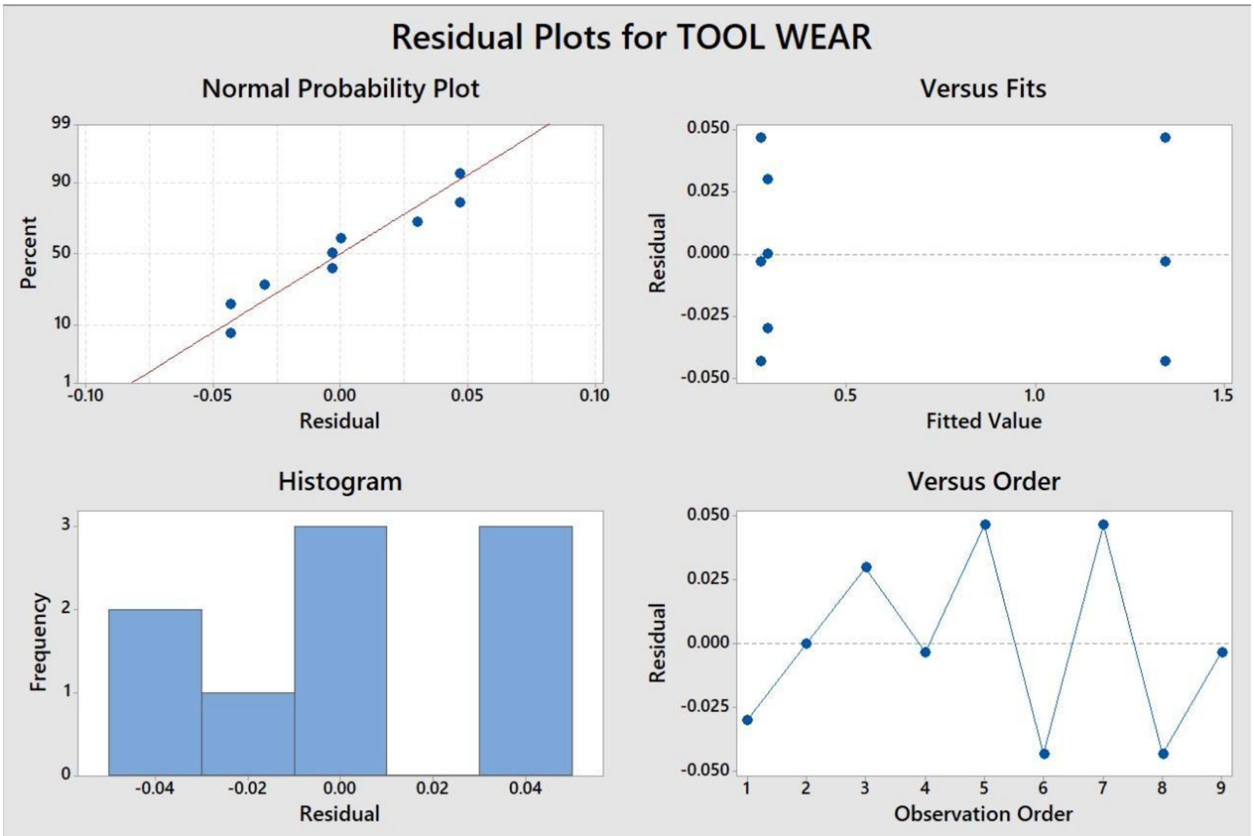


Fig 4.6 Tool wear for Dry condition

Taguchi Analysis: TOOLWEAR versus V, F, D

Response Table for Means

Level	V	F	D
1	-0.6400	0.3933	0.3567
2	0.4567	0.3900	0.3967
3	1.3600	0.3933	0.4233
Delta	2.0000	0.0033	0.0667
Rank	1	3	2

Table 4.9 Response table for Ra - wet turning

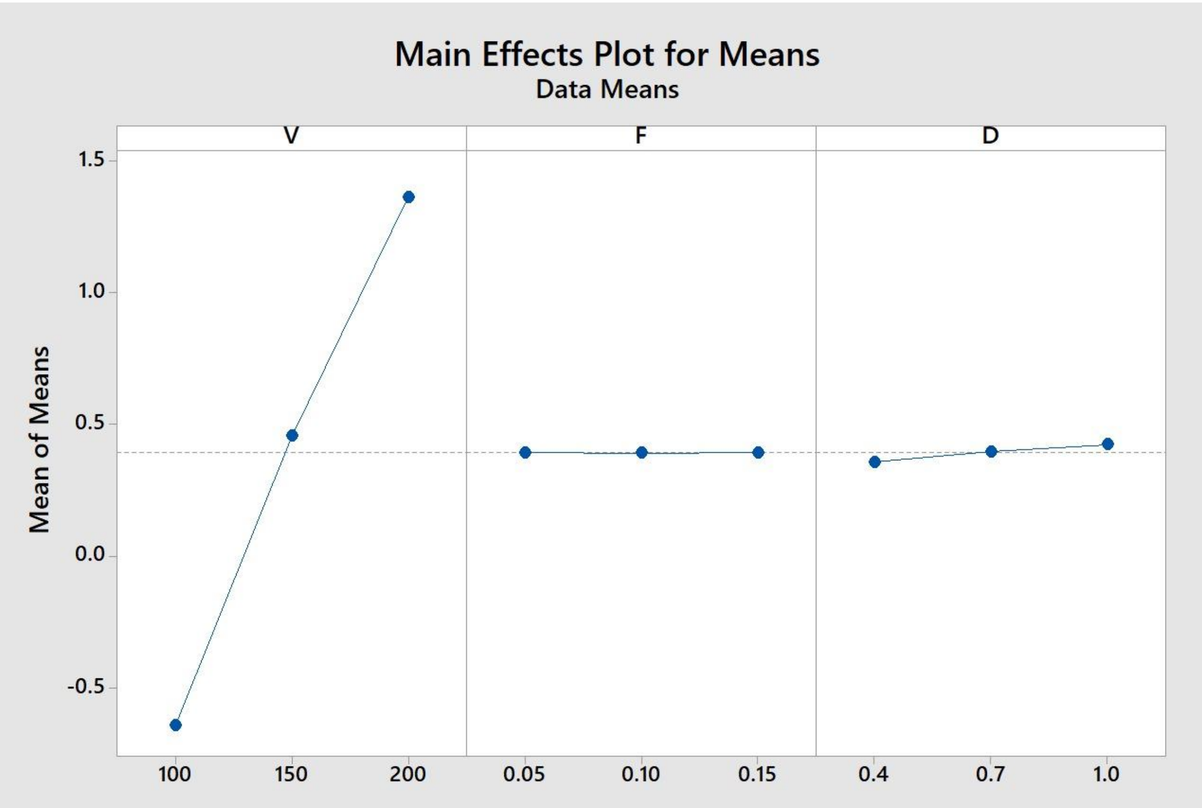


Fig 4.7 Surface roughness vs velocity, feed and depth of cut (wet)

Regression Analysis: TOOLWEAR versus V, F, D

Analysis of Variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Regression	3	6.00667	99.69%	6.00667	2.00222	530.00	0.000
V	1	6.00000	99.58%	6.00000	6.00000	1588.24	0.000
F	1	0.00000	0.00%	0.00000	0.00000	0.00	1.000
D	1	0.00667	0.11%	0.00667	0.00667	1.76	0.241
Error	5	0.01889	0.31%	0.01889	0.00378		
Total	8	6.02556	100.00%				

Table 4.10 Results of ANOVA for Ra - wet turning

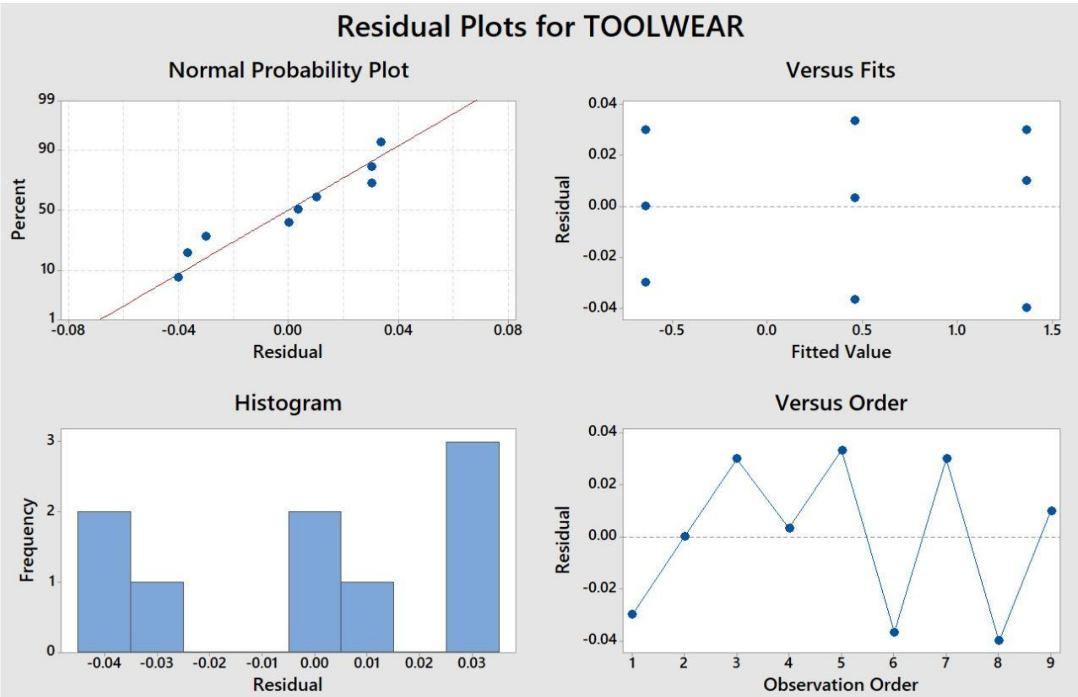


Fig 4.8 Tool wear for Wet condition

Additional machining tests were performed to verify the tool wear. The parametric set that produced the best surface finish is chosen. The workpiece is exposed to 5 minutes of continuous machining under each condition with different tool inserts. After the machining process, the machined edges are mounted on the profile projector and inspected for tool wear.

CHAPTER 5

CONCLUSION

The Taguchi method was employed to find the optimum machining conditions of 304 stainless steel alloy in CNC dry and turning operation. The analysis of Mean and ANOVA were used to evaluate the machining performance. The outcomes of this work are given as follows:

Lower value of cutting velocity (100 m/min), lower value of depth (0.5 mm) and medium value of feed rate (0.15 mm/rev) are preferred to achieve the minimum surface roughness in dry turning operation.

From the ANOVA analysis, depth of cut, feed rate and cutting velocity were found to influence the surface finish by around 58 %, 13 %, and 2 %, respectively during dry turning operation.

Lower value of cutting velocity (100 m/min), lower value of depth (0.5 mm) and higher value of feed rate (0.10 mm/rev) are preferred to achieve the minimum surface roughness in wet turning operation.

From the ANOVA analysis, cutting velocity, depth of cut and feed rate were found to influence the surface finish by around 23 %, 15 %, and 4 %, respectively during wet turning operation.

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