STUDY OF RESIDUAL STRESSES AND SURFACE ROUGHNESS IN CNC MILLING OF AISI 202 STEEL

A DISSERTATION

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE

OF

MASTER OF TECHNOLOGY

IN

PRODUCTION ENGINEERING

Submitted by

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I, **Vishal Singh**, 2K17/PIE/17 hereby declare that the major project Dissertation titled "**STUDY OF RESIDUAL STRESSES AND SURFACE ROUGHNESS IN CNC MILLING OF AISI 202 STEEL**" submitted to the department of MECHANICAL, PRODUCTION & INDUSTRIAL ENGINEERING, Delhi Technological university, Delhi in partial fulfillment of the requirement for the award of the **Master of Technology**, in **Production Engineering** was original and not copied from any source without proper citation. This was further to declare that the work embodied in this report has not previously formed the basis for the award of any Degree, Diploma, Fellowship or other similar title or recognition.

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ACKNOWLEDGEMENT

I would like to express my special thanks of gratitude to **Prof. Qasim Murtaza** and **Dr. Saurabh Agrawal** for their guidance, unwavering support and encouragement. This project work could not have attained its present form, both in content and presentation, without his active interest, direction and guidance. His personal care has been the source of great inspiration. He has devoted his invaluable time and took personal care in motivating me whenever I was disheartened.

I would also like to thank Prof. Vipin, HOD (Mechanical Engineering Department), Prof. Ranganath M. Singari, Mr. K.Srinivas, Mr. Parvez Ali for their support and guidance, although they had a very busy schedule in managing the corporate and academic affairs.

I am thankful to the technical staff of Delhi Technological University, Mr Virendra, Mr. Roshan, and Mr. Suneel for their support.

My deep and sincere gratitude to my family for their continuous and unparalleled love, help and support. I am grateful to my brother for always being there for me as a friend and always with me in every situation. I am forever indebted to my parents for giving me the opportunities and experiences that have made me who I am. They selflessly encouraged me to explore new directions in life and seek my own destiny. This journey would not have been possible if not for them, and I dedicate this milestone to them. I cannot forget to take the name of my cousins for helping me to manage the time and managing my journey to complete the project work.

I also want to thank all those who are directly or indirectly support me for my project.

Vishal Singh
(2K18/PIE/16)

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ABSTRACT

In today's manufacturing applications, it is seen that quality and productivity plays an essential role. The basic aim for manufacturing field which is directly under the influence of quality, whereas the profit of the manufacturing field relies subsequently on the productivity of the process, is a Customer fulfillment. The process of optimization is the basic point to control the machining parameters simultaneously for every manufacturing sector to fight in this competitive world.

The essential parameter of milling process is surface roughness. By improving surface roughness, the quality of injected product such as cell phones, laptops, aerospace and automotive parts which depend on finishing, is improved. With the decrease in feed rate, surface roughness slightly improved and the effect of milling speed on the surface roughness is negligible. In the case of residual stress on the machined surface, axial depth of cut has major influence followed by feed rate and milling speed. The measurement of Residual stress in feed direction by x- ray diffraction (XRD).

The aim of this project is to optimize the surface roughness and residual stress by RSM. RSM was applied to establish a quadratic relationship between input and output parameters and then analysis of variance (ANOVA) was applied for the evaluation of formula. RSM is also used for optimization of cutting parameters of minimum surface roughness. The major objective in CNC milling operation, while the response parameters selected are surface roughness and residual stress.

The main objective for every customer is to measure the Surface quality. Thus surface finish is kept as a main objective for CNC Milling performance. Different cutting parameter which influence Residual stress and surface finish, measured for the analysis on AISI 202 stainless steel with the use of Response Surface method (RSM).

For analyzing the parameters, ANOVA is used in milling operation. In ANOVA, The p value model is significant when cutting parameters below 0.05. The F value is different-different observed for different cutting parameter. In this way analyze and optimize the Response parameters.

ABREVATIONS

ANN	Artificial Neural Network
ANOVA	Analysis of Variance
CBN	Cubic Boron Nitride
CCD	Central Composite Design
CNC	Computer Numerical Control
CS	Cutting Speed
DOC	Depth of Cut
DOE	Design of Experiment
FR	Feed Rate
HSS	High Speed Steel
MCU	Machine Control Unit
MRR	Material Removal Rate
OA	Orthogonal Array
RS	Residual Stress
RSM	Response Surface Methodology
SF	Surface Finish
SR	Surface Roughness

CHAPTER 1

INTRODUCTION

1.1 Introduction

The most commonly used metal cutting process in manufacturing sector is Milling process. To produce high quality and low cost parts within certain period of time with high surface quality and high precision is the main objective of this process [1] . For analyzing and observing the machining parameters and cutting parameters like life of tool, formation of chip, quantity of chip and formation of built-up edge are the primary objective. The characteristic of the surface of the work piece is directly affected by these machining parameters [2] . Wear of tool, vibration of machine tool and other parameters is also affect the surface roughness, Residual stress and other response parameter [3]. Geometry of cutting edge of tool and hardness of the surface of the work piece also effect the response parameter of the work piece. Surface characteristics like roughness and integrity has best quality when tool has honed geometry and work piece has lower surface roughness geometry [4].

For calculating and analysing the response values and optimize the milling factors like surface roughness and Residual stress, the RSM and ANN was applied [5]. When the feed value is minimum in the better roughness and the cutting parameters have attained to reach their higher level. The adaptive Neuro-fuzzy inference (ANFIS) system is used to create the connection among machining parameters [6]. To determine appropriate factors for the minimum roughness the RSM and ANN are taken into account [7].

A commonly used conventional machining method for both general and important applications considering material removal and machining of difficult forms is a milling process as well as finishing of work piece. With the help of plain and end machining, a work piece surface can be easily machined into a flat surface [8].

The behavior of surface integrity is affected by response parameter like surface finish, surface roughness and residual stress and small quantity of hardness for a work piece.

Residual stress induced by machining has a better impact on influencing the fatigue characteristics than the surface roughness studied by research work. To enhance better fatigue life, it is beneficiated by large residual compressive stress [9].

It is obtained, milling brought surface strain hardening and surface residual compressive stress may increase the fatigue life [10]. The characteristics of machine surface like fatigue resistance is enhanced by analysing the machining parameters and their influence on response parameters like surface roughness and Residual stress [11].

Surface roughness is a mathematical computation of surface quality. It is also key standards for the getting of the finished component. Surface characteristics like surface integrity and surface roughness, analysing and optimizing of cutting parameter [12], performance of tool [13] , geometry of tool [14], cutting force [15], formation of chip [16], rigidity of work piece [17] , and application of lubricant for reducing temperature [18] by various literature survey.

1.2 Milling Operation

A metal taking away method is known as the milling operation by using a revolving cutter with one or additional teeth as shown in figure 1.2.

Cutting action is performed in the milling process by feeding the work piece against the revolving cutter. Spindle speed, table feed, cutting depth and revolving direction of the cutter are the main factors of the milling operation. Collections of these influencing factors are to affect surface roughness, Residual stress and tool geometry and tool wear and other factors.

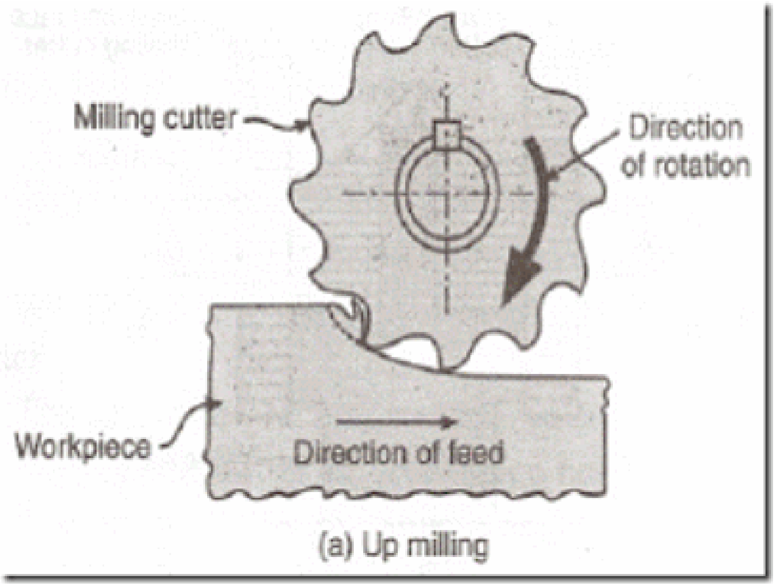


Figure 1.2 Milling operation [19]

The Milling Machine fundamentally have a work table that can be modified to install and feed the work piece.

1.3 Affecting Factors in Milling

The key parameters in some original revolving procedure are spindle speed, feed rate and cutting depth.

1.3.1 Spindle Speed

It can be expressed in terms of revolution per minute as shown in equation (1)

$$\mathbf{n = v \times 1000 / \pi \times d} \quad \textbf{(1)}$$

Where,

n is Rotation per minute of cutter

V is cutting velocity in m/min, and

d is cutter diameter in mm

1.3.2 Feed Rate

It is classified as working piece travel rate. Feed rate is also suggested by tool suppliers as the move per cutter tooth as shown in equation (2).

$$\mathbf{F = f \times z \times n} \quad \textbf{(2)}$$

Where,

F is table feed in mm / min.

f is movement per tooth of cutter in mm

z is number of teeth of cutter, and

n is rotation per minute of the cutter

1.3.3 Depth of Cut

This is layer thickness separated from work piece in a single pass. This is also distance to surface cut from the work piece uncut surface which is shown in equation (3). The measuring unit of Depth of cut is in mm.

$$\mathbf{D = (d_i - d_f) / 2} \qquad \textbf{(3)}$$

Where,

D = depth of cut (mm)

d_i = initial dia. (mm)

d_f = final dia. (mm)

1.4 Computer Numerical Control (CNC)

Emergence and progress of a machine tool that includes alphabet, numerical value, and CNC machine operate symbols. It may manage and function work piece or an instrument motion of system influencing factors such as feed, slice length, speeds and features such as on / off spindle switching, on / off coolant switching.

1.4.1 Applications

- Used commonly for Lathe
- Press the drill
- Unit of production
- Tool for data
- Laser
- Press the sheet metal
- Device for tube bending
- Welding tools
- Tools for location assessment

- Setup remotely
- Arrangement of the touch
- Integrated winding filaments etc.

1.4.2 Advantages and Limitations

- Minimize human error
- Short time of production, more flexibility
- Simpler deployment
- Machining of the contour
- High accuracy

Some Limitations are:

- Heavy maintenance requirements
- A qualified programmer is required.

1.4.3 Elements of a CNC

A typical CNC system consists of the 6 elements.

- Part Program
- Program Input Device
- MCU
- Drive System
- Machine Tool
- Feedback Device

1.4 Cutting Tool Materials

Present cutting tool materials are-

- HSS Tool
- Cobalt based alloy
- Cemented carbides
- CBN
- Polycrystalline Diamond

1.5 Response Surface Methodology

Several mathematics and technologies used to help difficult study in optimization techniques. With the support of RSM cutting parameter in machining, prediction and optimization are achieved. Using RSM, we create a relation and equation among the factors and the response like surface integrity (surface roughness) and Residual stress.

Example –

Two independent First-order model variables can be expressed as

$Y = b_0 + b_1x_1 + b_2x_2 + e$

For answer surface a higher degree of polynomial is used to curvature. A second order model is two-variable rule.

$Y = b_{0} + b_1 + b_2 + b_{11}.x^2_{11} + b_{22}.x^2_{22} + b_{12}.x_{12} + e$

For the least square method the highest approximation between response and variable of the polynomial relation is used.

Basically, it is a bunch of technique which involves mathematics and statistics, used for problem of analysis and modeling. It is a field of interest of affecting parameters like cutting speed, feed rate per tooth and depth and aim of it to optimize the Responses like surface roughness, Residual stress in milling operation.

For Example- Let us take a situation in which a chemical engineer wants to obtain the level of temperature (x1), pressure (x2) and maximize the yield (y) in his experiment using RSM.

To get maximize, minimize and obtain target values of responses in optimization process In the case of maxima, we take maximum enzyme yield until the optimization of parameters like temperature, pH and time of fermentation. In case of minimization, we take microbial contamination and in case of targeted, we take increase or decrease in the factor defect like strength of material.

Generally, RSM can be divided into two categories-

1. Box-Behnken Design
2. Central Composite Design

Number of continuous or numerical factors in BBD, are recommended is three. 3 levels are-

1. Upper level
2. Lower level
3. Centre point

With the three level of parameters, Central composite design has axial or star point. Star point is represented as α which increases the number of level up to 5 levels for design easiness of experiment.

Central Composite Design is better than Box-Behnken Design because it permits design expert to analyze, what is a response of affecting factors and design expert goes beyond the chosen level of parameters.

Minimum number of parameters in Central Composite Design is two like numerical or continuous factors.

The number of factors can be obtained from the equation-

N = 2n + 2×n + nc

Where

N is the run number

N is the factor number which involve in the optimization of experiment

nc is the centre point's number which is experimental designer expectation

For example

Let us take 2 factors then;

N = 22 + 2×2 + nc (which can be set between 2 to 6)

Therefore-

N = 4 + 4 +2 (if the centre point number is considered to be 2)

N = 10 runs

Therefore, in an experiment where the design expert considered the influence of temperature and pressure on yield. The Central Composite Design is applied like this

Table A Coded values of input factors

Factors	-α (1.1414) (axial point)	-1 (lower level)	0 (centre point)	+1 (upper level)	+α (1.414) (axial point)
X1 (Temperature)	53.79	60	75	90	96.21
X2 (Pressure)	3.965	5	7.5	10	11.035

To obtain the value for the axial point, firstly we obtain value of α

Alpha (α) = $2^{k/4}$where K is factor number

Example -

When the number of factors is two

Then

$\alpha = \sqrt{2}$ which has value equal to 1.414

To obtain the axial point, follow the formula

Axial point = Average of both the upper or lower level ± α (range between the upper and lower level divided by 2)

Axial point = X ± α (Range/2)

For the above example

Axial point for temperature = 75 ± 1.414 ((90-60)/2)

= 75 ± 1.414 (30/2)

= 75 ± 1.414 (15)

= 75 ± 21.21

Upper axial point (i.e. + α) = 75+21.21 = 96.21

Lower axial point (i.e. – α) = 75-21.21 = 53.79

Using formula for the estimation of axial points for pressure-

Axial point = 7.5 ± 1.414 (5/2)

Upper axial point = 7.5 + 1.414 (2.5) = 11.035

Lower axial point = 7.5 – 1.414 (2.5) = 3.965

For ten runs the experimental and coded value shown in the below table-

Table 1 Experimental and coded value of temperature and pressure

Experiment Runs	X1 (Temperature ˚C)	X2 (Pressure bar)
1	-1 (70)	-1 (5)
2	1 (90)	-1 (5)
3	-1 (70)	1 (10)
4	1 (90)	1 (10)
5	- α (96.21)	0 (7.5)
6	α (53.79)	0 (7.5)
7	0 (75)	- α (11.035)
8	0 (75)	α (3.965)
9	0 (75)	0 (7.5)
10	0 (75)	0 (7.5)

Runs 1- 4 is represent factorial runs, 5 – 8 represented as axial runs,9 and 10 shows centre point.

The table represent for run 1, temperature 70 ˚C and pressure is 5 bar and it responses yield.

1.7 Artificial Neural Network (ANN) Structure basics

A number of basic units which is called neurons consisted by Artificial neural networks. A neuron which takes one or more than one basic input and produce output, is an easier processor .Each input of neuron has its respective weight which explain and calculate intensity of input. The procedure by which action neurons are multiplication of each input with its associate weight by summation of resulting number for all inputs and explain the calculation of output is done by result of summation and activation function. A single neuron has very less or limited use. A network which joins a number of neurons shows some task. Use of input layer is for feeding the data into network with the help of one or more hidden layers and finally fed into networks with the help of output layers.

The reduction of error function is done by estimating local or global minima. By taking small step, the training algorithm is reduced iteratively along the negative direction of derivative. Due to the efficient and advanced algorithm of training, the interest of ANN'S is increased.

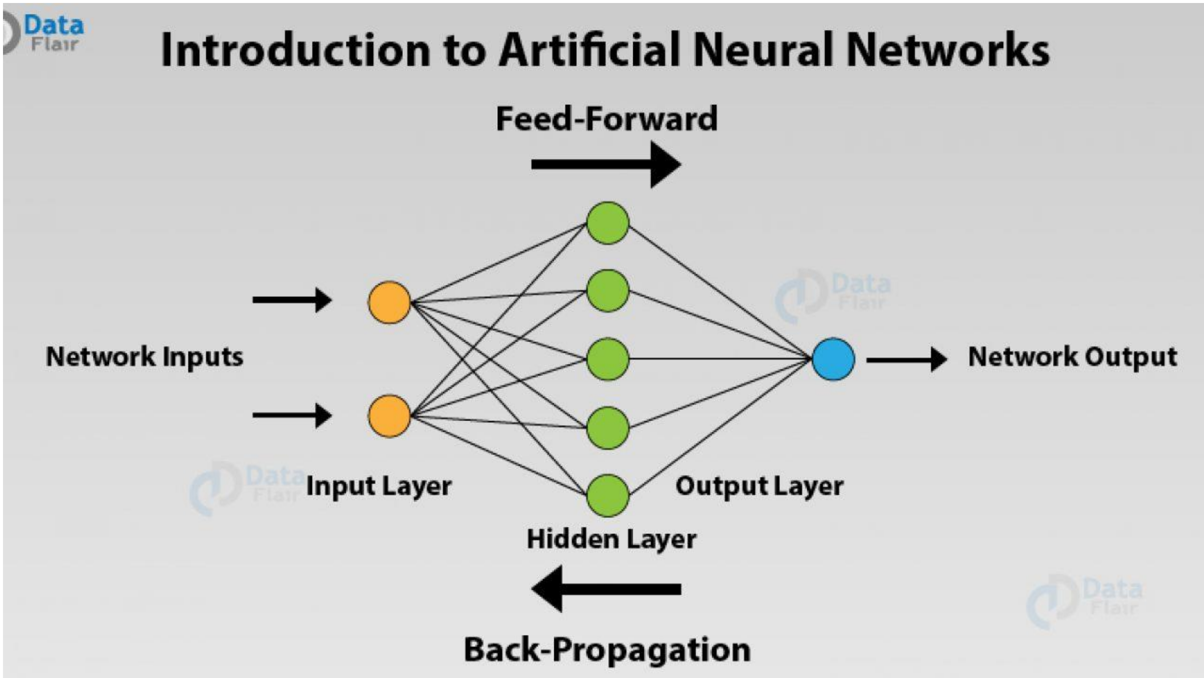


Figure 2 A Typical Neuron Network [20]

According to the above figure, some network permit the data travels in backward as well as in forward direction, some other data permits data to travel between neurons in the same level or permit to send data to backward direction into itself. These different type of expectance of the network will influence its total procedure and performance and also influence all the suited applications.

For performing neural network, there are many mathematical and other techniques. By balancing respective weight with the help of input neurons, preparation of neural network is done. Training of a network is done with the help of input data alone by preparation of unsupervised. Categorisation of data is done by network. A series of input and output example is used as supervised training.

According to the training, algorithm of a network will balance its associate weight. With the help of associate weight, memory of a network is made. With the help of memory, we can store the information and try to solve and analyse the problem. Different algorithms were used in the algorithm model. With the help of feed forward ANN'S is used in the analysis of surface roughness. Backward direction propagation is reason behind network error function.

1.7.1 Application of ANNs

In recent years, ANNs is used in different field which are –

- Image processing
- Artificial vision
- Signal processing
- Medicine
- Financial studies
- Automated control
- Artificial intelligence

1.7.2 Different type of network in ANN

ANN is like a human brain structure, which has different type-

- Feed Forward (FF)
- Radial Basis Function (RBF)
- Recurrent neural network
- Dynamic neural network etc.

1.7.3 Advantages of ANN

When we compare with other old methods, ANN has some more advantages which are –

- It has ability to explain the procedures that are similar but not identical.
- When we trained the neurons, a memory can save the data and generalise the data.
- There is no essential need for experimental issue type solving algorithm and avoid the statement of the issue.
- It shows large calculating power that can balance difficult problems.

1.8 Comparison between ANN and RSM Models

Although different type of modelling techniques used in ANN and RSM, it is useful to describe comparison between them. Some points of comparison are –

- ANN explains better predictive quality than RSM.
- ANN is used to obtain correlations even data are non-linearly correlated.
- RSM is used to provide explicit relationship between process factors and it is a way of calculating and obtaining main factors and optimum conditions for experiments
- RSM take less time than ANN for correlation of model.
- RSM model is less accurate and have limited data in comparison than ANN.

1.9 Surface Roughness

Quality of a product is decided by surface roughness and it affects the properties mechanical component and the price of manufacture.

Mechanical properties influenced by roughness of the surface are

- Fatigue behaviour
- Corrosion strength
- Existence of Creep.

Characteristics of part activity influenced by surface roughness-

- Friction
- Touch
- Reflection of colour
- Heat transmission

Surface roughness defines surface texture structure and machined surface area. Surface texture is based on a process and plays a significant part in the working features such as excessive friction or wear. Repetitive systems achieve the desired benefit and time consumption is more. More than one time to certain time, machining of a part is done before it is achieved. Because of very difficult mechanism of surface roughness formation, it is not easy to calculate and analyse the surface roughness by mathematical equation. Different theoretical surface roughness representations are suggested but are not sufficiently reliable and used in limited range. There is a tool requirement for evaluation of the surface roughness that will evaluate before the work piece is machined and at that time, it may also use to minimize time and cost in the production. For better roughness of the surface, successful state of cutting must be used.

Factors which, according to experience and experiments, result in poor surface finish or surface roughness in the milling operation are –

- Errors during construction of cutter
- Continuous adjustment of work piece rigidity, tool cutting and computer method.
- Wear in tool during cutting
- Built-up edge shape during machining
- Non uniform machining parameter

According to [21] neural network, cutting conditions and vibration intensity per revolution are affects surface roughness in milling operation. Ironically enough, neural networks are used in real time. Hybrid techniques i.e. ANN are applied and combined with fuzzy logic [22], in the same context. Fuzzy Petry nets were similarly used in the same context [23].

1.10 Factors affecting Surface finish

In milling operation, machining parameter are major machining factor that affects surface finish –

1.10.1 Spindle speed

It is the parameter that influences most in the machining process. This can cause poor roughness to the surface. Machine stability can be achieved with the aid of normalized spindle speed [24]. As speed increases over built up edge speed decreases the surface finish improves.

1.10.2 Depth of cut

It is tool's axial motion towards the piece of work. Cutting force increases when cut depth is wide [25]. It increases vibration of the machine tool which causes chattering of the tool [26]. Residual stress at tool cutting edge is often produced by rising cutting depth [27].

1.10.3 Feed Rate

One revolution of tool travel spindle is referred to as feed rate. It has direct relation to roughness of the surface. With low value of feed rate it is possible to achieve a reasonable surface roughness.

1.10.4 Cutting tool Engagement

It is the ratio of machining width and cutting diameter of the blade. Even this element affects like cut size. Independent surfaces of face milling have greater consistency than traditional one-time milling.

1.10.5 Cutting tool wear

Tool wear is created from cutting edge irregularities. Many dynamic phenomena such as vibration increase as the wear of the tool increases, and the surface quality deteriorates.

1.11 The use of cutting fluid

In the case of surface roughness it is beneficial Fluid cutting influence cutting method in 3 dissimilar ways-

- Remove heat from tool and work surface during machining.
- The friction between the rake face and the chip and between the flank and the machined surface is minimized.
- Cleaning operation such as scraping fragment chips and wearing pieces.
- Using cutting fluid with a contrast to dry machining is ideal for enhanced surface roughness.

1.12 Force Analysis

Three cutting force components are used in the milling process. Force is not a key component, it is used as a measure of work piece, cutting tool and machining device active characteristics. Machined material's resistance is determined by machined components which are overcome during the process of machining. One of the principal cutting forces (tangential cutting force) offers details on materials' machine ability.

1.12.1 Tangential Cutting Force (Fc)

Tangential cutting force depends on a cutting speed. This component of force is twice the other two components of force. Cutting force first decreases then increases when cutting speed is increased from 40-449 m/min.

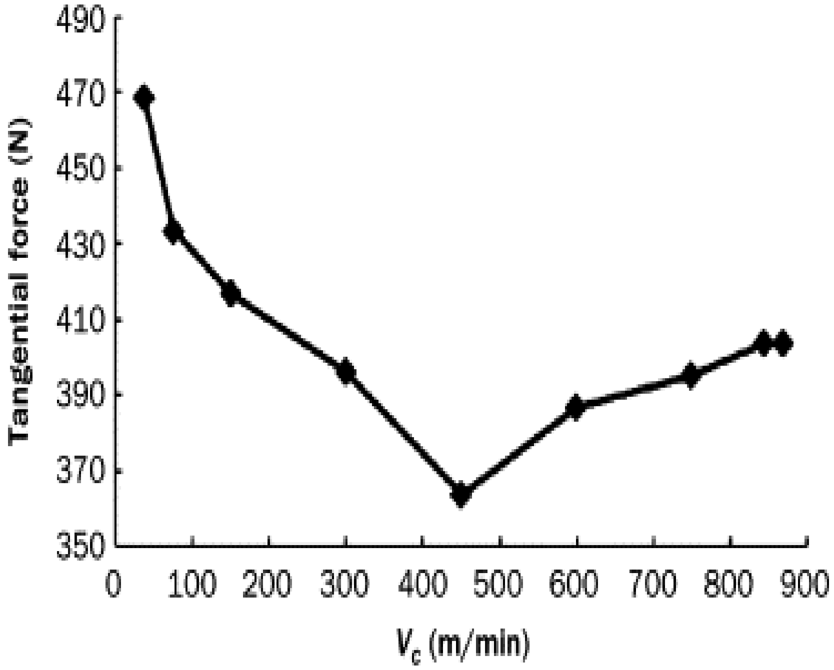


Figure 3 Relationship between Tangential force and cutting speed (fn= 0.2 mm/ rev.) adopted by [28]

Tangential force is 70-80% of total force. Power P is calculated by-

$$\mathbf{P = F_c . V}$$

Where,

F_c = Cutting Force

V = Velocity of tool

1.12 .2 Feed Force (Fx)

The power of motion of feed is determined by force of feed. This force is against feed. This force represents 20 per cent of the total force. Often it is known as axial force.

1.12.3 Radial force

Radial forces continue to move the blade away and constitute 10 per cent of the overall cutting force.

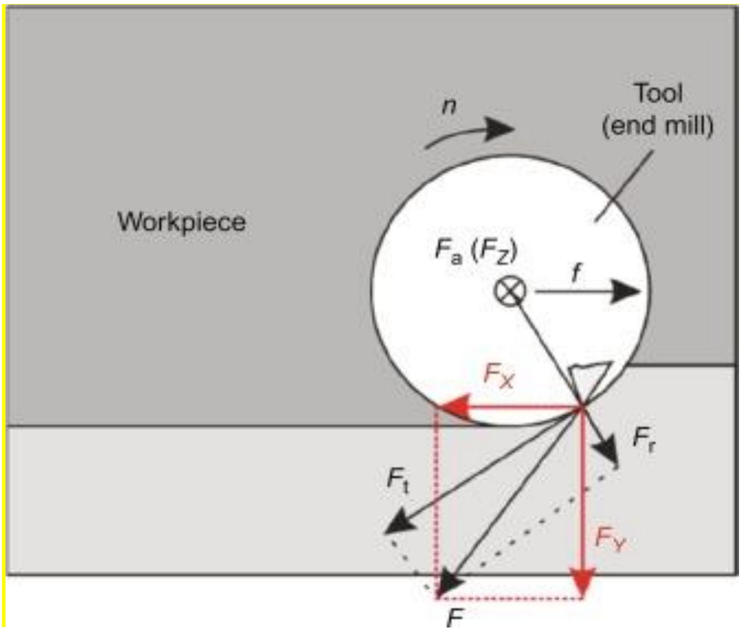


Figure 4 The Relationship between components of cutting forces in milling operation adopted by [28]

1.13 Surface Roughness Measuring Instruments

Taylor Hobson Surtronic 3 + tests the mean surface roughness Ra. This is used in labs and in classrooms. The ground texture factors are determined for Ra, Rq, Rz (DIN), Ry, Sm. The microprocessor is used for variables and other functions for apparatus valuation .The. LCD panel is used to show measurement results, and the voluntary Printer or other device is used to show output results. The unit is power-driven by a non-rechargeable, alkaline battery. This can be used with the rechargeable Ni-Cd battery.

Figure 5 Surface roughness measurement instrument in Metrology Lab

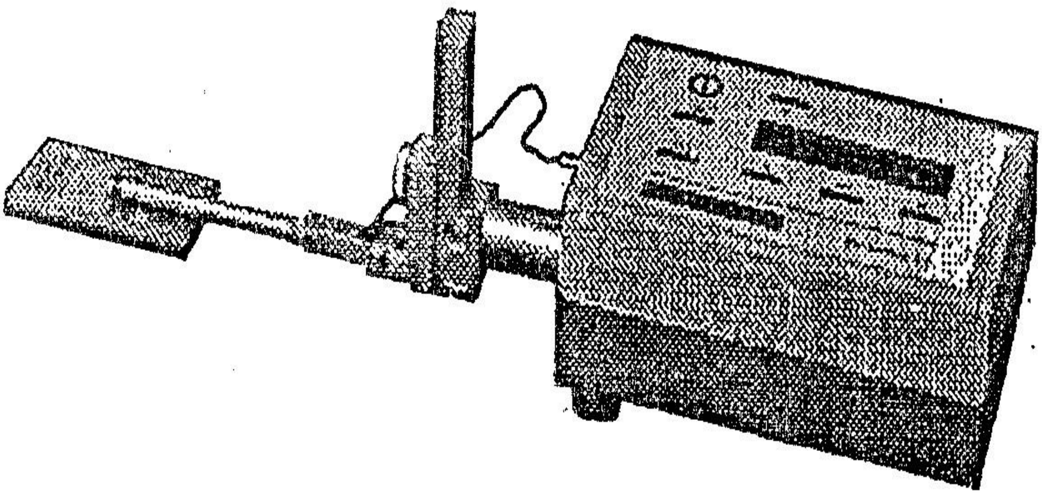


Figure 6 Surface Roughness measurement instrument (Referred from Instrument Manual)

1.13.1 Display Transverse Unit

It has a base board that contain a mesh short control board, and a liquid crystal screen. It includes electronic system to observe and control the test procedure, calculate the test information and show the results on display or use printered port RS232.

This machine also contains a ride engine that travels to the ground via. The bin to be calculated. The instrument has measuring stroke which often begins from outside, from the extreme spot.

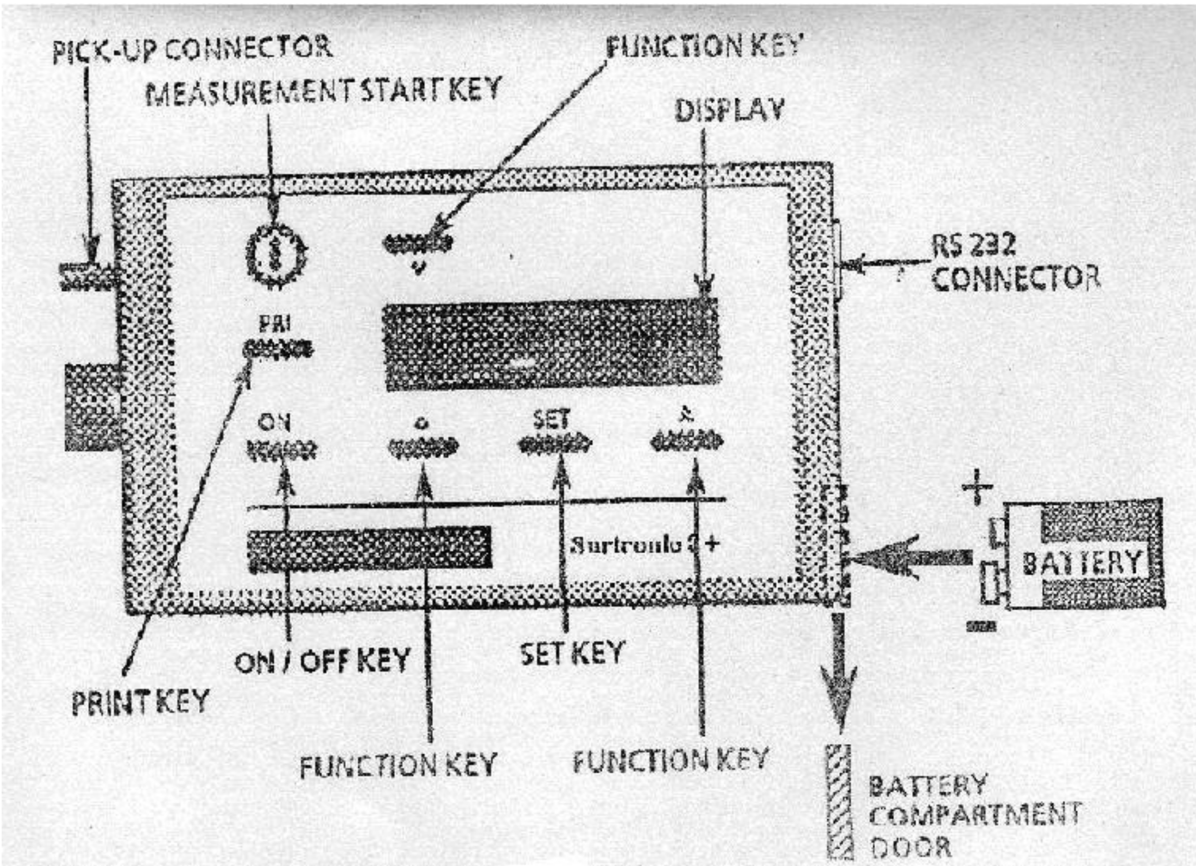


Figure 7 Display Transverse Unit (Referred from Instrument Manual)

1.13.2 Pick Up Mounting Components

The drive shaft is attached to the system. The Pick Up returns to this location at the end of measurement for next calculation. To calculate the time of the crossing, the cut off (Lc) or duration (Ln) is used. Taylor Hobson Sutronic 3 + system is attached with a skid pickup, which is used to automatically go via the rid motor. Such transport would encompass a range of about 12 mm. So we should involve the appropriate length of ground transportation. Help of Stylus is for better surface moving. Since it may be inappropriate to cut at the beginning or at the end. It will also reduce the measurement error, so there is less risk of calculating the value from wrong sides.

1.13.3 Mounting Bracket

Mounting bracket is fastened via the knurled button to the drive shaft. When used horizontally, pick-up moved from the centre line to rotate or delete it. It may also be set up in the drive shaft sideways, if the right angle pick-up is used.

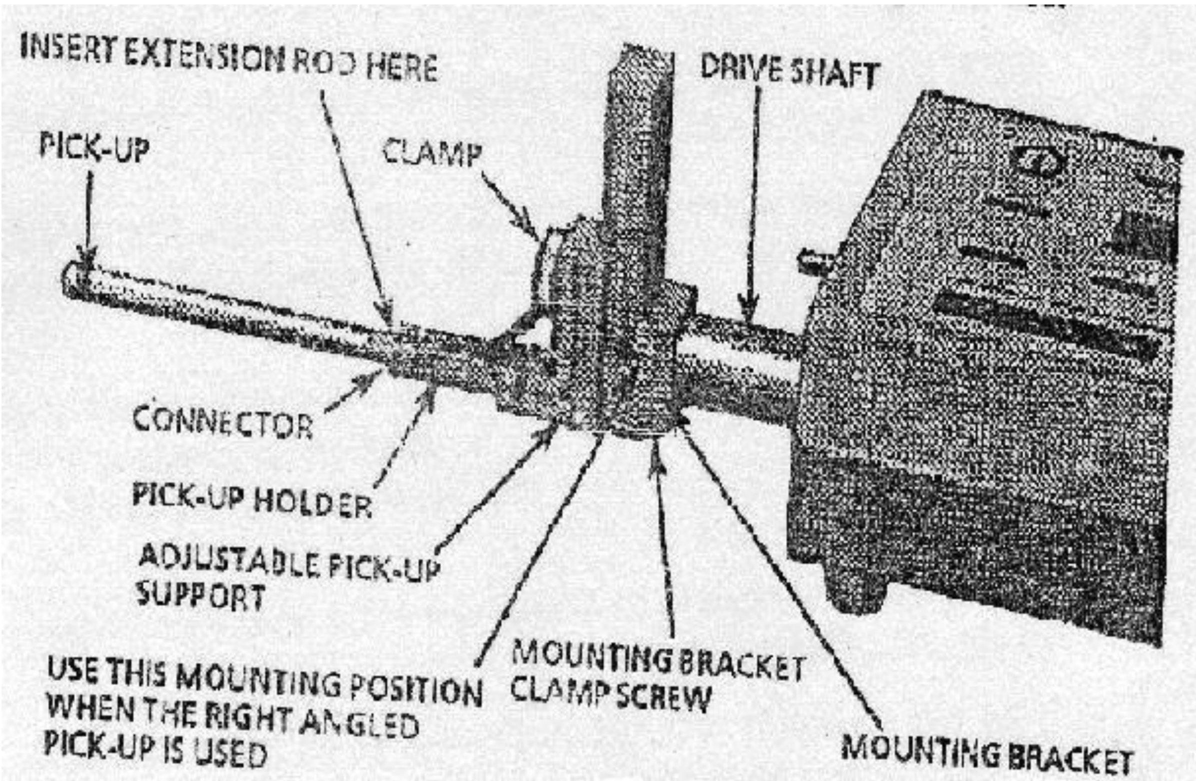


Figure 8 Mounting Bracket (Referred from Instrument Manual)

1.13.4 Adjustable Support

It can be clamped at any place on the side of the mounting bracket to provide height adjustment for the pickup.

1.13.5 Pick-up Holder

A spring plunger holds it in place, and it falls into the support pick-up crutch.

1.13.6 Connector

In a connector, a ribbon loop pick-up is put inside into the pick-up system unit and put in the pick-up shelf systems unit with the product coming out of the pocket holder. Next attach the guide to view traverse unit. The brief pick up is not needed when using the expansion string.

1.13.7 DIP switch setting

Standard computer configurations are set when charging up fresh batteries through DIP buttons. Menu / Push button is used to adjust the option. The functionality of the DIP switches is achieved by screwing three feet off the panel traverse unit frame.

1.13.8 Pick- up

It is a variable reticence type transducer that is protected by a skid on the rim. Skid is a bent-based, projected from the bottom of the pickup in the stylus field. Similar to the skid, the movement of the stylus is the same and converted into a corresponding electrical signal as the pickup moves through the surface. The skids curvature radius is much larger than the ruggedness spacing. This makes running around the field almost uninfluenced by the ruggedness. When waviness is widely spread, it will be appropriate to use pickup with shoe in combination with the 2.5 mm cut off.

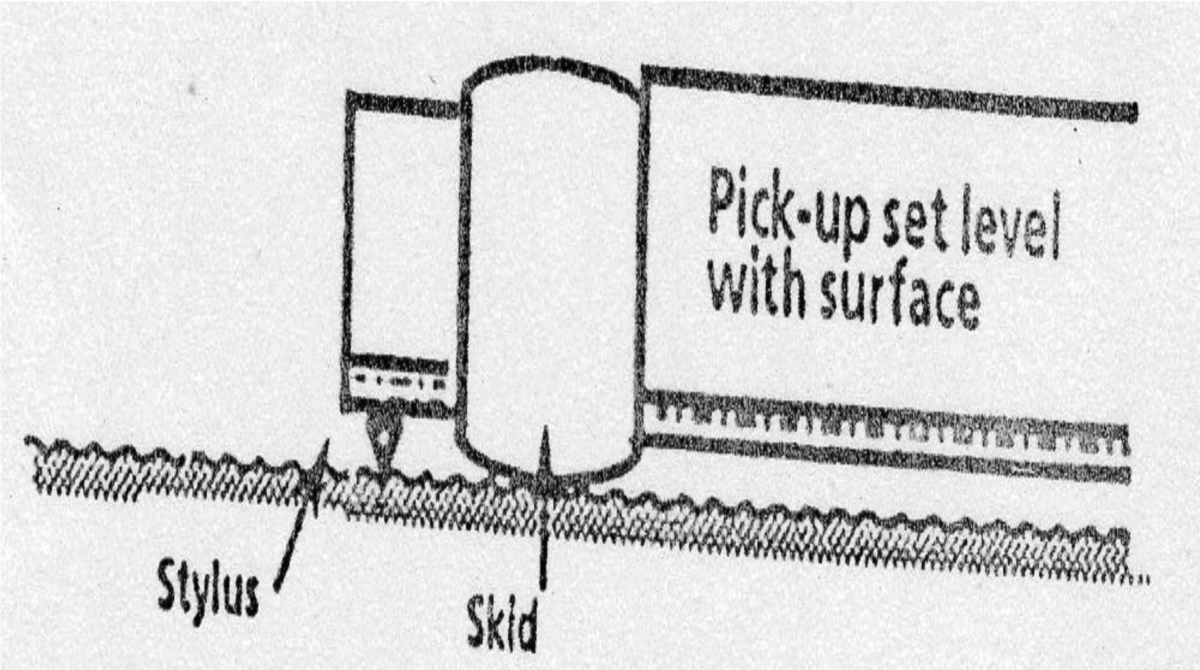


Figure 9 Pick-up (Referred from Instrument Manual)

Table 2 Surtronic 3 + Specifications (Referred from Instrument Manual)

Battery	Alkaline- Minimum 600 measurements of 4 mm measurement lengths, Ni-Cad- Minimum 200 measurement of 4 mm length Size- 6 LR 61(USA/Japan), fixed battery External Charger(Ni-Cad only) 110/240V, 50/60 Hz
Traverse unit	Traverse speed- 1mm/sec
Measurement	Metric/ Inch Preset by DIP -Switch
Cut – off Values	0.25 mm,0.8mm and 2.50 mm
Traverse Length	1,3,5,10, Or 25.4+ 0.2 mm At 0.8 mm Cut- off
Display	LCD- Matrix/ 2 lines* 16 Characters

Keyboard	Membrane Switch Panel Tactile
Filters	Digital Gauss Filters or 2CR Filter (ISO) selectable by DIP switch
Parameters	Ra, Rq, Rz (DIN),Ry and Sm
Calculation time	Less than reversal time Or 2 sec whichever is the longer

1.14 Methods for Measuring Residual Stress in components

Residual stress can be described as the stresses that exist inside a material or body after processing of materials and manufacturing in the absent of thermal gradient or external load. Residual stress can be produced by service loading, causing non - uniform plastic deformation in the sample.

It could be represented as-

- Macro stresses
- Micro stresses
- May be both available at any time in the element.

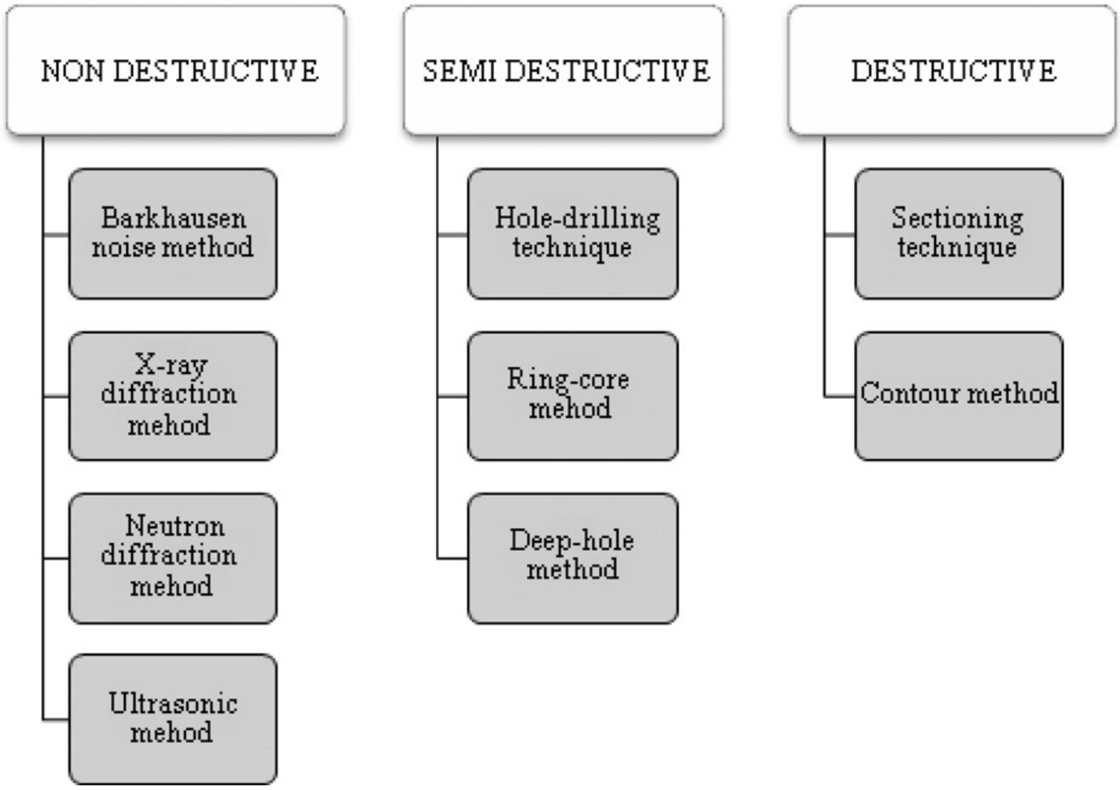


Figure 10 Methods of measuring Residual stresses (Adopted by 29)

1.15 Causes of Residual Stress

Residual stress generated at the time of manufacturing due to –

- Material's plastic deformation during manufacturing
- The temperature rise of work piece and tool during manufacturing, it is also called temperature gradient.
- The materials characteristics may be changed during manufacturing or during handling the materials.
- Residual stress may be generating when raw material is not processed.
- Residual stress may be generate when severe service loading during fabrication [30].

Origin of residual stress classified by

- A large change in the work piece or tool
- When material goes severe rate of plastic deformation
- When material goes severe rate of cooling etc.

CHAPTER 2
LITERATURE REVIEW

The literature review from various research work applied to this project's subject of interest is given in the form of a paragraph-

P.G .Benardos et al. [31] presented that surface roughness in CNC face milling. He uses artificial neural network and Taguchi’s design of experiment. According to the principle of the Taguchi’s design of experiment, various experiments has been performed on a CNC face milling. Depth of cut, feed rate per tooth and cutting speed are main cutting parameter in the experiment And other factors are components of cutting force, use of cutting fluids, engagement and wear of cutting tool. Most influencing factors are determined by using design of experiment and with the use of neural network and from these two methods; prediction of surface roughness is done. Mean squared error of surface roughness is equal to the 1.796 % and it is consistent to the entire range of value. In two different directions research can be extended –

- By investigating more cutting tools and work material combinations.
- Reverse problem is also good for consideration.

Gopikrishnan P et al. [32] presented the effect of machining parameters, speed, feed rate and depth of cut on surface finish in peripheral milling. AISI 4340 is used as the work piece .Response surface methodology is used as optimising process. Surface finish is calculated by using the variance of effective plastic strain value which is obtained from numerical model. Less number of trails are performed due to laborious and time consuming process. Response is prepared by using Mini tab and ANOVA table by adopting central composite design (CCD).

J.Unnikrishna Pillai et al. [33] presented end milling process of Al 6005 alloy to derive a set of optimal process on a six axis machine centre. The effect of process parameter like spindle speed, feed rate and tool strategic path and process characteristic such as machining time and surface roughness has been studied. Taguchi-Gray relation optimisation process has been used in this paper. The spindle speed is 1399 rpm and feed rate is 799 mm/min.

Nik Masmiati et al. [34] presented research work on S50C medium carbon steel. In this paper, cutting condition for minimum Residual stress, cutting force and surface roughness are optimised. The investigation of the effect of spindle speed, F.R. and D.O.C is done by Response surface methodology (RSM) with D- optimal experimental design. The obtained value of residual stress is 620 MPa and cutting force is 37 N, Surface roughness is0.659 µm.

G. Kiswanto et al. [35] presented research work on Aluminium alloy 1100 in micro milling operation. This paper explains the effect of cutting parameter and influence of machining time and tool condition to burr formation and burr growth. ANOVA statically analysis, scanning electron microscopes (SEM) is used as a technique to obtain value of spindle speed is 71000 rpm, F.R. is 1.01 mm/s, D.O.C. is 0.011 mm, single micro channel is 11.9 min. In this paper, we discovered the characteristics of cutting parameters and machining time with respect to surface roughness and burr formation.

Sunil Kumar et al. [36] presented research work on milling of AISI 1005 carbon steel. Surface roughness and material removal rate is optimised using Taguchi approach. Analysis of variance, steps involved in Taguchi optimization techniques are-

- Factorial design
- Roughness data measurement.
- Taguchi L 9 orthogonal array
- Signal to noise ratio and analysis of variance(ANOVA)
- Surface roughness and material removal rate calculation
- Conformational experiment.

Etory Madrills Arruda et al. [37] presented research work on AISIH13 hardened steel in the finishing milling. Vertical spindle with spindle speed of 90000 rpm which is maximum and main motor power 14.9 kW and work piece hardness was 49 ± 1.6 HRC and work piece dimension were $21\times21\times12\ mm^3$, was taken. Robust parameter design (RPD), RSM, normal boundary intersection (NBI) and Mean square error (MSE). Optimisation of controllable factors is done with the help of combination of mathematical and statistical methodologies of modelling.

Trung- Thanh Nguyen et al. [38] presented research work on SKD 61 milling. The machining parameters used in this paper were Energy consumption, surface integrity, productivity and tool wear, spindle speed, D.O.C, F.R. and nose radius are optimised. Machining parameters are investigated with the help of Pareto charts. Surface morphology and wear at various machining conditions are explained with the help of Scanning electron microscope. Optimal values of performance measurement are determined with the help of ANOVA analysis. Recommendation of this paper is high level process are D.O.C, spindle speed and F.R. is used to decrease the specific cutting energy. A low value of nose radius is used to decrease the specific cutting energy.

Jay Airao et al. [39] presented research work on End Milling of Super Duplex 2507 stainless steel. The aim of this study is to obtain surface roughness prediction model which is more accurate, flexible, reliable and non-destructive. The relationship between the cutting parameters and surface roughness of machined surface is analysed with the help of Regression model. Regression analysis and Taguchi method are used to optimise the cutting parameters like C.S. and F.R. and surface integrity parameters.

Krystian K Wika et al. [40] presented research work on AISI 304L stainless steel .This paper explains impact of supercritical carbon dioxide cooling with minimum quality lubrication on tool wear and surface integrity. A series of machining experiment is based on Design of Expert which has combination of cutting parameters like spindle speed, feed rate and tool wear on surface residual stress and surface roughness were investigated. Cutting tool pressure range is 55-71 bar and cutting speed is 216 m/min. and tool life is 8.8min.

Wooram Noh et al. [41]presented research work on hot rolled steel sheet. Residual stress and geometry of oxide layer on the interfacial debonding during bending deformation were investigated. Bending stress, interface geometry, scale thickness and Residual stress were used as parameters. ABAQUS software, FE analysis and semi analytic / numerical simulation were conducted. Both tensile normal stress at the peak is analysed and shear stress at the infection point are analysed.

Andreas Reimer et al. [42] presented research work on AISI H13 Steel in Precision Milling. Process parameters are cutting speed, depth of cut, feed rate and lead angle. A high speed machining of a material which is hard and finishing parameters is investigated and optimise. Artificial Neural Network (ANN) is used to predict Residual stress. Finite element analysis, artificial neural network, Fuzzy logic, FE simulation and XRD techniques are used to prediction and optimisation. A more consistent and precise prediction, RBF model is used to predict the Residual stress. Most influencing parameter is feed rate for plane residual stress state.

Yang Zhenchao et al. [43] presented research work on ultrahigh strength steel in high speed milling. Feed rate per tooth, milling speed, milling depth, milling width, tensile stress, surface roughness used as process parameters and their effect and influence were investigated and their effect on surface integrity is shown. German Leica 3 D confocal profile which is a micro measuring instrument is used to measure 3 D surface roughness with the use of X stress 3000 X-ray diffracto meter.

Weimin Huang et al. [44] presented research work on hardened steel ball in end milling with the use of different milling speeds. Comparison between surface integrity and fatigue performance is done in this paper. Spindle speed is 6100 rpm, D.O.C is 12 mm is used in the experimentation and obtained value of surface roughness Ra is 0.28- 0.38 µm. X- ray diffraction analyser and Servo hydraulic testing system and X- stress 3000 is used as a technique to investigate the effect on surface topography, surface roughness, Residual stress and micro hardness.

M.S. Kasim et al. [45] presented research work on Inconel 718 in ball nose end milling. Radial D.O.C., C.S., axial D.O.C., F.R., feed direction, flank wear and surface roughness is used as machining parameters. Surface roughness and chip formation is investigated in this paper during high speed end milling. Scanning electron microscope (SEM) and Response surface method (RSM) and multilayer coating technology is used.

T. Wang et al. [46] presented research work on Al/SiC/65p aluminium matrix composites of high speed milling. Feed rate, milling speed, axial depth of cut, surface roughness and residual stress is used as cutting parameters. Residual stress is calculated by X-ray diffraction (XRD). ANOVA is used to analyse the surface roughness and residual stress and these are also optimised by ANOVA. Pareto analysis is also done in this research paper. Surface morphology is also done in this research paper.

RESEARCH GAP

Very few points of Research gap have been identified, which are based on literature survey-

- Very little work reported on AISI 202 stainless steel as work piece in the literature survey.
- The surface characteristics like surface roughness, surface texture and surface integrity of AISI 202 stainless steel is not done in the literature survey.
- Residual stress measurement by cosα method of AISI 202 stainless steel is not done in the literature survey.

RESEARCH OBJECTIVE

Very few points of Research objective are identified on a detailed study of literature review which are:

- To prepare a Central composite Design matrix which involves input factors i.e. C.S., F.R. and D.O.C.
- To perform experiment by varying machining factors i.e. cutting speed, feed rate and depth of cut.
- To study the influence of machining factors on surface roughness and Residual stress during machining of AISI 202 stainless steel.
- To optimise and statistical analysis of surface roughness and residual stress is done during CNC milling.

CHAPTER 3
RESEARCH METHODOLOGY

3.1 CNC Milling

CNC Milling is a method of machining in which we have computerized control and multi-point cutting tool to extract material from the work piece. This machining method is developed to machine a large number of work piece such as metal, plastic, glass and wood and a different type of products. This is a method of machining of mechanical process like drilling, turning and other processes.

CNC milling has computerized control from which we operate and control the material cutting machine tool. CNC machine will perform all the processes that follow the same basic production steps, it also add design of CAD model, changing CAD into a CNC system and performing the milling operation.

Figure 11 CNC Milling Machine adopted by [48]

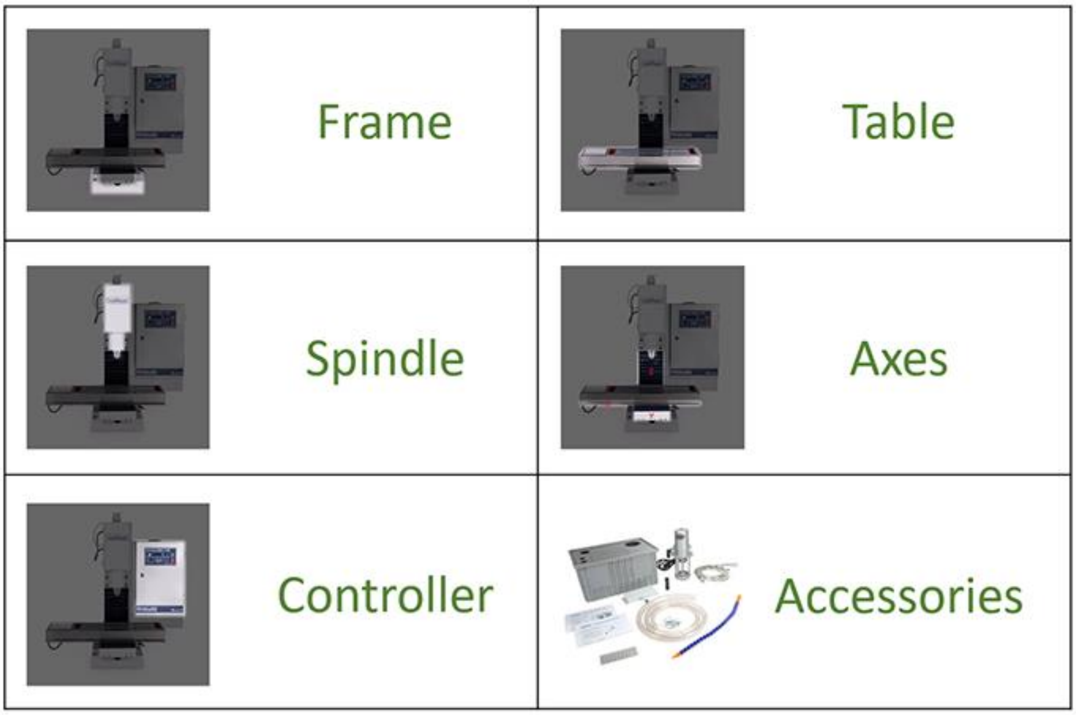


Figure 12 Parts of CNC Milling Machine adopted by [49]

The CNC milling will execute the following process –

- In CNC milling process, work material is feed into the rotating tool in a slow manner.
- In CNC milling process, Tool goes across the stationary work material
- In CNC milling process, Tool and work material is moved in relation to each other

CNC milling process is ideal for the manufacture of high precision and high tolerance parts. Most popular CNC Milling process –

- Face milling
- Plain milling
- Angular milling
- Form milling

Face Milling

In Face milling operation, the axis of rotation of tool is normal to surface of work piece. Face milling cutter that has teeth on the periphery as well as the tool face. The peripheral teeth are mainly used for cutting and facial teeth to finish operation.

Plain Milling

It is called as slab milling or surface milling. In this type of milling operation, cutting tool's rotational axis is parallel to the work piece.

Angular Milling

It is called as angle milling. In it, cutting tool's rotational axis is at angle relative to the surface of work piece.

Form Milling

This type involves discontinuous plains, contours and outlines.

Components of CNC Milling Machine

- Machine tool
- Arbor
- Spindle
- Ram
- Saddle
- Knee
- Column
- Machine interface

3.2 Methods to calculate Roughness

There are mainly three methods to calculate roughness –

3.2.1 Root Mean Square Roughness (RMS)

In this method, we square the length, calculate them, and calculate the count base of results. This method closely linked to the median roughness (Ra).Ground fabric comparative coefficient that is 11.01% larger than Ra score.

3.2.2 Maximum Peak to Valley Roughness (Rmax)

This process is second most prevalent process in the industry. This approach defines and measures the difference between the lines that touch the profile's highest outer and center boundary.

3.2.3 Ten Point Height (Rz)

In this method, we take five high and five low value to calculate roughness.

3.3 Taylor Hobson Talysurf

A shoe or skid cut across the work piece covering to match the ground general contours as tightly as possible. Stylus comes with skid. A stylus is a datum that runs along with skid over the surface. The stylus motion lies vertically close to the skid. Stylus is used to track surface roughness contours, no matter how wavy. This uses an amplifier to magnify the stylus. A motion of a monitoring machine produces a hint or record of the floor picture.

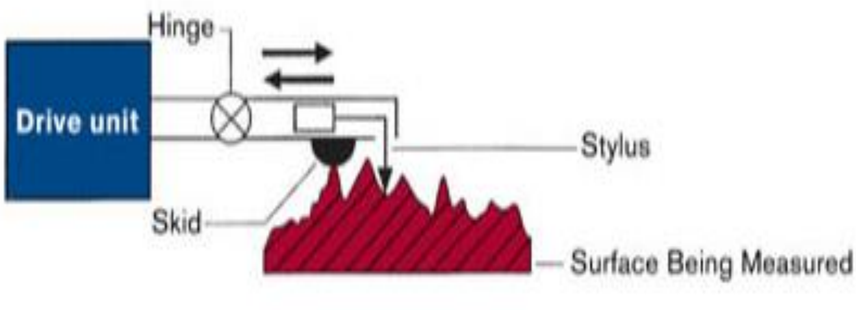


Figure 13 Surface Roughness Measurement adopted by [47]

The stylus is linked by an armature which spins around a stamping shaped portion E. The outer feet of the E shaped stamping are destroyed by electric coil. Coils, which is a part of the bridge loop, obtain a current excitation. Mapping roughness on the ground is achieved by skid. Electric motor traverses the experimental linear path. Owing to surface defects Stylus is moved up and down. The variation is generated in the air which creates circuit imbalance.

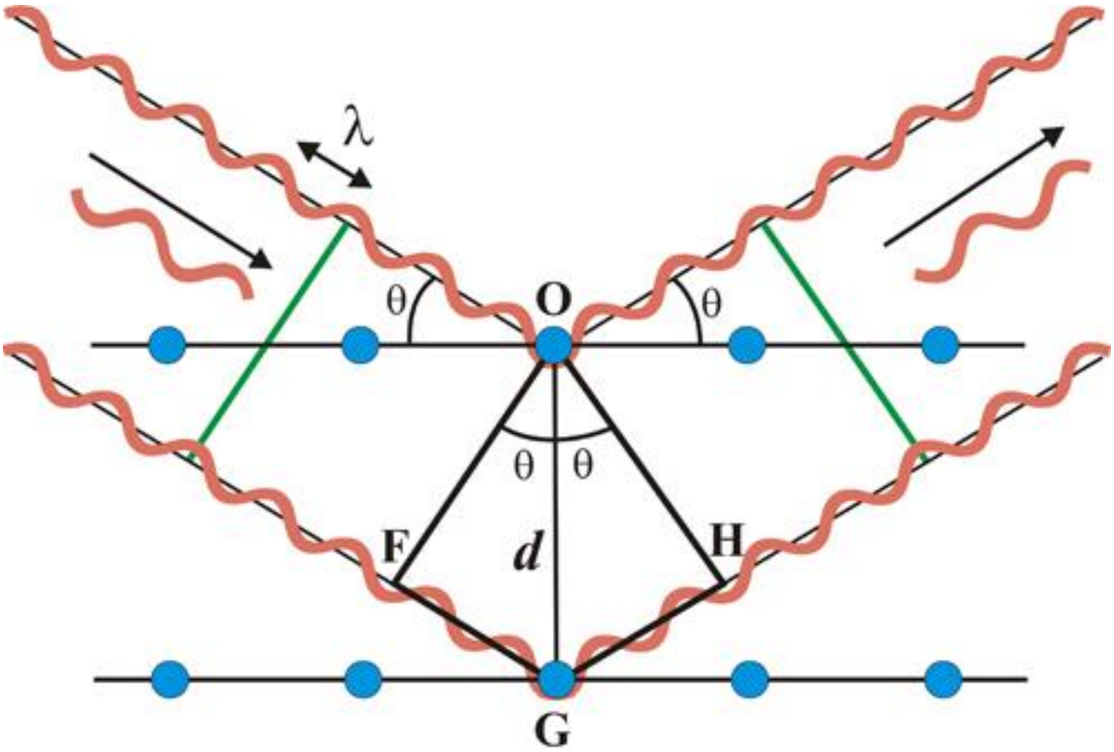
3.3 Analysis of Surface Traces

Analysis of surface traces is done by:

- The factor Roughness height or Roughness median (Ra) is commonly used in surface analysis of trace. It is the absolute height of profile, the arithmetic average.
- Another analysis is done by root mean square average of profile height over the length known as root mean square (Rq)
- Another approach is to measure the vertical distance between the highest and lowest point within the length of the sample as the average height within the length of the sample (Rti).
- Another approach is the estimation of the average maximum height of the profile (Rz) over the measurement period of the successive Rti value.

3.5 X- Ray Diffraction

X-rays wavelength is the same order as material inter-planar ranges. Beam constructional and disruptive interference is created when x rays hits the surface of the material. The residual stress is expected with the use of μ-X360 portable phones. This system is looking for the highest angle of interference with diffraction. With the aid of Bragg's law the presence of residual stress is calculated.



(a)

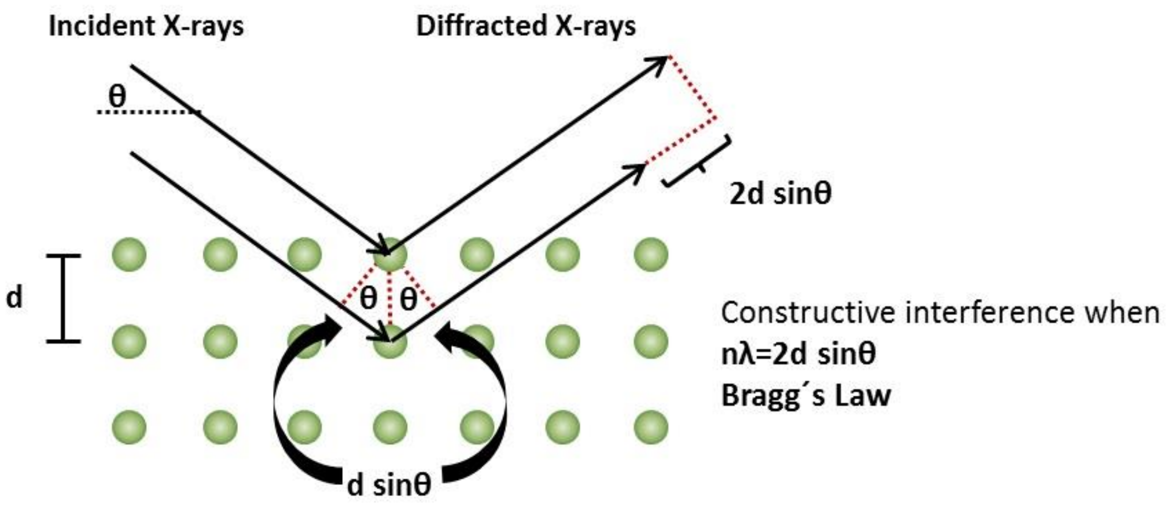


Figure 14 X- ray diffraction and Bragg's law diagram adopted by [50]

3.5.1 Cos α Method

A series of measurements using a point sensor with different sample orientations with respect to the diffract meter using the standard $\sin^2 \psi$ process. It is used to project the strain tensor along the various different vector orientations of the scattering.

Cos α process emerged in Japan. Debye Scherrer ring reported by single X-ray exposure on IP is used to measure the strain. In one measurement, the normal stress is determined by cos α diagram and shear stress through sin α diagram for a defined test profile in the studio venue, Debye loop emerges from each entity from a distinct angle of resulting matrix. The Cos α technique is quicker and easier. Because of this it uses mobile equipment to detect entire Debye loop at once from two dimensional sensor.

Principle of Cos α Method

A Debye Scherrer loop is acquired when checked using a picture panel (IP) and picture information to assess stress significance. The transformation of the evaluation scheme into a sample scheme is more complicated due to a geometry test with 2D planer. The full Debye circle is obtained through the use of the Cos α technique.

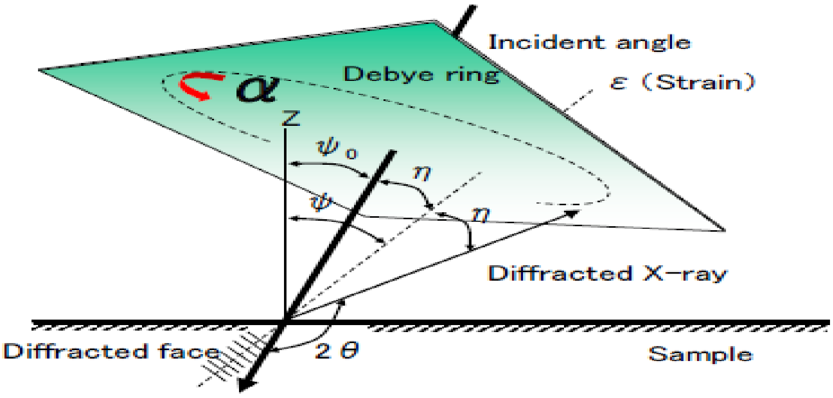


Figure 15 Geometrical Representation of Debye ring angles adopted by [30]

The translation of strain is expressed as

$$\varepsilon_\alpha = n_i n_j \varepsilon_{ij}$$

Where, n is known as diffraction vector which can be expressed as

$$n = \begin{bmatrix} \cos\eta \sin\psi_o + \sin\eta \cos\psi_o \cos\alpha \\ \cos\eta \sin\psi_o \sin\emptyset_o + \sin\eta \cos\psi_o \sin\psi_o \cos\alpha + \sin\eta\cos\emptyset_o \sin\alpha \\ \cos\eta \cos\psi_o - \sin\eta \sin\psi_o \cos\alpha \end{bmatrix}$$

Put the value of n in the Hook's law and equation is expressed as

$$\varepsilon_\alpha = \frac{1+\upsilon}{E} n_i n_j \varepsilon_{ij} - \frac{\upsilon}{E}\sigma_{kk}$$

From the detected position of the Debye scherrer ring, the magnitude of strain is determined. Using the formula it is calculated as

$$\varepsilon_{\alpha 1} = \frac{1}{2}\{(\varepsilon_\alpha - \varepsilon_{\pi+\alpha}) + (\varepsilon_{-\alpha} - \varepsilon_{\pi-\alpha})\}$$

$$\varepsilon_{\alpha 2} = \frac{1}{2}\{(\varepsilon_\alpha - \varepsilon_{\pi+\alpha}) - (\varepsilon_{-\alpha} - \varepsilon_{\pi-\alpha})\}$$

From the strain using proper elastic and other constants, the value of stress is calculated as

$$\sigma_x = -\frac{E}{1+\upsilon} \cdot \frac{1}{\sin 2\eta} \cdot \frac{1}{\sin 2\psi_o} \cdot \left(\frac{\partial \varepsilon\alpha_1}{\partial \cos\alpha}\right)$$

Using the remaining stress analyser μ-X360 which is mounted on a strong board, the residual stress is calculated after AISI 202 Stainless steel specimen is milled. While running down the tube shaft, various markings on a milling specimen are identified as the complete length of the sample. The stress detector piston is bent at an angle of 35 ° to obtain accurate tests of the ferrous metal.

The Residual stress produces a red laser where X-ray beam is conducted on the operating panel when the sample is placed on

Table 3 Specification of μ -X 360 X ray machine from lab manual

X-ray Tube Voltage, Current	30 KV, 1.0 mA
Target Material	Chromium (Cr)
Beam Wavelength (Energy)	λ= 2.29 Å (E = 5.4 KeV)
Collimator and Beam Spot Size	1 mm and 2 mm diameter
Sample to Detector Distance Approx.	35-40 mm
Typical Data Acquisition + Readout Time	90 seconds

Figure 16 Portable X-ray machine (μ-X360) using measurement of Residual stress in Precision Lab

CHAPTER 4

EXPERIMENTAL METHOD

4.1 Design of Experiment

Study the impact on mechanical properties of materials of machining parameters and percentage of engagement. Another parameter varies at a time and another is constant when one may clearly select the technique of experiment design.

Experimental goals are the effect of input factor and relationship between parameters and generate mathematical models. Following are steps to achieve the targets:

- Define reasons for process management
- Develop the matrix of design
- According to the configuration of the matrix exams
- Matching responses such as surface roughness and residual tension
- Develop numerical models
- System adequacy is verified
- Find out the significance of the pattern
- Development of final models
- Map diagrams and results collected as well.
- The findings are addressed

4.2 Work piece material

AISI 202 Steel is a stainless steel and is an austenitic steel produced in wrought iron products for the primary construction. The British code for the standard is 284S16. It can have tensile strength which is moderately strong. It is stainless steel low in nickel and high in Manganese. Not below 4 per cent and in AISI 202 steel Mn is around 8 per cent.

AISI 202 Stainless steel has excellent corrosion resistant mechanical properties. It has a high temperature resistance at 800 ° C than 18-8 steel.

Chemical composition

AISI 202 Stainless steel chemical composition:

Grade	Cr(%)	Ni(%)	Mn(%)	C(%)	Si(%)	P (%)	S (%)	N(%)	Mo(%)
202	17-19	4-6	7.5-10	0.15	0.75	0.06	0.03	0.25	-

Mechanical Property

Table 4 Mechanical Property

Density	7.79 ×1000 kg/m3
Poisson's Ratio	0.278-0.290
Modulus of elasticity	189-211 GPa
Tensile Strength	516 MPa
Yield Strength	276 MPa
Elongation (%)	39.9

Thermal properties

Table 5 Thermal Properties

Latent heat of fusion	291 J/g
Max. Heat : Corrosion	411 ℃
Max. Heat :Mechanical	911 ℃
Melting completion (liquidus)	1401 ℃
Melting Onset (Solidus)	1359 ℃
Specific Heat Capacity	481 J/Kg-k
Thermal Conductivity	14.9 W/ m-K
Thermal Expansion	16.9 µm/m-K

Typical Application

- Utensils for the kitchen
- Appliances for households
- Tableware
- Inserts of shoes
- Cladding indoors
- Frames for windows
- Transporter chains
- Concrete rebar
- Train coaches
- Applications for automotive

4.3 Process control parameter and their breaking points

S.NO.	Parameters	Units	Low level	High level
1	Cutting speed	m/min.	80	160
2	Feed Rate	mm/tooth	0.08	0.2
3	Depth of cut	mm	0.25	0.75

Experimental procedure of surface roughness

Following steps are described below for measurement of surface roughness:

1. The field roughness is assessed with the use of portable instrument Taylor Hobson.

2. V-blocks are used to provide appropriate assistance and stabilisation for the samples.

3. For the measurement process, a surface sampling system consisting of a small point stylus, sensor, crossing data and CPU is used.

4. The transducer converts and transmits this motion into a machine in a coded form by moving the stylus across the ground

5. Just the stylus point touches the ground, and the scale travels over the substrate.

6. For each sample the Ra value and the median value are gathered.

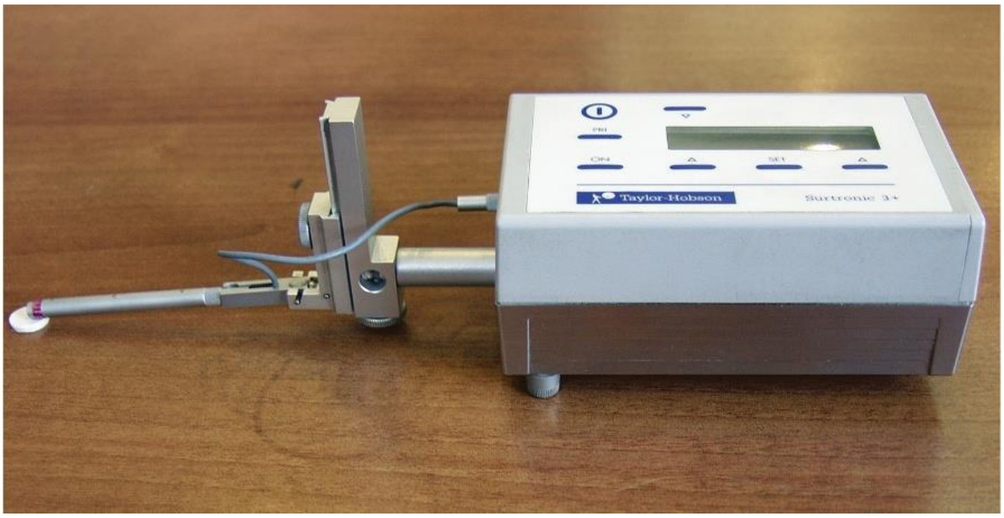


Figure 17 Taylor Hobson in Metrology lab DTU

Table 6 Measurement capability of Taylor Hobson in Metrology lab

Gauge Range	200 μm/100 μm/10 μm
Resolution	100 nm/20 nm/10 nm
Noise floor (Ra)	250 nm/150 nm/100 nm
Repeatability (Ra)	1 % of value + noise
Pickup type	Inductive
Gauge force	150-300 mg
Stylus tip radius	5 μm (200 μin)
Measurement type	Skidded
Calibration Process	Automated software calibration routine
Standards	Able to calibrate to ISO 4287 roughness standards
Evaluation length	0.25 mm - 17.5 mm (0.01 in - 0.70 in)
Measuring speed	1 mm / sec (0.04 in / sec)
Returning speed	1.5 mm / sec (0.06 in / sec)

Standards	ISO 4287, ISO 13565-1, ISO 13565-2, ASME 46.1, JIS 0601, N31007
ISO basic	Ra, Rv, Rp, Rz, Rt, Rq, Rsk, Rmr, Rdq, Rpc, RSm, Rz1max
Units	µm / µin

Experimental procedure of Residual stress

Following measures are used in residual stress tests which are-

1. On the surface of prepared samples there are four markings.

2. Samples are put on V-blocks below the laser.

3. Using laser, the irradiation of the marked point is done in the collimator focus.

4. After some time the residual stress values are detected and registered

.

Figure 18 Portable X-ray machine (µ-X360) using measurement of Residual stress in Precision Lab

Table 7 Specification of X- ray machine (μ-X360) in Precision lab

X-ray Tube Voltage, Current	30 KV, 1.0 mA
Target Material	Chromium (Cr)
Beam Wavelength (Energy)	λ= 2.29 Å (E = 5.4 KeV)
Collimator and Beam Spot Size	1 mm and 2 mm diameter
Sample to Detector Distance Approx.	35-40 mm
Typical Data Acquisition + Readout Time	90 seconds

4.4 Responses

The responses are recorded in Design of expert trial version

S.NO.	Std Order	Run order	Cutting speed (m/min.)	feed Rate (mm/tooth)	Depth of cut(mm)	Response 1 Surface roughness (micrometer)	Response 2 Residual stress(MPa)
1	13	1	80	0.14	0.50	0.50	-0.350
2	19	2	120	0.14	0.50	0.44	10
3	18	3	120	0.14	0.75	0.41	27
4	15	4	120	0.08	0.50	0.32	39
5	14	5	160	0.14	0.50	0.25	94
6	20	6	120	0.14	0.50	0.44	19
7	16	7	120	0.20	0.50	0.51	-25
8	17	8	120	0.14	0.25	0.36	19
9	2	9	160	0.08	0.25	0.16	28
10	5	10	80	0.08	0.75	0.72	19

11	8	11	160	0.20	0.75	0.48	-21
12	1	12	80	0.08	0.25	0.16	15
13	9	13	120	0.14	0.50	0.44	19
14	7	14	80	0.20	0.75	0.58	-27
15	12	15	120	0.14	0.50	0.44	19
16	6	16	160	0.08	0.75	0.31	42
17	10	17	120	0.14	0.50	0.44	19
18	4	18	160	0.20	0.25	0.42	-3.50
19	3	19	80	0.20	0.25	0.39	-5.66
20	11	20	120	0.14	0.75	0.44	19

CHAPTER 5
STASTICAL ANALYSIS

5.1 Response 1- Surface Roughness

Source	Sum of Squares	DF	Mean Square	F-value	p- value
Model	0.290842	10	0.29084	7.64	0.003
A-Cutting Speed	0.053290	1	0.053290	14.00	0.005
B-Feed Rate	0.050410	1	0.050410	13.25	0.005
C-Depth of cut	0.102010	1	0.102010	26.80	0.001
AB	0.014450	1	0.014450	3.80	0.083
AC	0.036450	1	0.036450	9.58	0.013
BC	0.026450	1	0.026450	6.95	0.027
A^2	0.002625	1	0.002625	0.69	0.128
B^2	0.000204	1	0.000204	0.05	0.122
C^2	0.001215	1	0.001215	0.32	0.186
Error	0.0000	4	0.000		
Total	0.325095				

Table 5.1.1 - Reduced Quadratic model for Surface Roughness using ANOVA

From the above table, the p-value of C.S., F. R. and D.O.C. is below 0.05.Conclusion of this p-value for AB, AC, BC,A^2,B^2, C^2 is significant. Model will become insignificant when value is more than 0.1.

Table 8 Fit Statistic for Surface Roughness

R^2	0.9843
Adjusted R^2	0.98014
Predicted R^2	0.9597

The difference between predicted R^2 and Adjusted R^2 value is very small and difference is nearly 0.2.

Final Equation in terms of Actual factor

Surface Roughness (micrometer) = -0.414 + 0.00376 C.S. (m/min.) + 0.30 F.R. (mm/tooth) + 2.091 D.O.C. (mm) – 0.000020 C.S. (m/min.) * C.S.(m/min.) + 2.4 F.R. (mm/tooth)* F.R. (mm/tooth) – 0.340 D.O.C (mm)* D.O.C. (mm) + 0.01771 C.S. (m/min.)* F.R. (mm/tooth) -0.00675 C.S. (m/min.)* D.O.C. (mm) – 3.83 F.R. (mm/tooth)*D.O.C (mm)

With the use of real parameters this equation is created and it frames hypothesis of yield information for each parameters. Each parameter for their corresponding range is necessary to quantify. Original coefficient is magnified to merge with each parameters parts.

5.2 Response 2: Residual stress

Table 9 Reduced Quadratic model for Residual stress using ANOVA

Source	**Sum of Squares**	**DF**	**Mean Square**	**F-value**	**p- value**
Model	10204.7	10	1020.47	2.66	0.078
A-Cutting Speed	1918.7	1	1918.67	5.00	0.05
B- Feed Rate	5070.0	1	5069.97	13.21	0.005

C- Depth of cut	16.5	1	16.47	0.04	0.041
AB	96.8	1	96.84	0.25	0.128
AC	23.9	1	23.92	0.06	0.108
BC	403.8	1	403.76	1.05	0.132
A^2	845.3	1	845.31	2.20	0.172
B^2	1308.5	1	1308.51	3.41	0.098
C^2	99.2	1	99.19	0.26	0.123
Error	40.5	4	10.13		
Total	13659.5	19			

From the above table, the p- value of C.S., F.R. and D.O.C is below 0.05. Conclusion of this p-value for AB, AC, BC, A^2, B^2, C^2 is significant. Model will become insignificant when value is more than 0.1.

Table 10 Fit Statistics for Residual stress

R^2	0.9471
Adjusted R^2	0.9321
Predicted R^2	0.9047

The difference between predicted R^2 and adjusted R^2 value is very small and difference is nearly 0.25.

Final Equation in terms of Actual factor of Residual stress

Residual stress (MPa) = 3 – 2.20 C.S. (m/min.) + 1753 F.R. (mm/tooth) +138 D.O.C. (mm) + 0.01109 C.S. (m/min.)* C.S. (m/min.) – 6133 F.R. (mm/tooth)* F.R. (mm/tooth) - 97 D.O.C (mm)*D.O.C. (mm) -1.45 C.S. (m/min.)* F.R. (mm/tooth) +0.173 C.S. (m/min.)* D.O.C. (mm) – 474 F.R. (mm/tooth)* D.O.C.(mm)

With the use of real parameters this equation is created and it frames hypothesis of yield information for each parameters. Each parameter for their corresponding range is necessary to quantify. Original coefficient is magnified to merge with each parameters.

CHAPTER 6
RESULT AND ANALYSIS

Result analysis of surface roughness

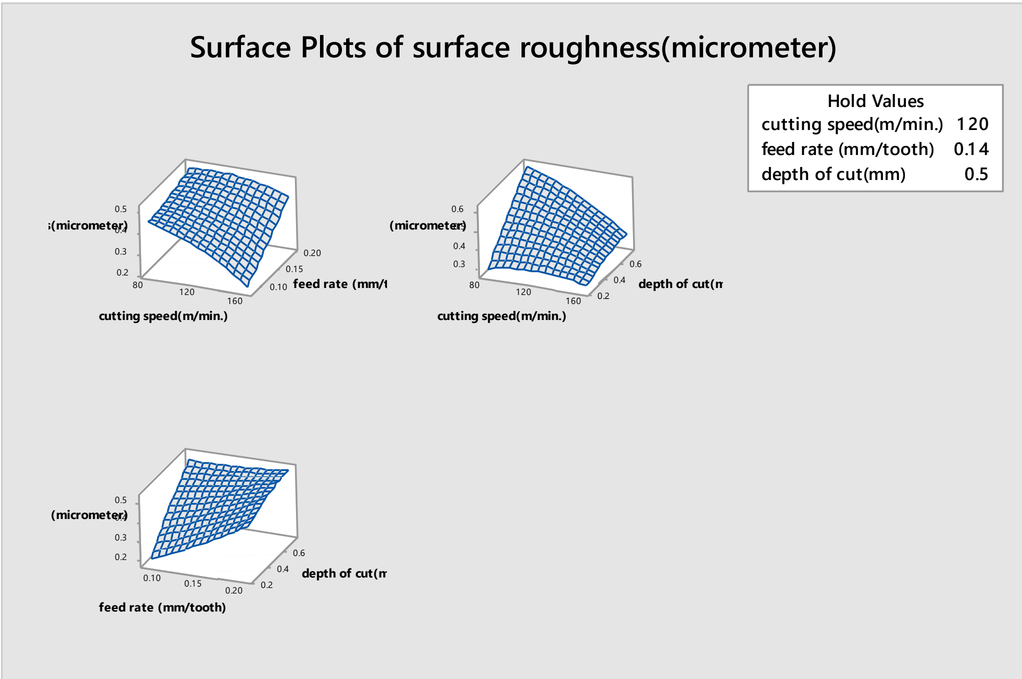


Figure 19 Surface plots of Surface Roughness (micrometer)

Surface plots represent variation of surface roughness when we vary input factors. When value of D.O.C. is hold at 0.5 mm, the surface plot drawn among surface roughness, C.S. and F.R. When value of F.R. is hold at 0.14 mm/min. graph plot among surface roughness, C.S. and D.O.C. When value of C.S. is hold at 120 m/min. graph plot among surface roughness, F.R. and D.O.C.

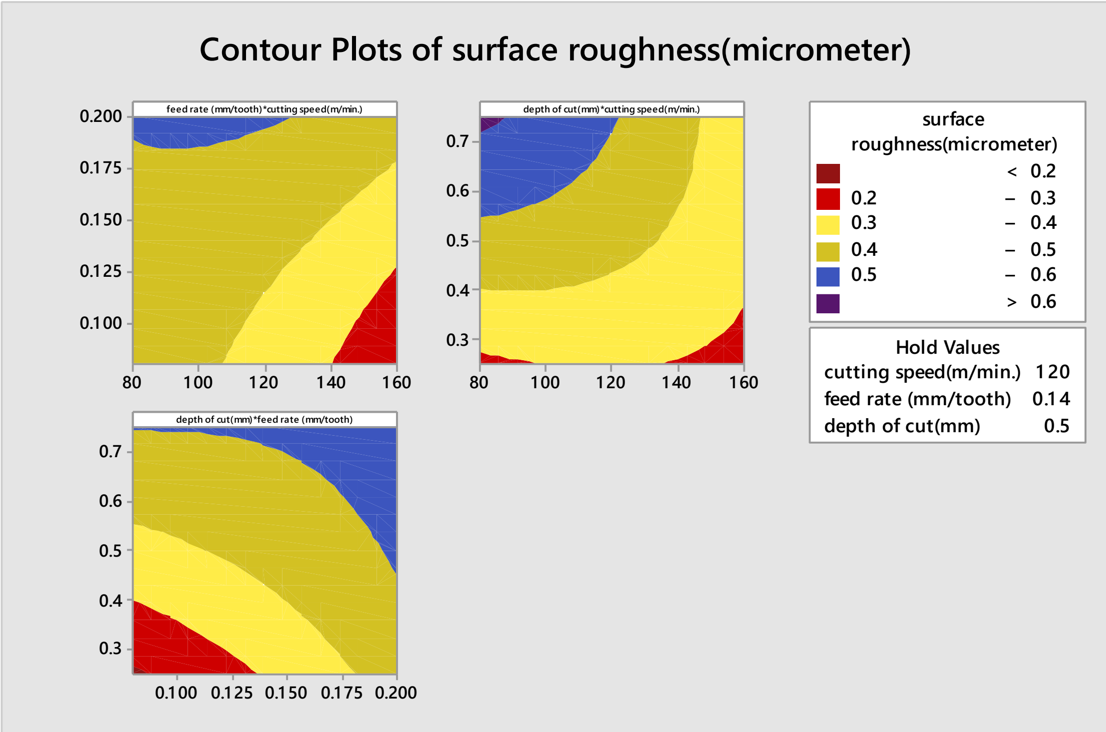


Figure 20 Contour plots of surface roughness between C.S. - F.R., C.S. – D.O.C. and D.O.C. - F.R.

Contour plots represent the variation in the range of surface roughness, when we vary C.S., feed rate and D.O.C. On the right hand side of the graph, range of surface roughness is shown according to colour like brown, yellow, navy, blue, when holding value of C.S. 120 m/min., F.R.0.14 mm/tooth and D.O.C 0.5 mm. When C.S. varies from140-160 m/min. and F.R. is below 0.1mm/tooth, then surface roughness decreases and when C.S. varies from 80-140 m/min. and F.R. is below 0.175 mm/tooth, surface roughness in between 0.4-0.5 micrometer, when C.S. varies from 80-110 m/min. and F.R. is above 0.175 mm/tooth then surface roughness is nearly 0.6 micrometer. When C.S. varies from 140-160 m/min. and D.O.C. is below 0.3 mm then surface roughness is minimum and it is nearly 0.3 micrometer, when C.S. varies from 80-120 m/min. and D.O.C varies from 0.55- 0.75 mm, surface roughness is maximum. On increasing F.R. and D.O.C., surface roughness increases and vice versa.

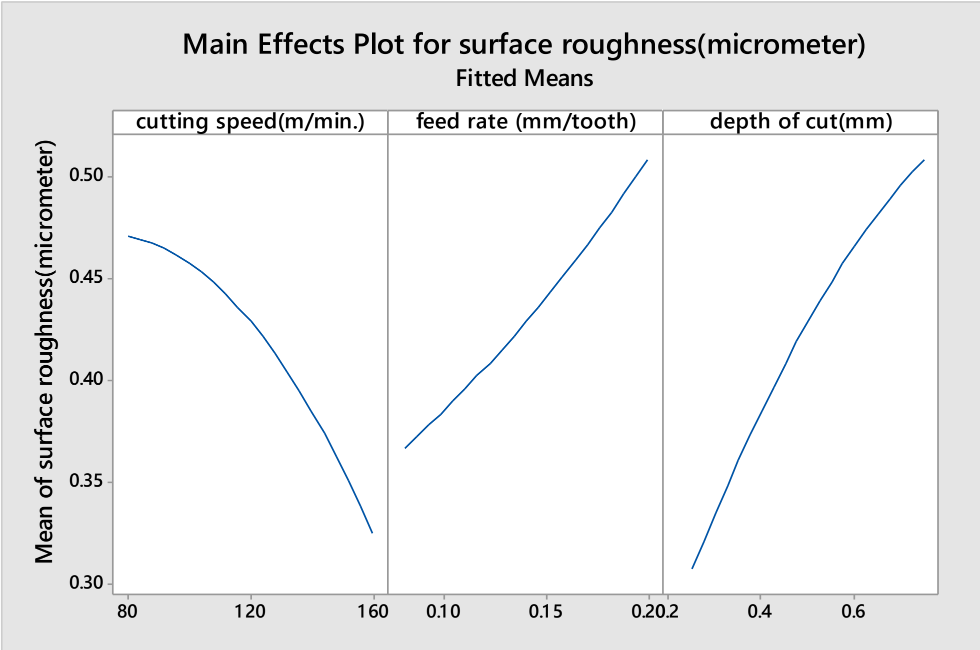


Figure 21 Main Effect plot of C.S., F.R. and D.O.C. on surface roughness

Main effect plot represent, when we vary cutting speed from 80-160 m/min. then surface roughness decrease continuously. When F.R. and D.O.C increases, Surface roughness increases.

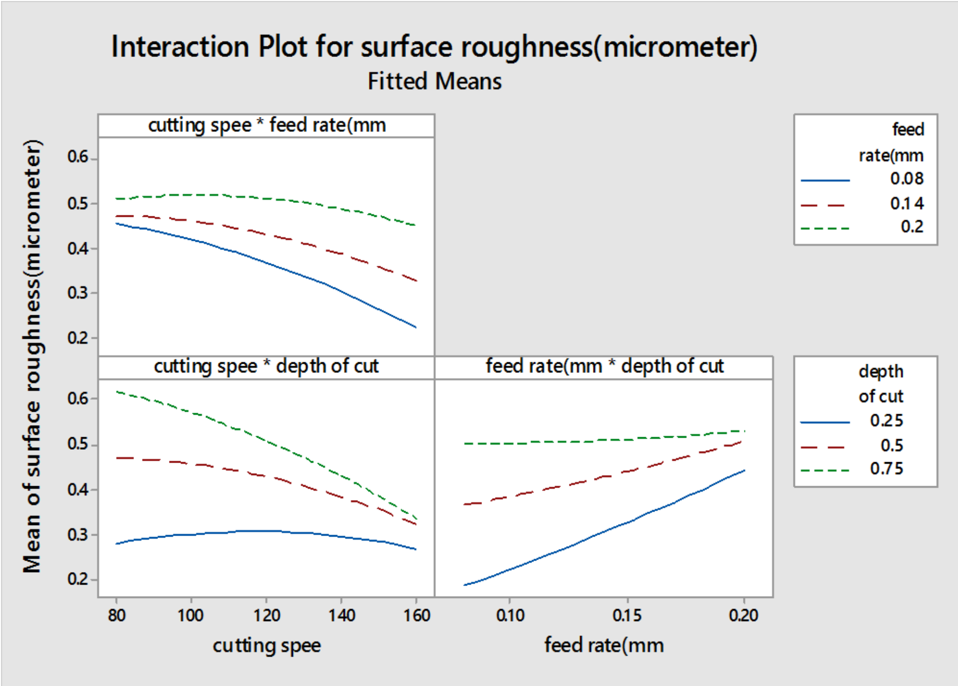


Figure 22 Interaction plot of surface roughness

Interaction plot represent combined effect i.e. C.S.* F.R., C.S.*D.O.C., F.R.*D.O.C. on surface roughness.

Result analysis of Residual stress

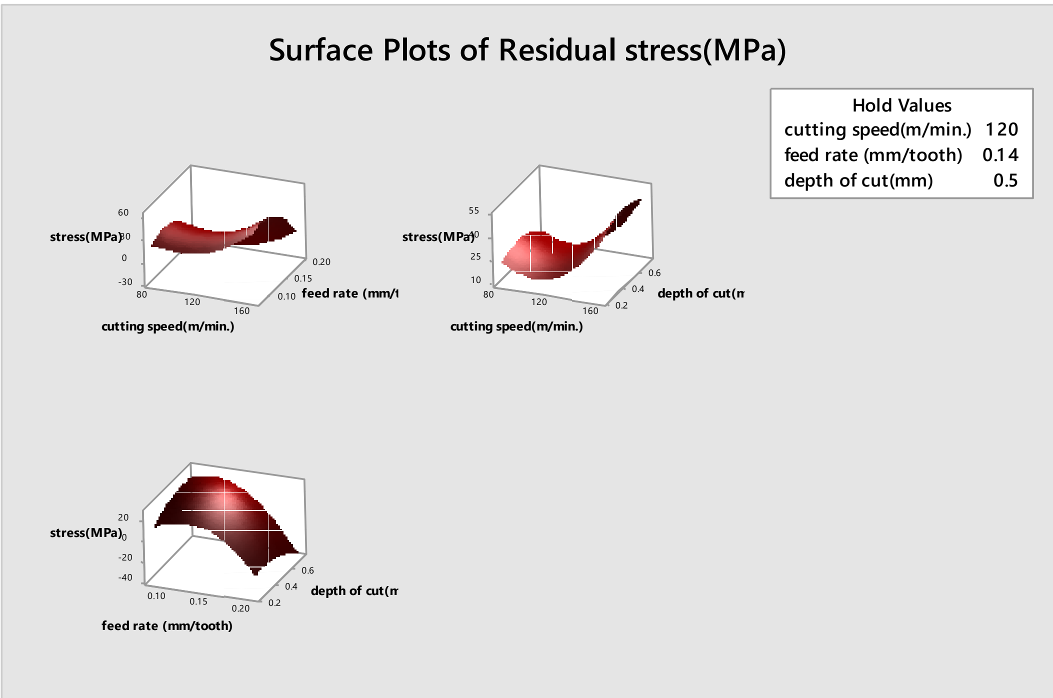


Figure 23 Surface plots of Surface Roughness (micrometer) between C.S. – F.R., C.S. – D.O.C. and F.R- D.O.C

Surface plots represent variation of Residual stress when we vary input factors i.e. C.S., F.R. and D.O.C. When value of D.O.C. is hold at 0.5 mm, the surface plot drawn among Residual stress, C.S. and D.O.C. When value of F.R. is hold at 0.14 mm/min. graph plot among Residual stress, C.S. and D.O.C. When value of C.S. is hold at 120 m/min. graph plot among Residual stress, F.R. and D.O.C.

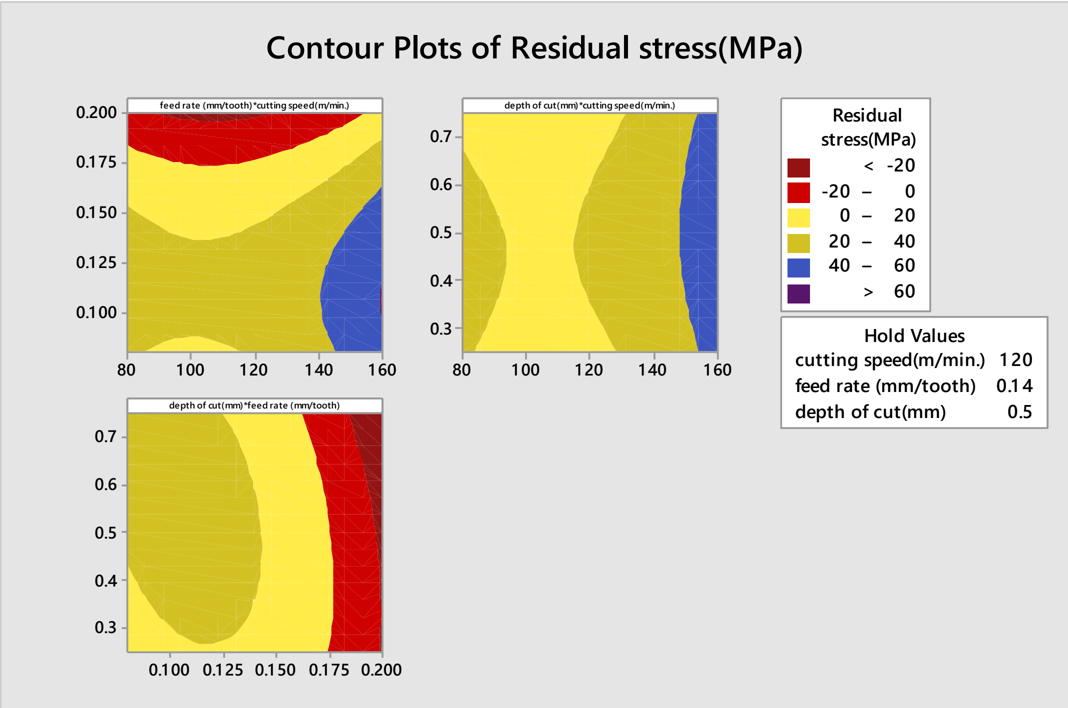


Figure 24 Contour plots of surface Residual stress between C.S. - F.R., C.S. - D.O.C. and D.O.C. – F.R.

Contour plots represent the variation in the range of Residual stress, when we vary C.S., F.R. and D.O.C. On the right hand side of the graph, range of Residual stress is shown according to colour like brown, yellow, navy, blue, when holding value of C.S.120 m/min., F.R. 0.14 mm/min. and D.O.C. 0.5 mm. When C.S. varies from140-160 m/min. and F.R. is below 0.15 mm/min., then Residual stress increases and when C.S varies from 80-140 m/min. and F.R. is below 0.175 mm/min., Residual stress in between 20-40 MPa, when C.S. varies from 80-140 m/min. and F.R. is above 0.175 mm/min. then Residual stress is nearly -20 to 0 MPa. When C.S. varies from 1400-160 m/min. and D.O.C. varies from 0.25- 0.75 mm, Residual stress is maximum. On increasing F.R. and D.O.C, Residual stress decreases and becomes minimum.

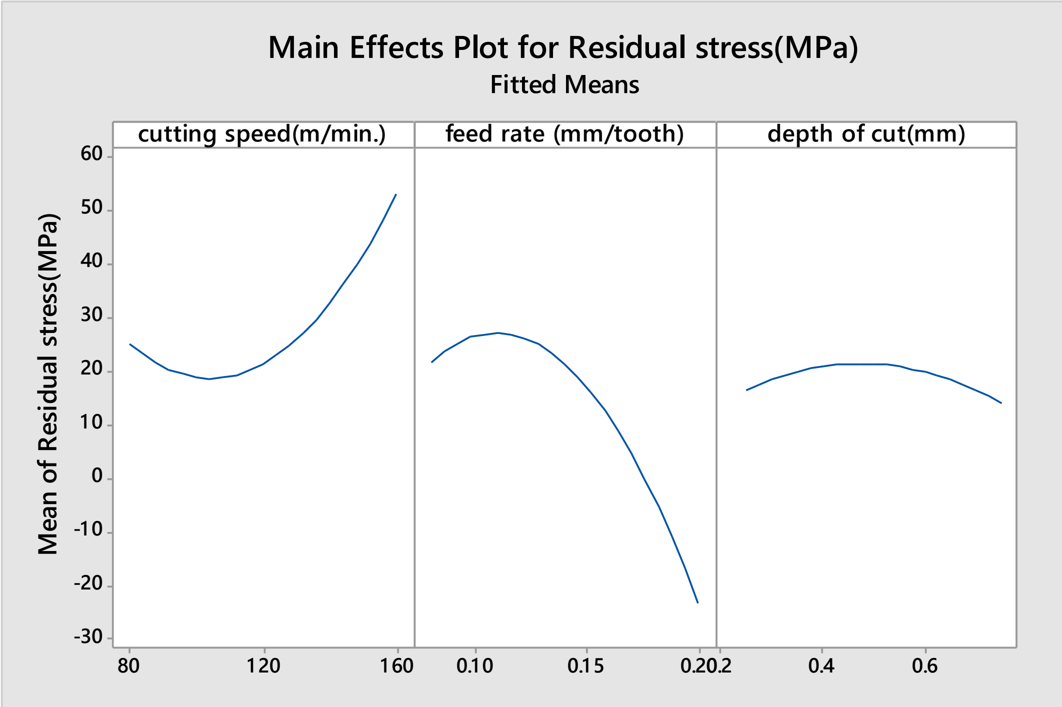


Figure 25 Main Effect plot of C.S., F.R. and D.O.C. on Residual stress

Main effect plot represent, when we vary C.S. from 80-160 m/min. then mean of Residual stress first decreases and then increases. When F.R. increases from 0.1 -0.2 mm/min. then Residual stress goes to negative direction i.e. axial compressive stress increases. When depth of cut increases, then Residual stress is first increases and then decreases continuously.

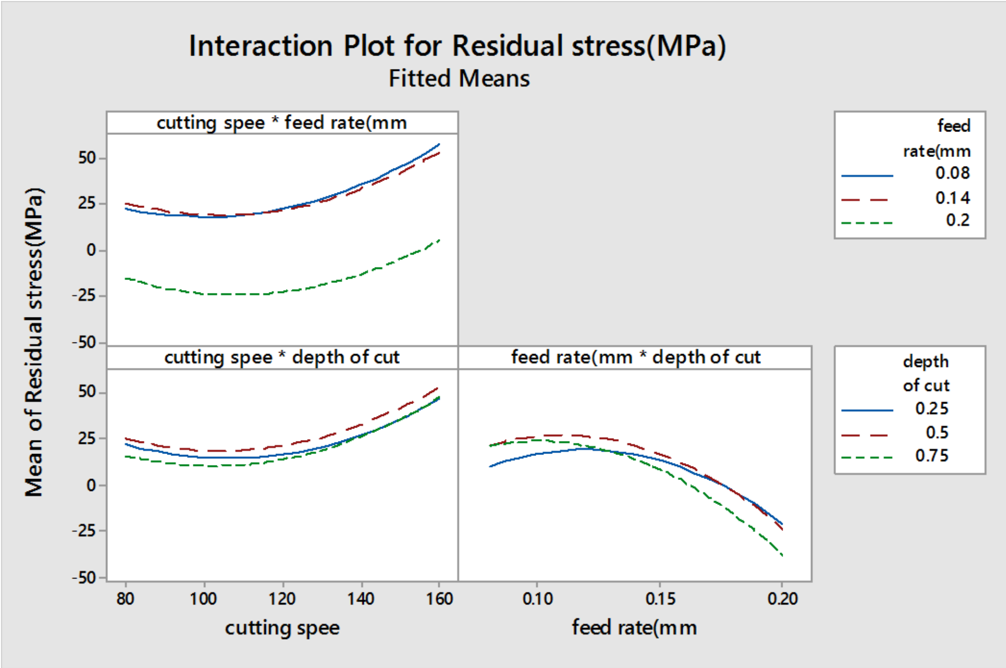


Figure 26 Interaction plot of Residual stress

Interaction plot represent combined effect i.e. C.S.* F.R., C.S.*D.O.C., F.R.*D.O.C. on Residual stress.

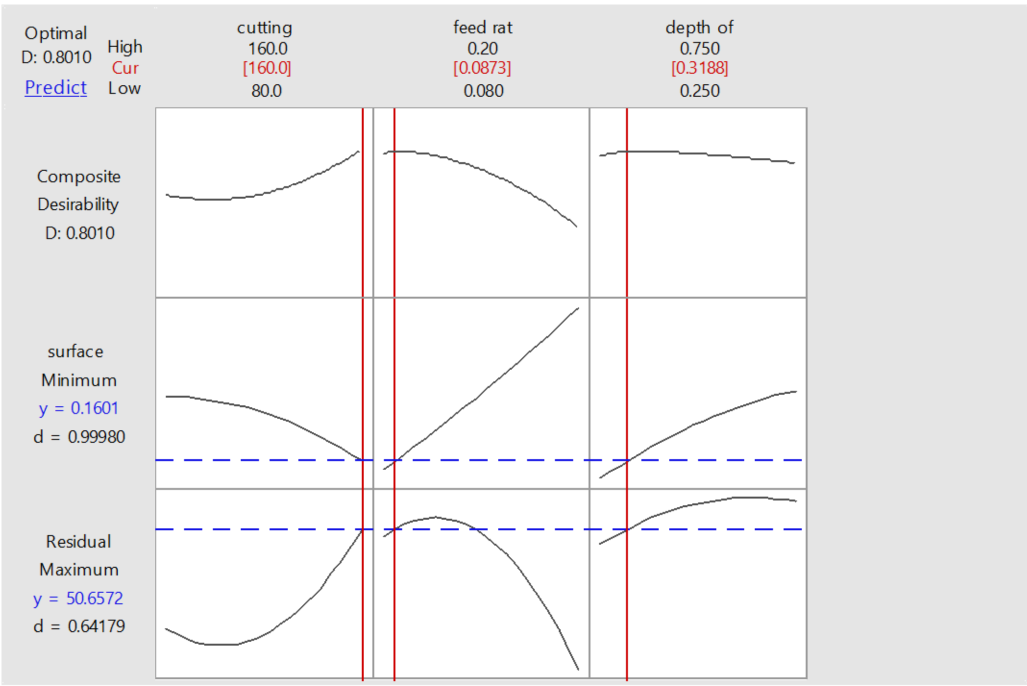


Figure 27 Optimization plot of surface roughness and Residual stress

Optimisation plot represent at C.S. = 160 m/min. F.R. = 0.0873 mm/tooth and D.O.C. = 0.318 mm, the optimum value has obtained. For minimum surface roughness, it is 0.1601 micrometer. For maximum surface roughness, it is 50.6572 MPa.

CHAPTER 7
Conclusions and Future Scope

CONCLUSIONS

Optimisation of CNC Milling using AISI 202 stainless steel is done in this dissertation work with the use of RSM. Some points are taken on the basis of results:

- C.S. which has F value 14.00, F.R. which has F value 13.25 and D.O.C. which has F value 26.80 is primarily influenced surface roughness and has a major effect to influence it.
- C.S. which has F value 6.08, feed rate which has F value 5.00 and D.O.C. which has F value 13.21 is primarily influenced surface roughness and has a major effect to influence it.
- At C.S. = 160 m/min. F.R.=0.0873 mm/tooth and D.O.C. = 0.318 mm, the optimum value has obtained. For minimum surface roughness, it is 0.1601 micrometer. For maximum surface roughness, it is 50.6572 MPa.
- The interaction of C.S.*F.R., C.S.*D.O.C. and F.R.* D.O.C. has significant effect.

FUTURE SCOPE

Huge possibility is available in milling operation in the area of research and development.

- Other factor like tool geometry, machine vibration which has effect on surface roughness and Residual stress is necessary to focus in research work.
- The rise in temperature and tool life in milling operation is need to analyse and evaluate.
- Influence of Rake angle on parameters and cutting edge condition of tool has also need to investigate.
- Effect of tool wear on cutting and surface parameters need to be focus in research work.

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