

**OPTIMIZATION OF MACHINING PARAMETERS IN CNC LATHE  
MACHINING OF D2 STEEL TO MINIMIZE SURFACE ROUGHNESS  
AND TOOL WEAR**

**A Thesis Submitted**

**in Partial Fulfillment of the Requirement**

**for the Degree of**

**DUAL DEGREE**

**in**

**MECHANICAL ENGINEERING**

**With specialization in**

**“Production and Industrial Engineering”**

**by**

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INTEGRAL UNIVERSITY, LUCKNOW**

**July 2022**



# INTEGRAL UNIVERSITY

## इंटीग्रल विश्वविद्यालय

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### CERTIFICATE

This is to certify that **Mr. Umar Siddique** (Enrollment No. 1700103180) has carried out the research work presented in the thesis titled “**Optimization of Machining Parameters in CNC Lathe Machining of D2 Steel to minimize surface roughness and tool wear**” submitted for partial fulfillment for the award of the Degree of Master of Technology in Mechanical Engineering from Integral University, Lucknow under my supervision. The thesis embodies result of original work, and studies are carried out by the student himself.

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Date:

## **CANDIDATE'S DECLARATION**

I hereby declare that the work which is being presented in the thesis entitled “**Optimization of Machining Parameters in CNC Lathe Machining of D2 Steel to minimize surface roughness and tool wear**”, submitted to the Dept. of Mechanical Engineering, **INTEGRAL UNIVERSITY, Lucknow (U.P.)**, India for award of degree of Master of Technology in Mechanical Engineering (**Production and Industrial Engineering**), is an authentic record of my own work carried out during my M.tech course under the supervision of **Dr.Mohd Faizan Hasan**

I have not submitted the matter presented in the thesis for the award of any other degree of this or any other university.

**Umar Siddique**

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## **ACKNOWLEDGEMENT**

At this moment of accomplishment, I wish to pay my heartfelt gratitude and sincerest thanks homage to my guide, Professor Dr. Mohd Faizan Hasan Department of Mechanical Engineering, Integral University Lucknow. This work would not have possible without their able guidance, support, and encouragement. Under their guidance I have successfully overcome many difficulties and learned a lot. They used to review my thesis progress, give their valuable suggestions, and made correction. Their unflinching courage and conviction will always inspire me, and I hope to continue to work on their noble thought.

I am also extremely indebted to Dr. P.K Bharti, HOD, Mechanical Engineering Department, Integral University, Lucknow, for providing necessary infrastructure and resources to accomplish my research work. I warmly thank Er. Abhishek Dwivedi, and Er. Mohd. Anas for their valuable advice and encouraging me at regular interval. I would also like to thank Mr. Danish Sir workshop instructor for their support during my work.

Last but not least, it goes without saying that I am indebted to a number of friends and well-wisher specially who have extended their co-operation and help during the work.

**Umar Siddique**

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## ABSTRACT

The present work concerned an experimental study of turning on D2 Steel by a TiAlN coated carbide insert tool. The primary objective of the ensuing study was to use the Response Surface Methodology in order to determine the effect of machining parameters viz. cutting speed, feed, and depth of cut, on the surface roughness of the machined material and the wear of the tool. The objective was to find the optimum machining parameters so as to minimize the surface roughness and tool wear for the selected tool and work materials in the chosen domain of the experiment. The experiment was conducted in an experiment matrix of 20 runs designed using a full-factorial Central Composite Design (CCD). Surface Roughness was measured using a Talysurf and tool wear with the help of a Toolmaker's microscope. The data was compiled into MINITAB 17 for analysis. The relationship between the machining parameters and the response variables (surface roughness and tool wear) were modelled and analysed using the Response Surface Methodology (RSM). Analysis of Variance (ANOVA) was used to investigate the significance of these parameters on the response variables, and to determine a regression equation for the response variables with the machining parameters as the independent variables, with the help of a quadratic model. Main effects and interaction plots from the ANOVA were obtained and studied along with contour and 3-D surface plots. The quadratic models were found to be significant with a p-value of 0.033 and 0.049. Results showed that feed is the most significant factor affecting the surface roughness, closely followed by cutting speed and depth of cut, while the only significant factor affecting the tool wear was found to be the depth of cut. The top three optimum settings for carrying out the machining were obtained from Response Surface Optimizer and are shown in the results section.

## **Chapter 1**

### **INTRODUCTION**

## **1.1 INTRODUCTION AND STATE OF ART**

A fundamental metal machining technique that is frequently utilised in sectors that deal with metal cutting is turning. To achieve excellent performance, choosing the right machining parameters for a turning operation is crucial . High performance is defined as having good machinability, a better surface finish, lower tool wear, a higher rate of material removal, a higher rate of output, etc.

Surface roughness, a parameter, is typically used to gauge a product's surface finish. It is regarded as a measure of the quality of a product. Improved strength characteristics, such as resistance to temperature, corrosion, and longer fatigue life of the machined surface, can be attained with a better surface polish. The functional behaviour of machined parts can be influenced by surface polish in addition to strength characteristics, such as friction, light reflection, heat transmission, ability to distribute and hold lubricant, etc. Costs of production are also impacted by surface finish. For the aforementioned reasons, it is crucial to minimize surface roughness, which can be done by optimizing some of the cutting settings.

Every traditional cutting operation has an intrinsic problem called tool wear. Because tool wear impacts both product quality and production costs, researchers work to eliminate or reduce it. Extensive research on tool wear characteristics must be done in order to increase tool life. Machining parameters including cutting speed, feed, depth of cut, etc., as well as tool material and its characteristics, are some of the elements that determine tool wear and surface roughness. tool shape and the qualities of the work material. The product quality and tool life may significantly change with very little changes to the aforementioned criteria.

Optimization is required to get the desired results. The science of optimization focuses on achieving the best outcomes while working under a variety of resource restrictions. To fulfil the increased need for higher product quality, lower production costs, and faster production rates, companies and researchers must prioritize optimization in the modern environment. Optimization procedures make considerable use of statistical design of experiments. The process of organising experiments so that appropriate data can be analyzed using statistical methods, leading to reliable and impartial findings is known as statistical design of experiments. Nowadays, design techniques like Response Surface Methodology (RSM), Taguchi's method, factorial designs, etc., are widely used in place of the previous one factor at a time experimental approach, which was more expensive and time-consuming.

According to Neseli et al , who employed the RSM method and the input variables nose radius, approach angle, and rake angle, the nose radius has the greatest impact on surface roughness.

Using feed, cutting speed, and tool nose radius as predictors in the RSM approach, Nanavati and Makadia found that feed had the greatest impact on surface roughness, followed by the tool nose radius. The Taguchi approach was utilised by Yang and Tarnng to identify the ideal cutting parameters. An investigation by Bouacha indicated that, after cutting speed, the feed rate had the greatest influence on a product's surface finish. According to Halim , the depth of cut has the greatest impact on tool wear, with other aspects appearing to be inconsequential. The goal of the current study is to optimize the machining parameters of cutting speed, feed, and depth of cut in order to achieve the lowest possible levels of surface roughness and tool wear.

Quality and customer requirements are the two main objectives any manufacturing industry in the world tries to achieve. Machining is one of the main metal processing operations in any manufacturing industry. The quality of metal cutting obtained depends on many process parameters. These process parameters affect the output response or Performance characteristics. Hence, proper selection of process parameter is an important task in machining operations. Poor process parameter selection results in non-optimal machine running which results in lower material removal rate, lower surface finish, higher machining time, reduced tool life, increased tool wear, increased energy consumption etc. For example, in a turning operation there are many process parameters [cutting parameters, cutting tool parameters, work piece material (surface and temperature) and environmental parameters etc.] which affects characteristic responses such as Material Removal Rate [MRR], Surface Roughness[Ra], vibration, geometric tolerance, tool wear etc. Turning operation is the most widely used machining operation and the demand for increased quality in the present industrial scenario demands researchers for finding optimized process parameters to deliver sound quality products using less energy. The machinability of materials in turning is assessed in terms of various parameters such as feed and radial forces, Ra, tool wear and work piece temperature. The present work focuses on optimizing machining parameters in machining stainless steel on a turning centre. Stainless steel is a low density, corrosion resistant, highly durable material with special characteristics such as ease of joining, ease of casting, high thermal conductivity, high surface finish and formability. The reason for selecting stainless steel is that it is widely used in various manufacturing industries for wide range of applications. Due to modernization in industry and an upsurge in demand for the finished product, CNC machines are dominating the manufacturing industry. There may be several reasons for use of CNC's for example it might be the finishing obtained or the time saved

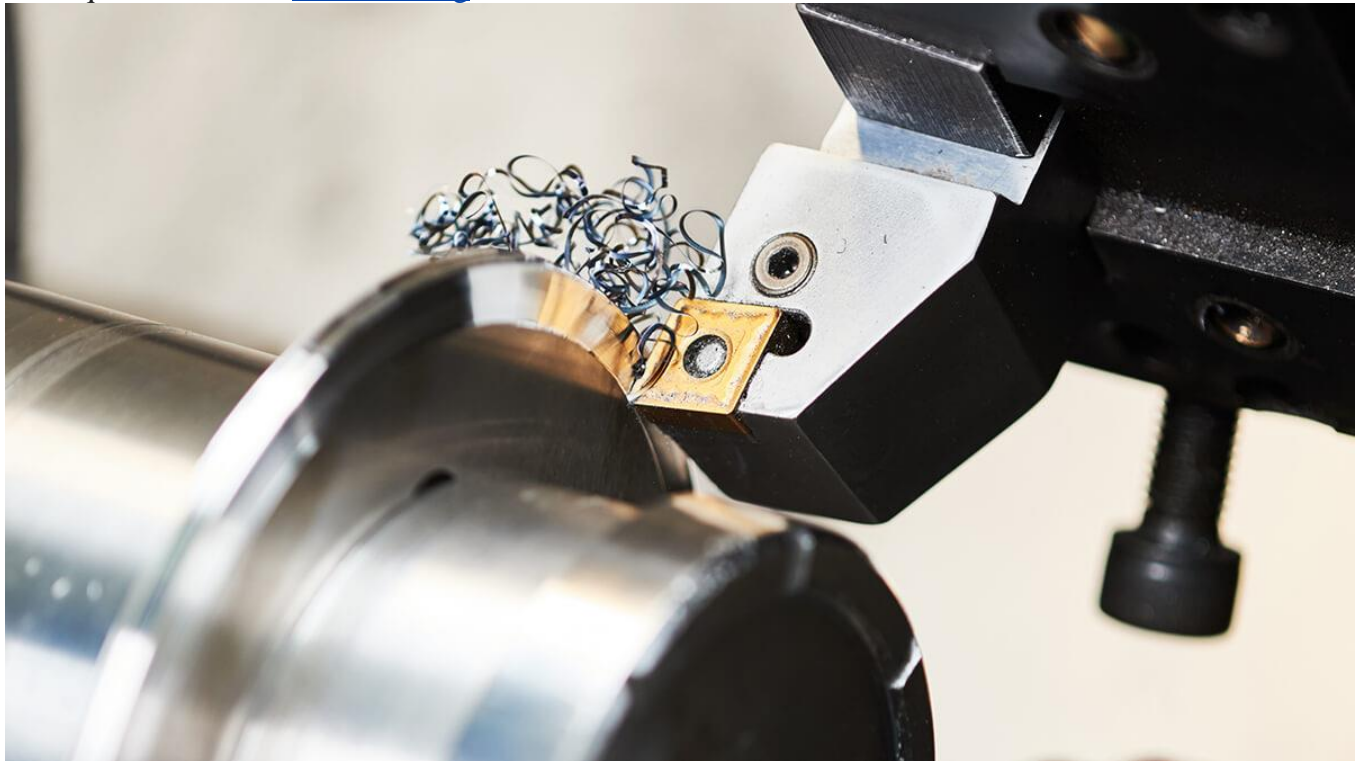
or minimizing human efforts. Before obtaining a final product, the raw material has to go through many manufacturing processes which include casting, machining, forming, joining, etc. In this paper we have done experiments on one of the most important machining operation, namely turning. Turning can be put into simple words as a machining process that reduces the diameter of a round work piece with help of a tool. Input variables such as speed of cutting, lubricant, rate of feed, cut depth, etc have a noticeable effect on the performance for a turning process, that are surface roughness(Ra), wear of the tool, material removal rate(MRR), and tool's life. So we intend to carry out a detailed study on the impact of different input variables on surface roughness. Surface roughness generally measured in Ra or Rz, is vital because it directly impacts the performance and durability of a component. It is often regarded that, a failure in an engineering part emerges from poor surfaces i.e. abruptions. Metals are formed into completely different usable forms through numerous processes during which no chip formation takes place. In these processes, the metal is formed under the action of heat, pressure or each. This class includes operations like shaping, drawing, spinning, rolling, extruding etc. A few of the important machining processes falling in this category are turning, milling, drilling, shaping, planning, broaching etc. Turning is that the most generally used among all the cutting processes. The demands for turning operations are attaining new dimensions at the present, in which the growing competition needs all the efforts to be directed towards the economical manufacture of machined parts. This can be made possible by the use of lathe machines. Material Removal Rate can be very helpful to predict the importance of different set-up variables. Hence by optimizing these desired results are considered to be important in the present industrial applications. Metals are formed into completely different usable forms through numerous processes during which no chip formation takes place. In these processes, the metal is formed under the action of heat,

pressure or each. This class includes operations like shaping, drawing, spinning, rolling, extruding etc. A few of the important machining processes falling in this category are turning, milling, drilling, shaping, planing, broaching etc. Turning is that the most generally used among all the cutting processes. The demands for turning operations are attaining new dimensions at the present, in which the growing competition needs all the efforts to be directed towards the economical manufacture of machined parts. This can be made possible by the use of lathe machines. Material Removal Rate can be very helpful to predict the importance of different set-up variables. Hence by optimizing these desired results are considered to be important in the present industrial applications. The three principal machining processes are classified as [turning](#), [drilling](#) and [milling](#). Other operations falling into miscellaneous categories include shaping, planing, boring, [broaching](#) and sawing.

- Turning operations are operations that rotate the [workpiece](#) as the primary method of moving metal against the cutting tool. Lathes are the principal machine tool used in turning.
- Milling operations are operations in which the cutting tool rotates to bring cutting edges to bear against the workpiece. Milling machines are the principal machine tool used in milling.
- Drilling operations are operations in which holes are produced or refined by bringing a rotating cutter with cutting edges at the lower extremity into contact with the workpiece. Drilling operations are done primarily in drill presses but sometimes on lathes or mills.
- Miscellaneous operations are operations that strictly speaking may not be machining operations in that they may not be [swarf](#) producing operations but these operations are performed at a typical machine tool. [Burnishing](#) is an example of a miscellaneous operation. Burnishing produces no swarf but can be performed at a lathe, mill, or drill press.

An unfinished workpiece requiring machining will need to have some material cut away to create

a finished product. A finished product would be a workpiece that meets the specifications set out for that workpiece by [engineering drawings](#) or [blueprints](#). For example, a workpiece may be required to have a specific outside diameter. A lathe is a machine tool that can be used to create that diameter by rotating a metal workpiece, so that a cutting tool can cut metal away, creating a smooth, round surface matching the required diameter and surface finish. A drill can be used to remove metal in the shape of a cylindrical hole. Other tools that may be used for various types of metal removal are milling machines, saws, and [grinding machines](#). Many of these same techniques are used in [woodworking](#).



**Fig 1: Basic turning operation on Lathe**

## **1.2 Cutting tool**

A cutting tool has one or more sharp cutting edges and is made of a material that is harder than the work material. The cutting edge serves to separate chip from the parent work material. Connected to the cutting edge are the two surfaces of the tool:

- The rake face; and

- The flank.

The rake angle (" $\alpha$ ") refers to the angle at which the rake face guides the flow of newly generated chips. In relation to the plane perpendicular to the work surface, it is measured. Both positive and negative rake angles are possible. In order to prevent abrasion, which would damage the finish, the tool's flank creates a space between it and the newly produced work surface. The relief angle refers to the angle formed by the work surface and the flank surface. There are two basic types of cutting tools:

- Single point tool; and
- Multiple-cutting-edge tool



**Fig 2: Basic turning operation on Lathe**

A single point tool is used for turning, boring, and planing and has only one cutting edge. The tool's point penetrates below the workpart's original work surface during machining. Sometimes the point is rounded to a radius known as the nose radius.

Tools with multiple cutting edges often use rotation to move in relation to the workpiece and have more than one cutting edge. Rotating tools with several cutting edges are used in milling and drilling. Although these tools don't have the same forms as single-point tools, they have many geometrical characteristics.

### **1.3 Cutting conditions**

To carry out a machining operation, the tool and work must move relative to one another. At a specific cutting speed, the main action is completed. The tool must also be moved laterally across the project. The feed has a considerably slower motion than this. The depth of cut, also known as the remaining dimension of the cut, is the depth to which the cutting instrument penetrated the original work surface. The cutting conditions refer to speed, feed, and depth of cut taken as a whole. They create the three dimensions of the machining process, and for some operations, you may use their product to calculate the process's material removal rate:

### **1.4 Stages in metal cutting**

According to the intended use and the cutting circumstances, machining processes are typically divided into two categories:

- Roughing cuts
- Finishing cuts

Roughing cuts are used to remove large amount of material from the starting work part as rapidly as possible, i.e. with a large Material Removal Rate (MRR), in order to produce a shape close to the desired form, but leaving some material on the piece for a subsequent finishing operation.

Finishing cuts are used to complete the part and achieve the final dimension, [tolerances](#), and surface finish. In production machining jobs, one or more roughing cuts are usually performed on the work, followed by one or two finishing cuts. Roughing operations are done at high feeds and depths – feeds of 0.4–1.25 mm/rev (0.015–0.050 in/rev) and depths of 2.5–20 mm (0.100–0.750 in) are typical, but actual values depend on the workpiece materials. Finishing operations are carried out at low feeds and depths – feeds of 0.0125–0.04 mm/rev (0.0005–0.0015 in/rev) and depths of 0.75–2.0 mm (0.030–0.075 in) are typical. Cutting speeds are lower in roughing than in finishing. To cool and lubricate the cutting tool during machining, a cutting fluid is frequently used. The definition of cutting condition typically includes deciding if a cutting fluid should be used and, if so, selecting the appropriate cutting fluid.

## **OBJECTIVES OF THE CURRENT WORK**

Any machining process will inevitably involve tool wear. Tool life and product quality are impacted by wear. Therefore, changes must be made to lengthen tool life.

Another crucial component of a machined product is surface finish.

- a) To investigate how machining parameters such as speed, feed rate, and depth of cut effect how much a clamped insert-type tool wears out.
- b) To use RSM to select the best machining parameter settings for the selected tool/work combination in order to reduce tool wear and surface roughness.
- c) Creating an empirical model for Surface Roughness and Tool Wear for the selected tool/work combination within the given parameter range.

**Chapter 2**  
**LITERATURE REVIEW**

**Venkata Ramana et.al.(2014)** Taguchi's method of robust design on tool wear is applied to determine the machining conditions. The factors selected in this work are speed of cutting, environment of machining feed rate and type of carbide tool material. Titanium alloy is machined under various lubrication conditions and it is found that the minimum quantity lubrication shows more optimum result compared to dry and flooded lubrication condition. The ANOVA approach shows that speed of cutting has more influence on the optimization of tool wear rate.

**Vikas B Magdum et.al.(2013)** In this research the use of materials for tool & process parameters for forces in turning for selected range of parameters. This work illustrates a method for optimizing forces of cutting and different parameters. ANOVA and Taguchi orthogonal array approaches are used for the optimization purpose and experiments are conducted for the obtained optimized results and the results of experiments gives the minimum thrust force.

**Mohd. Raffeq et.al. (2013)** This paper outlines the optimal process parameters to obtain reduced feed and radial forces while turning En31 steel with carbide tool inserts coated with TiC. Experimental investigation is carried out using Taguchi's orthogonal array principle. The results shows depth and feed rate in cutting affects significantly in comparison with spindle speeds.

**C R Barik et.al.(2012)** Optimizing of Ra in machining EN 31 steel is carried out by applying genetic algorithms. Mathematical models are developed using three level composite designs and the second order mathematical design is carried out using experimental results. Spindle speed, cutting depth, feed are the three parameters considered. The experimental result indicates that roughness of the surface parameter decreases with incremental spindle speed and increased feed

and raise with increase in cutting depth.

**D Lazaravic (2012):** The work in this paper throws light on the reducing Ra in machining of polyethylene on turning center. The influence of speed of cutting, feed, cutting depth and nose radius of tool is studied on the basis of Taguchi orthogonal array principle. The optimal cutting parameters are determined using MINITAB, ANIOM and ANOVA. ANOVA results shows that the feed is most important parameter after which falls are nose radius and speed of cutting. The effect of depth of cutting was insignificant.

**M. Aruna et.al. (2012)** Inconel 718 is a nickel based alloy used extensively in aerospace engines which operated at elevated temperatures. The surface roughness is an important parameter for such materials used in aero engine application. The optimization is done for machining i.e. turning, using RSM. Quadratic mathematical strategies are developed for Ra based on speed of cutting, depth of cutting & feed. Experiments were conducted for the predicted parameters and the response values are on par with the predicted values.

**S. R. Das et.al. (2010)** This work is carried out in the objective of optimizing the parameters such as speed of cutting, depth of cutting and feed in machining of AISI D2 steel without using any cutting fluids to have minimum wear of tool tip and reduced temperature of blank. Taguchi's principle is used to setup the experimental layout; ANOVA is performed to study the behavior of cutting process using varied parameters. Out of selected characteristic parameters the results from ANOVA shows that speed and depth of cutting influences more on the wear of tool. The minimum wear and temperature characteristics are presented based on the predicted and experimental results.

**Santosh Kumar et.al. (2017):** In this Study, Taguchi method and regression analysis was used to optimize the machining parameters during the turning of EN-45 spring steel by plain carbide cutting tool. Experiments were designed and conducted by Taguchi's L16 orthogonal array. Optimisation of input parameters speed, feed and depth of cut was done by using signal-to-noise ratio in the Taguchi technique (Minitab) for maximum material removal rate (MRR), minimum tool wear (TW) and minimum surface roughness (SR) The regression analysis was generated which are equations for output parameter as a function of input variables. The analyzed results revealed that the feed rate was the most dominating factor for surface roughness and the cutting speed is the most dominating factor for material removal rate and tool wear.

**VenkataRamana et.al.(2014)**Taguchi's technique for strong plan on instrument wear is connected to decide the machining conditions. The elements chose in this work are speed of cutting, condition of machining feed rate and kind of carbide device material. Titanium combination is machined under different oil conditions and it is discovered that the base amount oil demonstrates progressively ideal outcome contrasted with dry and overwhelmed grease condition. The ANOVA approach demonstrates that speed of cutting has more effect on the improvement of hardware wear rate.

**Raman B Magdum et.al.(2015)** In this research the use of materials for tool & process parameters for forces in turning for selected range of parameters. This work illustrates a method for optimizing forces of cutting and different parameters. ANOVA and Taguchi orthogonal array approaches are used for the optimization purpose and experiments are conducted for the obtained optimized results and the results of experiments gives the minimum thrust force.

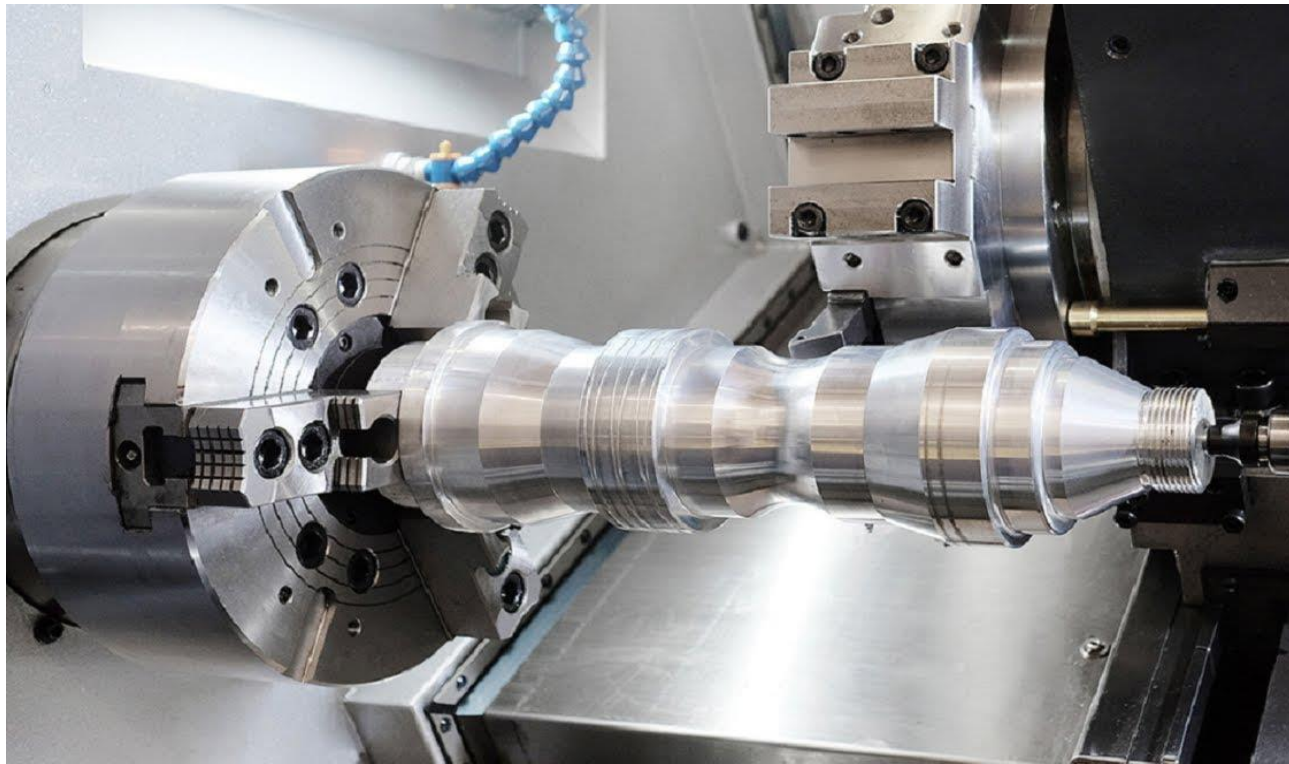
**Mohd. Ahmad et.al. (2013)** This paper outlines the optimal process parameters to obtain reduced feed and radial forces while turning En31 steel with carbide tool inserts coated with TiC. Experimental investigation is carried out using Taguchi's orthogonal array principle. The results shows depth and feed rate in cutting affects significantly in comparison with spindle speeds.

## **2.1 INTRODUCTION**

The following chapter discusses research on the turning process that has been published and aims to optimize parameters. It presents concepts and facts specifically related to the experiment and the turning process. The review's scope includes many optimization methods that can be utilized to find the best answer, with the Response Surface Method as its primary focal point.

## 2.2 THE TURNING OPERATION

A fundamental metal machining technique that is frequently utilised in sectors that deal with metal cutting is turning. In a turning operation, a high-precision single point cutting tool is rigidly held in a tool post and fed past a rotating work piece in a direction parallel to the work piece's axis of rotation at a constant rate. Unwanted material is removed in the form of chips, creating a cylindrical or more complex profile. In a lathe machine, this action is carried out either manually under the direction of an operator or by a controlling computer programme. In a turning action, there are two different forms of motion. The first is the cutting motion, which is the work's circular motion, and the second is the feed motion, which is the tool's linear motion. Fig. 2 and Fig. 3 illustrate the fundamental turning operation and the motions involved. A single point cutting tool and its nomenclature are shown in Fig. 4.



**Fig 3: Basic turning operation in Lathe**

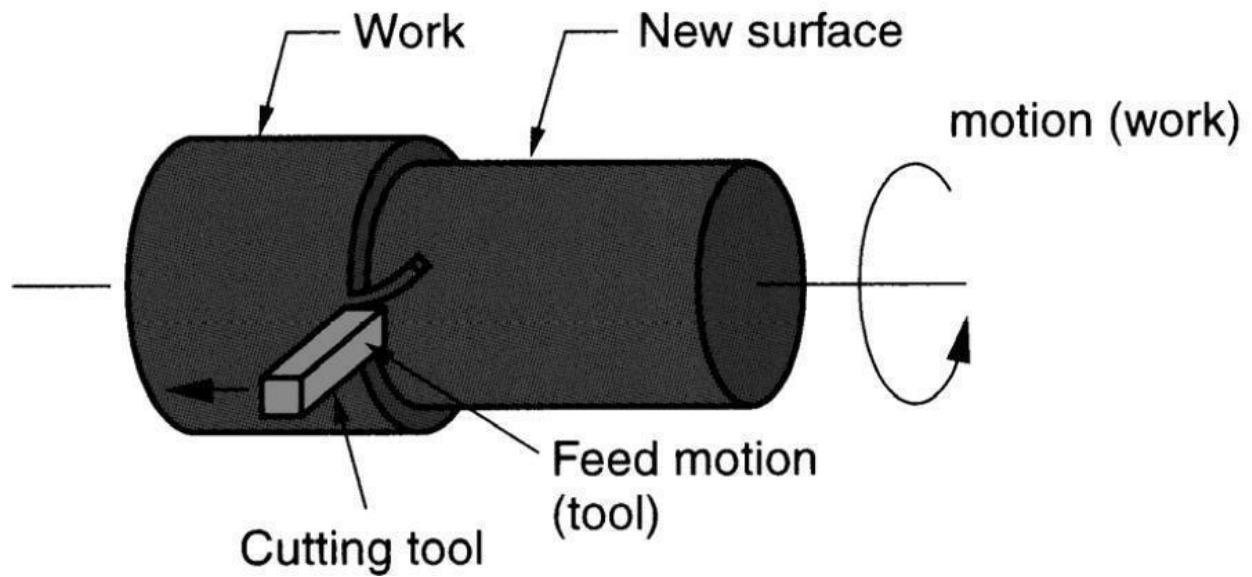


Fig 4: Motions in turning operation

**Nomenclature of single point cutting tool:**

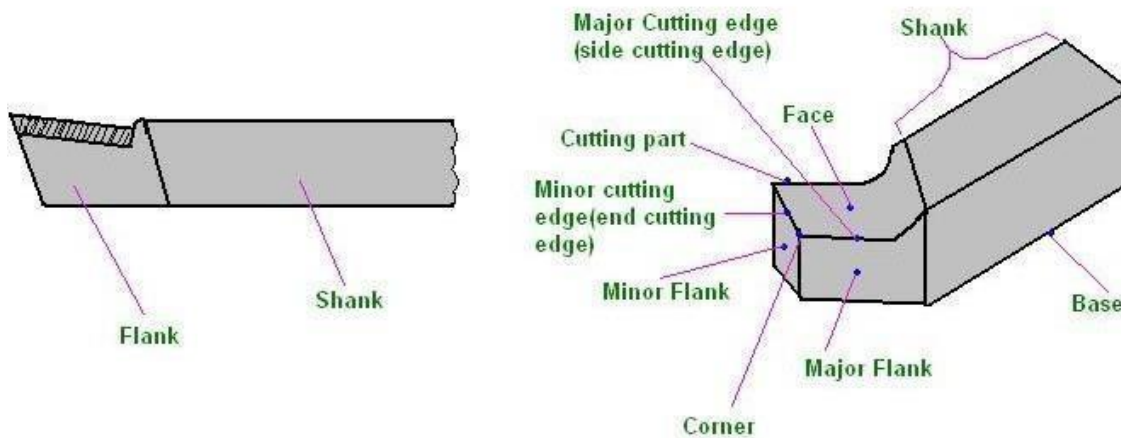


Fig 5: Single point cutting tool using in turning and its nomenclature

## 2.3 MACHINING PARAMETERS

Geometry and machining parameters control the turning process. The three main machining parameters that can be adjusted in a basic turning operation—speed, feed, and depth of cut—are the subject of this paper.

These three factors are shown in Figure (6). These three parameters are combined to provide material removal. There are other input elements that affect the output parameters as well, such as surface roughness and tool wear, however these latter two can be easily changed by the operator as the process is being performed.

### 2.3.1 Cutting Speed

The rate at which the work piece's uncut surface moves past the cutting tools can be used to describe cutting speed. The term "surface speed" is frequently used, and it is typically represented in m/min, however ft/min is also a valid metric. The spindle speed can be used to determine cutting speed. The spindle speed is the rate of rotation of the spindle and, consequently, the work piece. It is given in terms of number of revolutions of the work piece per minute i.e. rpm. If the spindle speed is „N“ rpm, the cutting speed  $V_c$  (in m/min) is given as

$$V_c = \frac{D}{1000} \dots\dots\dots \text{eqn. (1)}$$

where, D = Diameter of the work piece in mm

### 2.3.2 Feed

Feed is the amount of material the tool tip moves for each rotation of the work piece along its path of travel. It is given in mm/rev and is indicated by the letter "f." Occasionally, it is also stated as the spindle speed in mm/min as

$$F_m = FN \dots\dots\dots \text{eqn. (2)}$$

where,

f = Feed in mm/rev

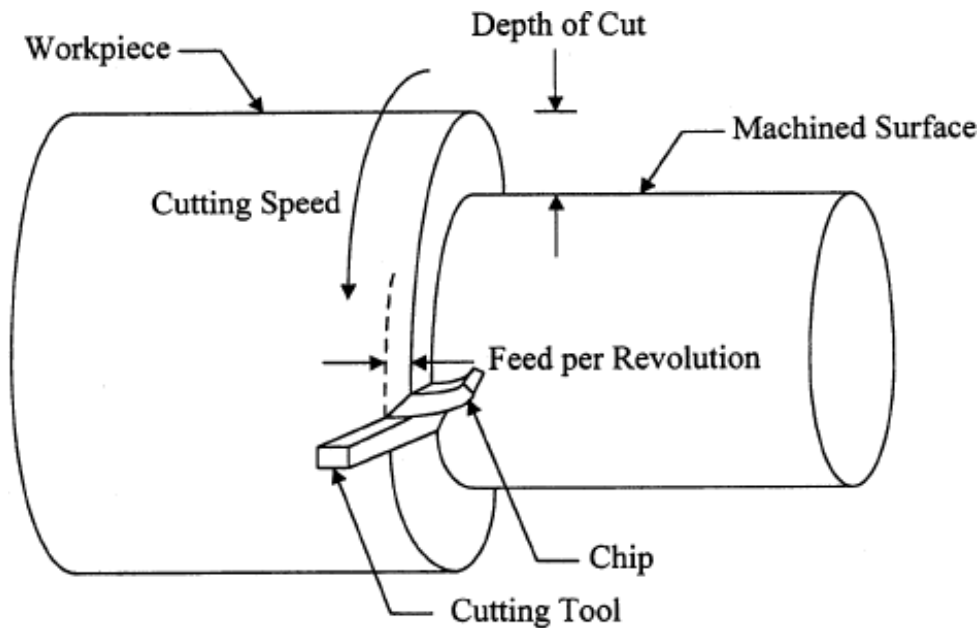
N = Spindle speed in rpm

### 2.3.3 Depth of cut

The distance between the freshly machined surface and the uncut surface is known as the depth of cut (d). In other words, it refers to how much of the work piece's material is being eliminated. It can alternatively be described as the tool's level of penetration into the workpiece as measured from its surface prior to rotation. Due to the rotation of the tool, the thickness is removed from both sides, causing the diameter to be lowered by twice the depth of cut.

$$d = \frac{D_1 - D_2}{2} \dots\dots\dots \text{eqn. (3)}$$

where,  $D_1$  = Initial diameter of job  $D_2$  = Final diameter of job



**Fig 6: The adjustable machining parameters**

## **2.4 CUTTING TOOL**

A cutting tool is a component of a machine tool that removes extra material from the work piece through shear deformation and direct mechanical abrasion. According to Choudhury et .al and Schenider, an efficient cutting tool should have the following characteristics –

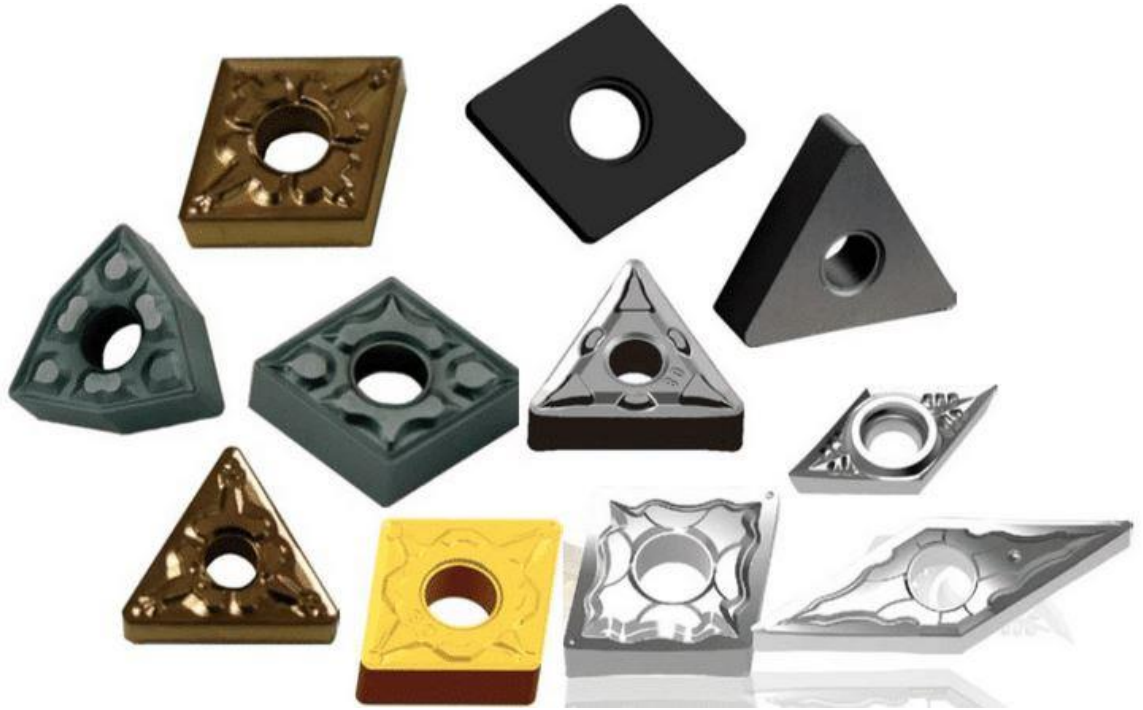
- a) **Hardness:** It is ideal for the work material to be softer than the tool material.
- b) **Hot hardness:** At the high temperatures experienced throughout the machining process, the tool must keep its hardness.
- c) **Wear Resistance:** Before wearing out and needing to be replaced, the tool should have performed to the acceptable degree of life.
- d) **Toughness:** The material must be robust enough to endure vibrations and shocks.

The tool shouldn't break or chip while cutting intermittently.

For the ensuing study, the cutting tool used will be a clamped insert-type tool.

## **2.5 Cutting Tool Insert**

The phrase "Insert" describes the circumstance in which a cutting tool is screwed or fastened to a holder that is then secured to the tool post. Various locking systems are used to clamp inserts. The benefit of inserts is that they may be rotated to present a new cutting edge when a specific edge becomes worn out. After all of these edges have been utilised, the insert can occasionally, if the geometry permits, be withdrawn, turned upside down, and fastened again to reveal a brand-new collection of cutting edges. Inserts are available in a wide variety of sizes and forms, some of which are depicted in Fig. 5.



**Fig 7: Various shapes of cutting tool inserts**

### **2.5.1 Insert Material**

There is a wide range of cutting tool materials available, and each has unique characteristics and functional capabilities. Carbon speed steels, carbides, HSS, CBN, and diamond are a few examples of insert materials. Because they can be machined at greater temperatures and faster speeds, carbide tools are frequently used in the metal cutting sector.

### **2.5.2 Insert Coating**

To improve it, the cutting tool insert has a coating. There are many different coating materials, and each has its own unique uses and benefits. One of the popular techniques for coating a cutting tool is physical vapour deposition (PVD). Chemical vapour deposition is

another method (CVD). Tool steels cannot be coated with CVD coating because it demands a higher temperature. the use of Titanium Nitride (TiN) can be applied using the PVD technique at substantially lower temperatures (about 40000 C). Additionally, PVD promotes the development of corners with a reduced coefficient of friction.

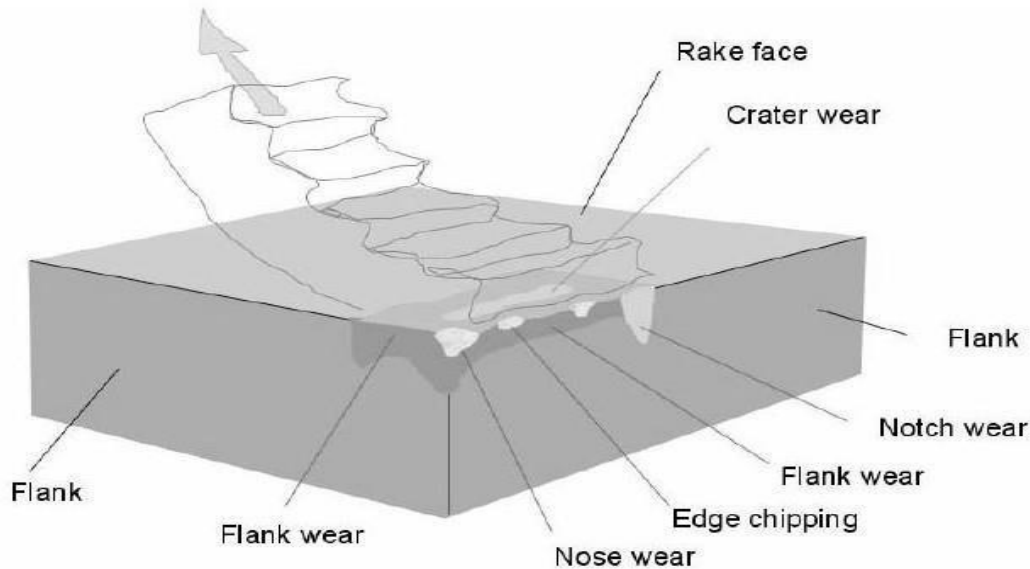
## **2.6 TOOL WEAR**

Every traditional machining procedure involves the inevitable occurrence of tool wear. According to Bin Halim, tool wear is comparable to the slow deterioration of a pencil's tip. Cutting tool failure occurs gradually as a result of routine use . The material of the tool, its shape and geometry, the material of the work piece, etc. all affect how quickly a tool wears out. Process parameters are the most significant elements determining tool wear that are easilycontrollable.

The temperature reached during machining is a significant impact in the rate at which materials wear out their tools. The general theory is that a significant portion of the energy used for cutting is transformed into heat and removed in the chip. As a result, the cutting tool receives around 20% of the heat produced. It is possible to see the following kinds of tool wear modes.

## 2.7 Some of these tool wear modes can be evident from Fig 8

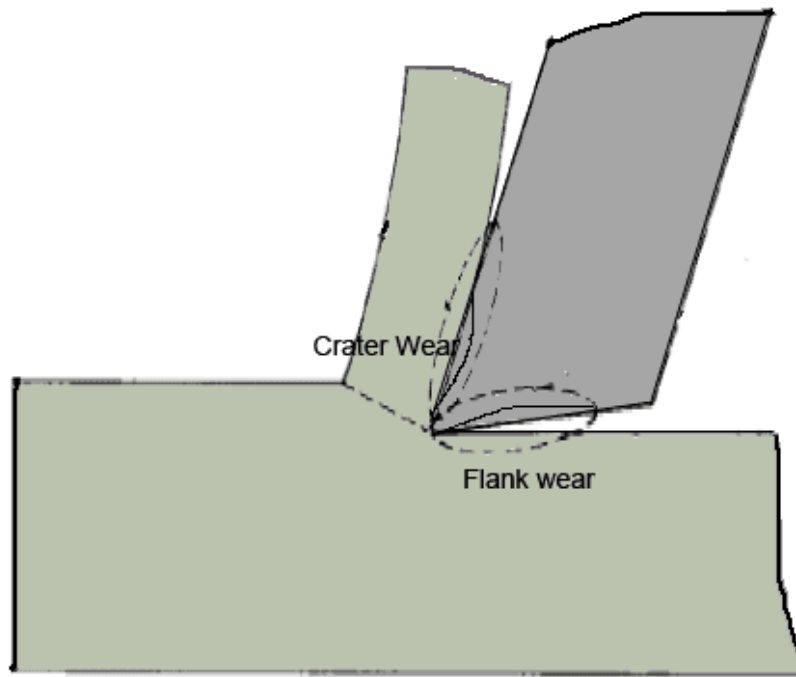
Even for short machining durations, the two main types of wear—flanker wear and crater wear—appear fairly immediately. This study will be focusing on these two types only as our machining time was chosen to be 1 min.



**Fig 8: Different modes of tool wear**

### 2.7.1 Flank Wear

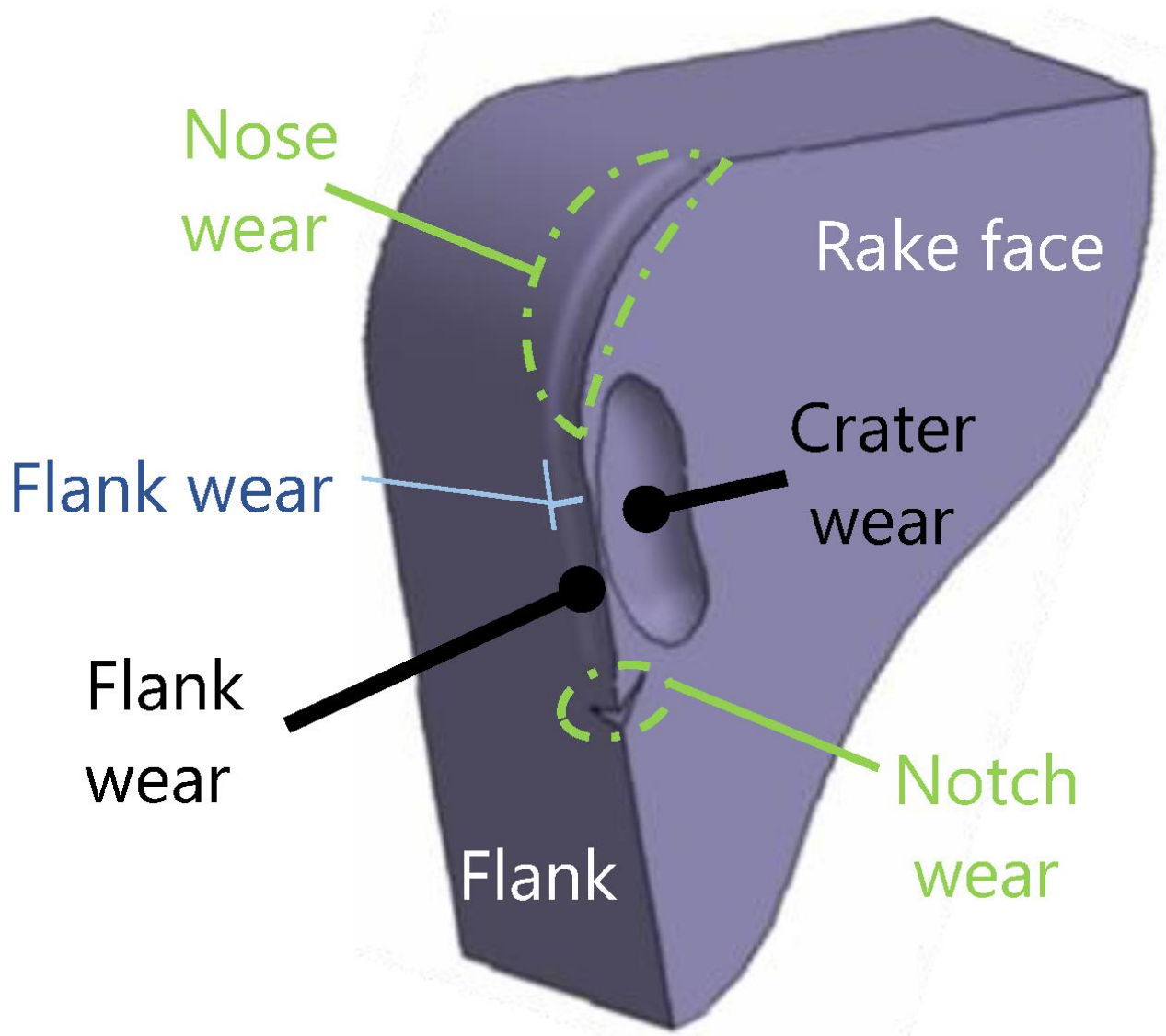
Flank wear (Fig 9,) is the wear that occurs on the flank surface or flank faces of the cutting tool. This happens as a result of mechanical friction and direct abrasion that take place throughout the operation between the flank surface and the work piece. A simple way to measure flank wear is the breadth of the wear land. The letter VB stands for width. When the average flank wear land reaches 300  $\mu$ m or the maximum flank wear land reaches 600  $\mu$ m, the tool life is typically regarded as being over. Choudhury and Srinivas found that cutting speed and diffusion coefficient index have the most notable effect on the flank wear, followed by feed and depth of cut.



**Fig 9 : Flank wear**

### **2.7.2 Crater Wear**

Crater wear is the wear that develops on the rake face or top face of the cutting tool (Fig. 10.). It takes place parallel to the main cutting edge. This kind of erosion happens when a chip rubs against the rake face while being machined. The temperature at the chip- tool interference and the chemical affinity between the tool and work materials at the high temperatures experienced during machining, according to Kalpakjian and Schmid are the two most prominent parameters that influence the crater wear phenomenon. Crater wear is influenced by the same factors that drive flank wear B.V. Manoj Kumar, J. Ram Kumar and Bikramjit Basu, found out during the dry machining of boiler steel using TiCN-Ni-WC cermet inserts that crater wear increases significantly with cutting speed and feed.



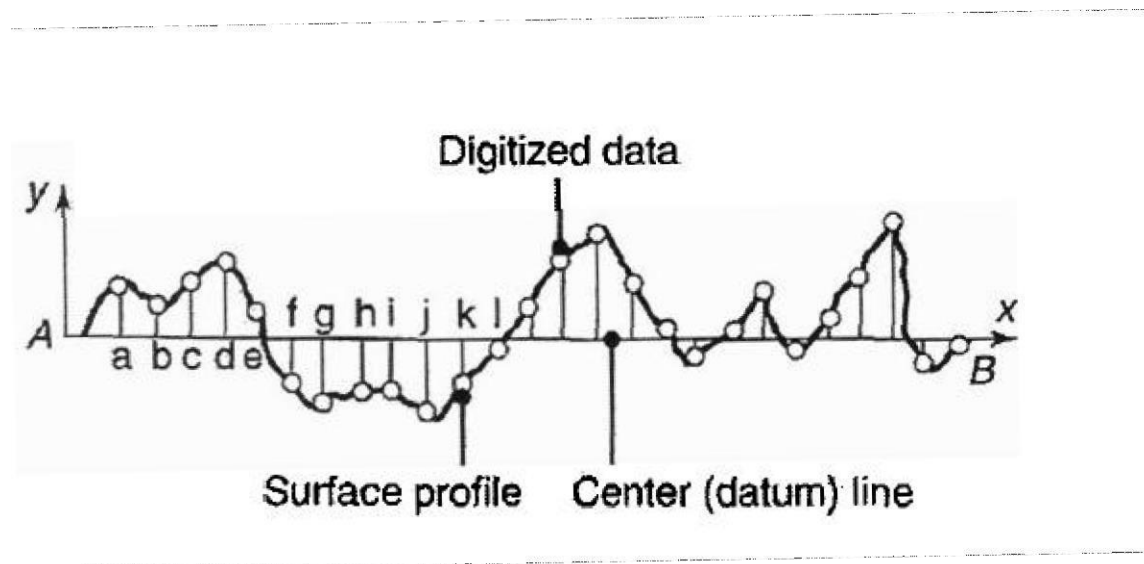
**Fig 10: Crater wear**

## 2.8 SURFACE ROUGHNESS

Surface roughness is a metric for a product's surface polish and a barometer for its quality. The heights of a physical surface's minor changes in size are measured as surface roughness. It is expressed through a variety of techniques, like arithmetic mean or centre-line average (Ra), Root-mean square average (Rq), maximum peak (Ry), ten-point mean roughness (Rz), maximum valley depth (Rv), maximum height of profile (Rt = Rp – Rv) etc. Out of all these, the most commonly used indicator for surface roughness is Ra.

Ra, or the arithmetic mean value, previously known as AA (Arithmetic Average) or CLA (Centre-Line Average) is the arithmetic mean of deviations of a series of points from the centre line or datum line. The datum line is such that sum of the areas under the profile above the datum will be equal to the sum of areas below the datum. Generally, surface roughness is expressed in microns (µm).

$$Ra = \frac{a+b+c+d+e+f}{n} \dots \dots \dots \text{eqn. (4)}$$



**Fig 11: Co-ordinates used for Surface Roughness Measurement**

Studies by Sahin Y. and Motorcu A.R, have shown that surface roughness is mostly dependent on feed rate which is the dominating factor.

The surface roughness is usually measured in a direct way by the use of devices called Profilometer. The Profilometer is a stylus probe instrument in which the stylus mounted in the pick-up unit traverses across the machined surface by means of a motor drive. The pick-up receives and rectifies the output which is further amplified and the average height of the roughness is reported digitally. One of the common types of Profilometer available is the Taylor-Hobson Talysurf. It works on the principle of carrier modulation.

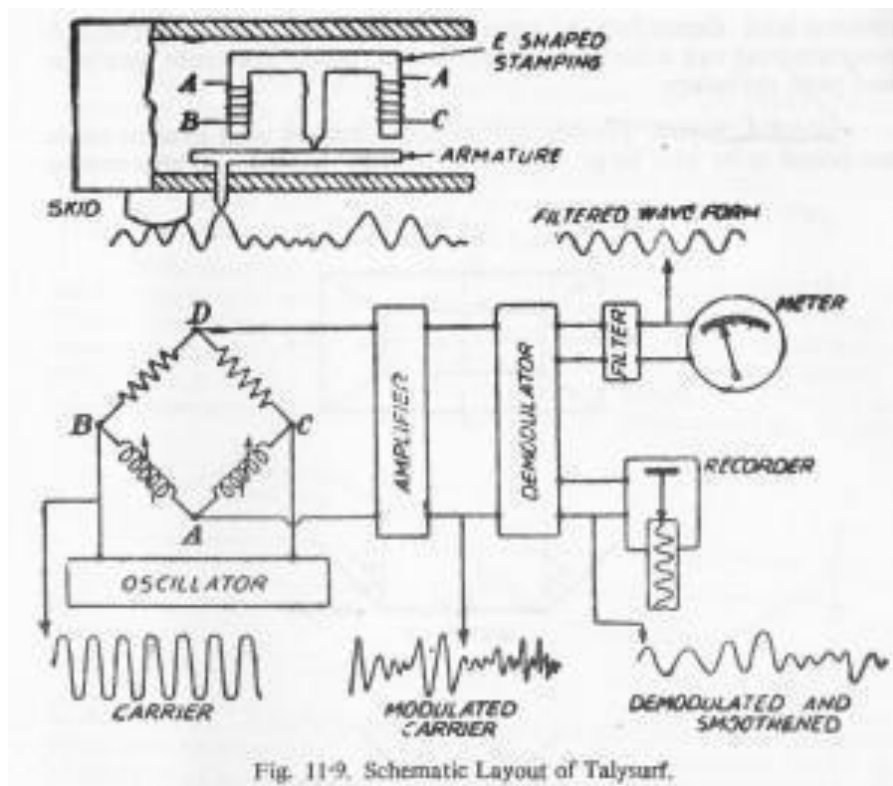


Fig. 11-9. Schematic Layout of Talysurf.

### Fig 12: Schematic Layout of Talysurf

The schematic layout of the Talysurf is shown in the above figure from. It consists of a diamond stylus with a tip radius of 0.002mm. The arm carrying the stylus forms an armature

which pivots about the center leg of E-shaped stamping. Coils are wound around the two outer legs of the E-shaped stamping and they carry alternating current. These two coils with other two resistances form an oscillator. Movements in the stylus cause a variation in the air gap between the armature and the stamping thereby modulating the amplitude of the alternating current. The demodulator demodulates the signals such that the current becomes directly proportional to only the vertical displacements of the stylus. The output is fed to a recorder which records and produces the numerical output.

## **Chapter 3**

### **DESIGN OF EXPERIMENTS**

### 3.1 Design of experiments

Design of experiments (DOE) is a structured method that is used to identify relationships between several input variables and output responses. With the help of DOE, the resources needed to carry out the experiment can be optimized. Hence, it finds wide use in R & D studies. A few methods used as DOE are Taguchi Method, Response Surface Method and Factorial Designs. We will be focusing on the Response Surface Methodology during the ensuing study.

### 3.2 Response Surface Methodology (RSM)

Response Surface Method (RSM) is a collection of mathematical and statistical tools which are useful for the modeling and analysis of problems in which an output response of interest is influenced by several input variables and our objective is to optimize (minimize or maximize based on the need) the response. It is a method which was developed by Box and Wilson in the early 1950's. It is capable of establishing causal relationships between input and output variables.

For „n“ number of measurable input variables, the response surface can be given as –

$$Y = f(x_1, x_2, x_3, x_4 \dots x_n) + \epsilon \dots \dots \dots \text{eqn. (5)}$$

Where,  $x_1 \dots x_n$  are the independent input parameters and  $\epsilon$  is the random error.  $Y$  is the output or response variable which has to be optimized.

In a turning operation with three input variables, the response function can be written as –

$$Y = f(x_1, x_2, x_3) + \epsilon \dots \dots \dots \text{eqn. (6)}$$

Where,  $x_1 = \log V_c$ ,  $x_2 = \log f$ , and  $x_3 = \log d$ .  $Y = \log Ra$  and  $\epsilon$  is the random error.

Usually, RSM is used in conjunction with multiple regression models. Finding a good approximation for the response function that the regression models can produce is our aim. For example, the first order or linear multiple regression model can be used –

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \epsilon \dots \dots \dots \text{eqn. (7)}$$

For better approximation, interaction terms can be included –

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_{12} x_1 x_2 + \beta_{13} x_1 x_3 + \beta_{23} x_2 x_3 + \epsilon \dots \dots \dots \text{eqn. (8)}$$

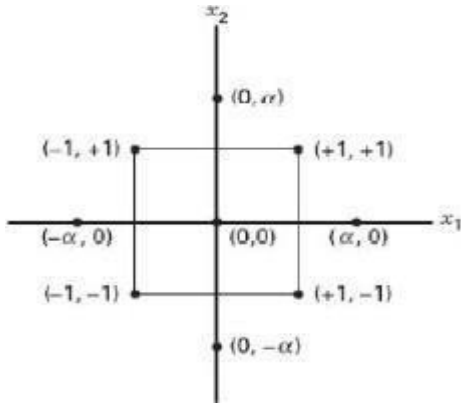
The second order or quadratic regression model includes the square terms in addition to the terms above –

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \beta_{33} x_3^2 + \beta_{12} x_1 x_2 + \beta_{13} x_1 x_3 + \beta_{23} x_2 x_3 + \epsilon \text{ eqn. (9)}$$

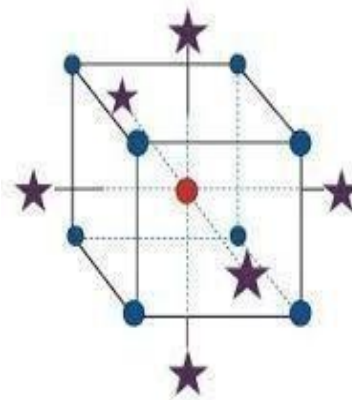
The quadratic model given in above equation is generally utilized in RSM problem, the simplicity comes from the availability of several lovely designs for fitting quadratic models, for example. Central Composite Design (CCD) and Box-Behnken Design.

### 3.3 Central Composite Design (CCD)

One of the most widely used models for fitting second-order models is CCD. A  $2^k$  factorial design with  $n_j$  runs,  $2k$  axial or star runs, and  $n_c$  centre runs often makes up the CCD. The CCD for  $k = 2$  and  $k = 3$  factors is shown in the image below (Fig. 11).



(a)  $k = 2$



(b)  $k = 3$

**Fig.13: Central Composite Design for 2- and 3-factors**

#### 3.3.1 Central Composite Design for 2- and 3-factors, Fig. 13

A  $2^k$  first order model is utilised initially. Axial and centre runs are added to the model in order to include the quadratic terms if the model does not fit. For the axial runs, it's critical to choose the value of  $\alpha$ . The design is said to be face-centered if  $\alpha = 1$ . Additionally, the number of centre points must be chosen. 6 centre points are typically chosen for a CCD with three input parameters to get 20 as the total number of runs including 8 cube points (cube corners and 6 axial/star points (Fig b)

### 3.4 WORK MATERIALS

D2 steel is a high-carbon, high-chromium tool steel that air hardens. High wear and abrasion resistance characteristics are present. It can be heated to a hardness between 55 and 62 HRC and is machinable in the annealed state. On proper hardening, D2 steel exhibits low deformation. The high chromium concentration of D2 steel gives it some modest corrosion resistance after it is hardened

**Table 1: Chemical composition (wt %) of D2 Steel**

<b>Element</b>	<b>Wt %</b>
Iron, Fe	68
Chromium, Cr	11-13
Nickel, Ni	0.30
Manganese, Mn	0.60
Silicon, Si	0.60
Nitrogen, N	0.25
Carbon	1.40-1.60
Phosphorous, P	0.03
Copper	0.25

**3.5 INSERT MATERIAL**

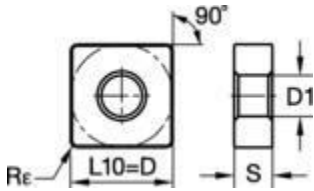
The coated carbide tool insert chosen was one made by Kennametal, and its specs are listed below. It has been discovered that coated carbide tools perform better than uncoated ones.

**Table 2: Specification of Cutting Tool**

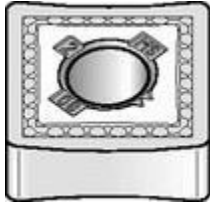
ISO Catalog Number	ANSI Catalog Number	Grade	Dimensions									
			D		L10		S		R <sub>ε</sub>		D1	
			mm	in	mm	in	mm	in	mm	in	Mm	in
SNMG  120408	SNMG  432MS	KCU25	12.70	0.5	12.70	0.5	4.76	0.1875	5.16	0.203		

The specifications of the coated carbide tool insert used, which was made by Kennametal, are provided below. Tools made of carbide that have been coated have been found to perform better than those that have not.

Special surface treatments that enhance machining performance in high-temperature materials are a benefit of PVD coating technology. The coating on the insert is TiAlN (Titanium Aluminium Nitride).

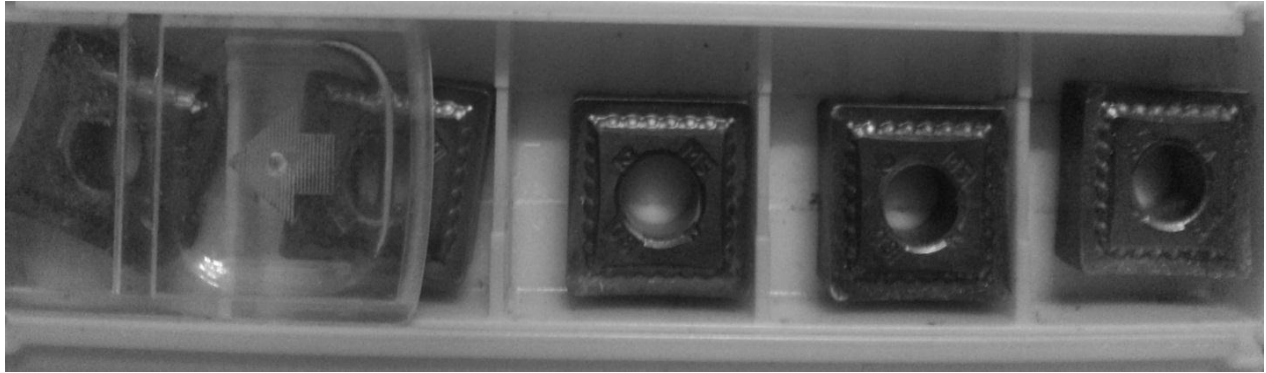


(a)



(b)

**Fig 14: Selected cutting tool insert**



**Fig 15: Set of cutting inserts used in the experimentation.**

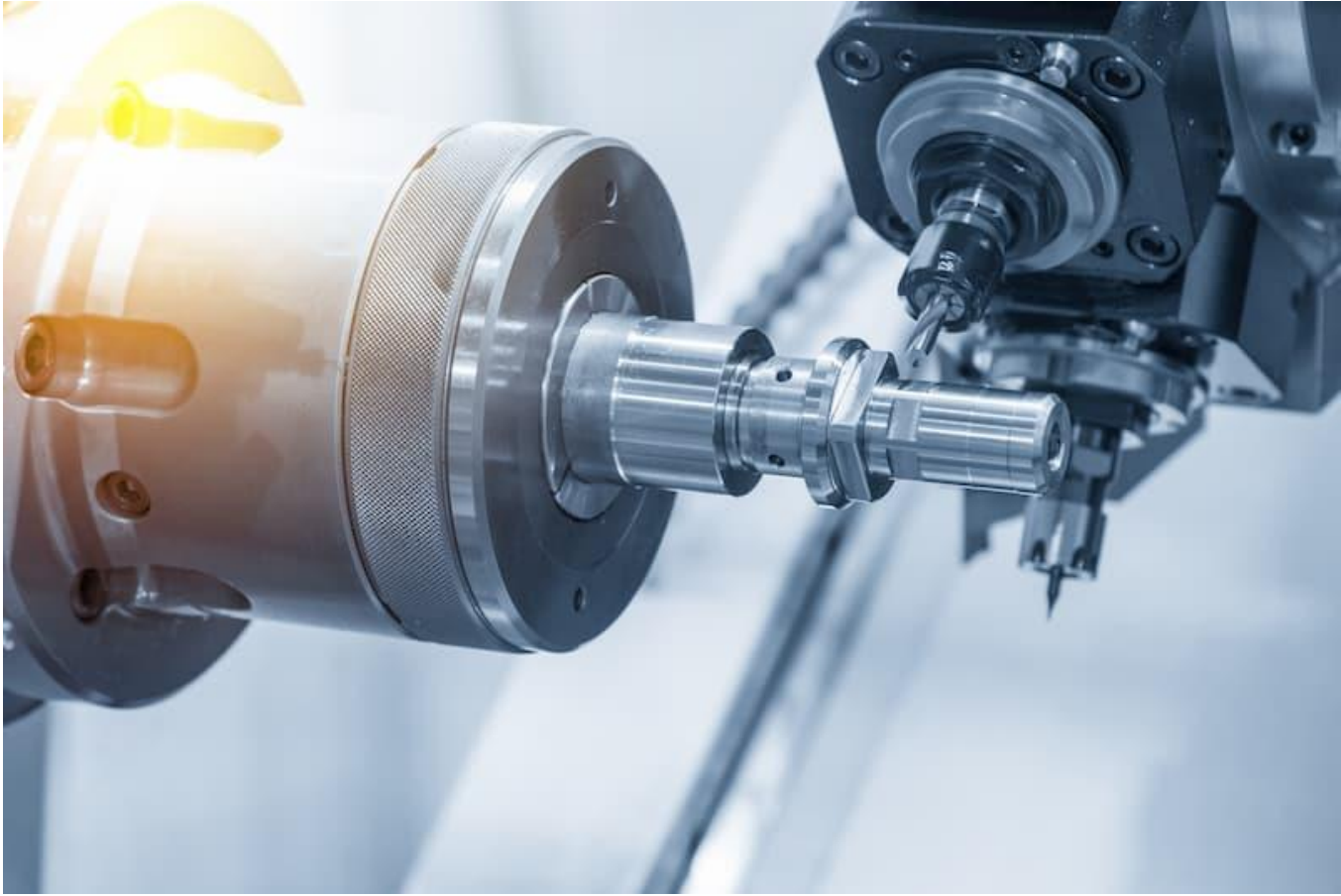
**Chapter 4**  
**METHODOLOGY**

#### **4.1 EXPERIMENTAL SETUP AND INITIAL PREPARATION**

The machining was done on a centre lathe. The insert was installed on the tool post after being clamped in a holder. The lathe's chuck kept the task firmly in place. A skin pass was completed after centre drilling, and the job was held at the other end by the tail stock. As a result, the setup was finished, and the runs could now be performed.



**Fig 16: Experimental Setup**



**Fig 17: Mounting of tool and workpiece**

## **4.2 CUTTING CONDITION**

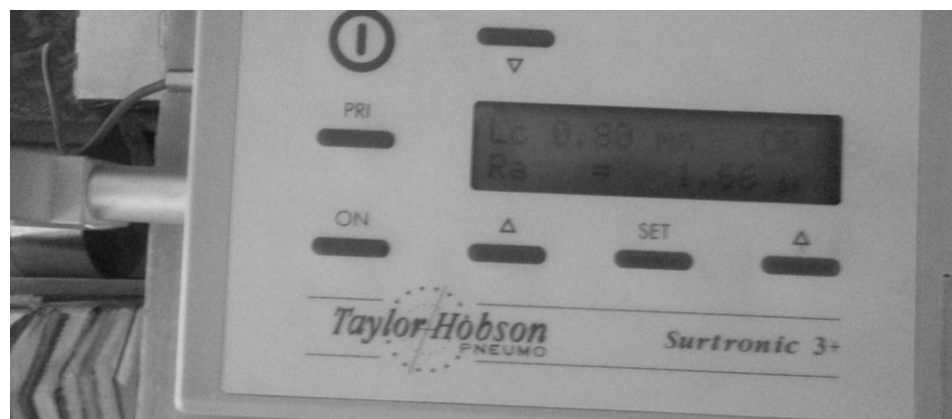
The experimentation was done in a dry cutting environment. Dry cutting is a machining technique that doesn't need coolant. Dry cutting reduced the need for cutting fluid and its associated costs. Cutting fluids are environmentally unfriendly and corrosive. Dry cutting is more environmentally friendly and lowers machining costs. Additionally, inserts operate more effectively at higher cutting temperatures obtained during dry cutting.

### 4.3 MEASUREMENT OF SURFACE ROUGHNESS

A handheld stylus-style profilometer called Talysurf (Taylor Hobson, Surtronic 3+, UK) has been used to precisely assess surface roughness. For each run, the average of measurements made at several sites was given.



**Fig 18: Talysurf setup for measuring surface roughness**



**Fig 19: Reading shown in Talysurf**

#### 4.4 MEASUREMENT OF TOOL WEAR

For each run, a fresh cutting edge was applied. Using a Toolmaker's Microscope (Fig. 18) with a digital read-out device, the resulting tool wear was measured (Fig 20). Fig. 19 also displays a view of the tool insert as seen via the eyepiece.

**Table 3: Specification of Toolmaker's Microscope**

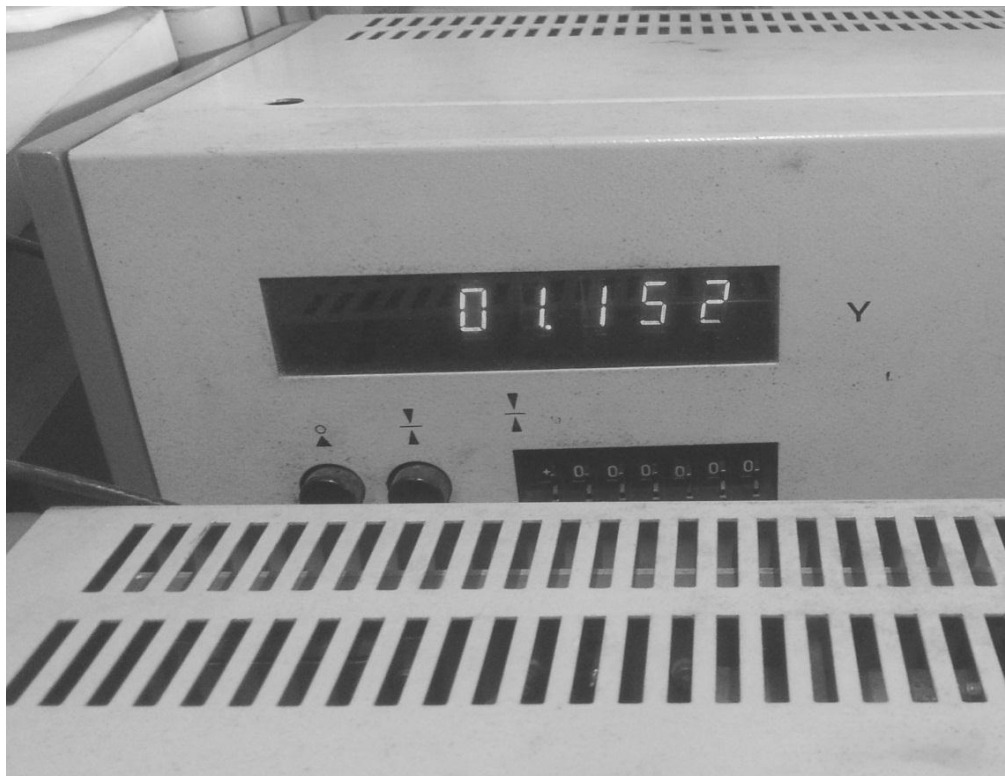
1.1	Nr	14832
DDR	Made in the CDR Achsenhohe 42.52 mm	
1554		



**Fig 20: Toolmakers' Microscope**



**Fig 21: Through the eyepiece, you can see the insert.**



**Fig 22: Digitized reading of tool wear**

#### 4.5 PROCESS PARAMETERS

The levels of the selected cutting parameters are displayed in the following table (Table 5).

**Table 4: Factors and levels for the Response Surface Study**

Code	Parameter	Level (-1)	Level (+1)
A	Cutting Speed (m/min)	66	112
B	Feed (mm/rev)	0.05	0.15
C	Depth of cut (mm)	0.4	0.8

#### 4.6 LAYOUT OF EXPERIMENT FOR RSM

The experiment layout was obtained in accordance with the 3-level full-factorial Central Composite Design with 8 cube points, 6 axial points, 4 centre points, and 2 centre points in axial, resulting in a total of 20 runs.  $\alpha$  was chosen as 1 to make the design face centered. Table 5 below contains the experimental layout

**Table5: Design layout/Run Table**

<b>Std Order</b>	<b>Run Order</b>	<b>Pt Type</b>	<b>Blocks</b>	<b>Cutting Speed (m/min)</b>	<b>Feed (mm/rev)</b>	<b>Depth of Cut (mm)</b>
<b>1.</b>	4	1	1	66	0.05	0.4
<b>2.</b>	1	1	1	112	0.15	0.4
<b>3.</b>	3	1	1	112	0.05	0.8
<b>4.</b>	2	1	1	66	0.15	0.8
<b>5.</b>	15	0	1	89	0.1	0.6
<b>6.</b>	16	0	1	89	0.1	0.6
<b>7.</b>	7	1	2	112	0.05	0.4
<b>8.</b>	6	1	2	66	0.15	0.4
<b>9.</b>	8	1	2	66	0.05	0.8
<b>10.</b>	5	1	2	112	0.15	0.8
<b>11.</b>	17	0	2	89	0.1	0.6
<b>12.</b>	18	0	2	89	0.1	0.6
<b>13.</b>	10	-1	3	66	0.1	0.6
<b>14.</b>	9	-1	3	112	0.1	0.6
<b>15.</b>	13	-1	3	89	0.05	0.6
<b>16.</b>	11	-1	3	89	0.15	0.6
<b>17.</b>	12	-1	3	89	0.1	0.4
<b>18.</b>	14	-1	3	89	0.1	0.8
<b>19.</b>	19	0	3	89	0.1	0.6
<b>20.</b>	20	0	3	89	0.1	0.6

## **Chapter 4**

### **RESULTS AND DISCUSSIONS**

#### 4.1 EXPERIMENTAL RESULTS

Table 6 shows that the model's P-Value is 0.033, which is less than the significance level of 0.05. The model is important as a result. With a P-value of 0.11, the lack of fit is insignificant, which is preferable. With the lowest P-value of the three parameters, feed is discovered to be the factor that has the most bearing on surface roughness.

The results obtained from the experimental work are summarized in the Table 6.

**Table 6: Results Obtained**

Std Order	Run Order	Cutting Speed (m/min)	Feed (mm/rev)	Depth of Cut (mm)	Ra ( $\mu\text{m}$ )	Flank wear (mm)
1	4	66	0.05	0.4	0.947	0.443
2	1	112	0.15	0.4	1.513	0.768
3	3	112	0.05	0.8	1.353	0.932
4	2	66	0.15	0.8	1.7	1.17
5	15	89	0.1	0.6	0.86	1.629
6	16	89	0.1	0.6	0.887	1.209
7	7	112	0.05	0.4	0.88	0.487
8	6	66	0.15	0.4	1.947	0.57
9	8	66	0.05	0.8	1.893	1.104
10	5	112	0.15	0.8	1.673	1.151
11	17	89	0.1	0.6	1.053	1.844
12	18	89	0.1	0.6	1	1.604
13	10	66	0.1	0.6	1.16	0.928
14	9	112	0.1	0.6	0.96	1.001
15	13	89	0.05	0.6	2.16	0.948
16	11	89	0.15	0.6	2.013	0.859
17	12	89	0.1	0.4	1.413	0.788
18	14	89	0.1	0.8	1.007	1.116
19	19	89	0.1	0.6	0.967	1.807
20	20	89	0.1	0.6	0.96	1.793

## 4.2 ANALYSIS OF RESULTS AND PLOTS

The results obtained from the experiment were fed into MINITAB for further analysis.

## 4.3 ANOVA

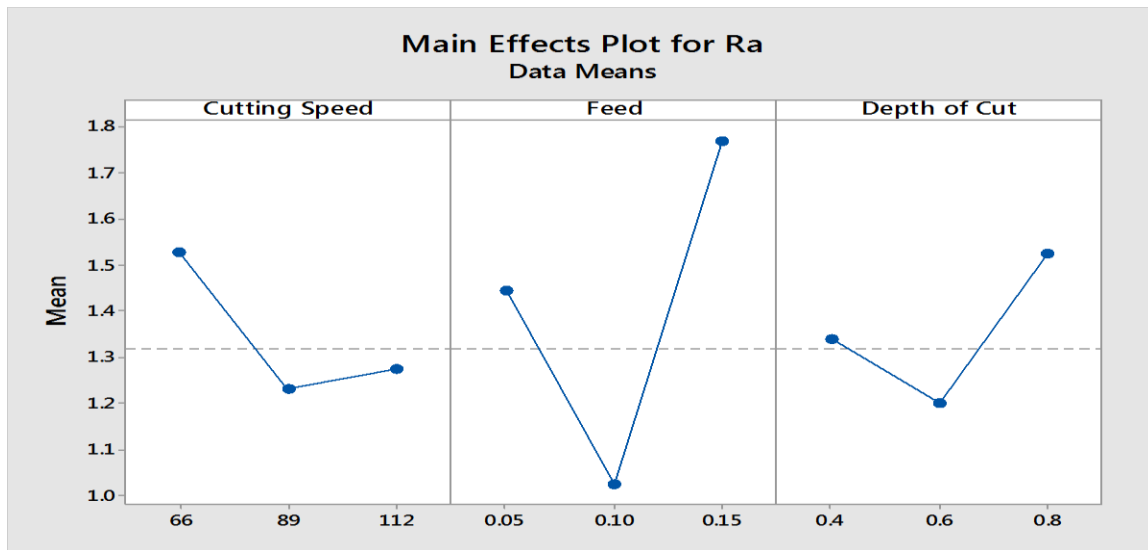
The significance and impact of the cutting parameters on the response variables, Ra and Tool wear, were investigated using the analysis of variance (ANOVA) (Tables 7 and 8).

**Table 7: ANOVA for Surface Roughness**

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	9	2.7542	0.30602	3.47	0.033
Linear	3	0.50671	0.1689	1.92	0.191
Cutting Speed	1	0.16078	0.16078	1.82	0.207
Feed	1	0.26018	0.26018	2.95	0.117
Depth of Cut	1	0.08575	0.08575	0.97	0.347
Square	3	1.96078	0.65359	7.41	0.007
Cutting Speed*Cutting Speed	1	0.16281	0.16281	1.85	0.204
Feed*Feed	1	1.68678	1.68678	19.13	0.001
Depth of Cut*Depth of Cut	1	0.02395	0.02395	0.27	0.614
2-Way Interaction	3	0.28671	0.09557	1.08	0.4
Cutting Speed*Feed	1	0.00266	0.00266	0.03	0.865
Cutting Speed*Depth of Cut	1	0.00054	0.00054	0.01	0.939
Feed*Depth of Cut	1	0.2835	0.2835	3.21	0.103
Error	10	0.88184	0.08818		
Lack-of-Fit	5	0.8564	0.17128	33.66	0.11
Pure Error	5	0.02545	0.00509		
Total	19	3.63604			

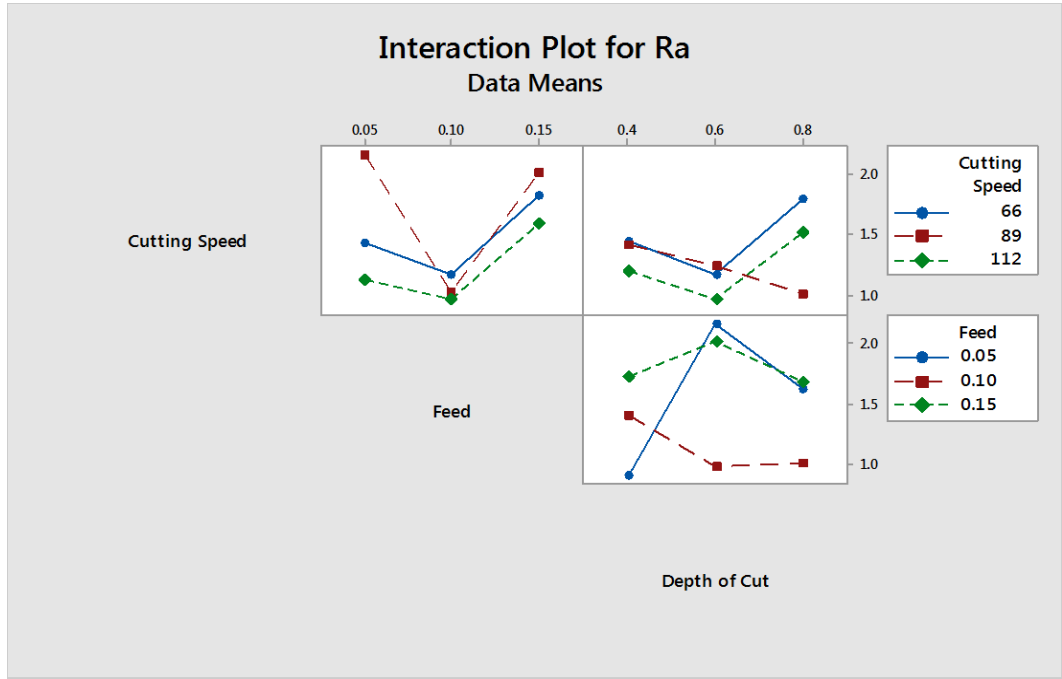
We can see from Table 8 that the model's P-Value is 0.049, which is less than the significance level of 0.05. The model is important as a result. With a P-value of 0.141, the lack of fit is insignificant, which is preferable. With the lowest P-value (0.041, significant) among the three parameters, depth of cut is discovered to be the factor that has the most influence on the stool wear.

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**Fig 23: Main effects Plot for RA**

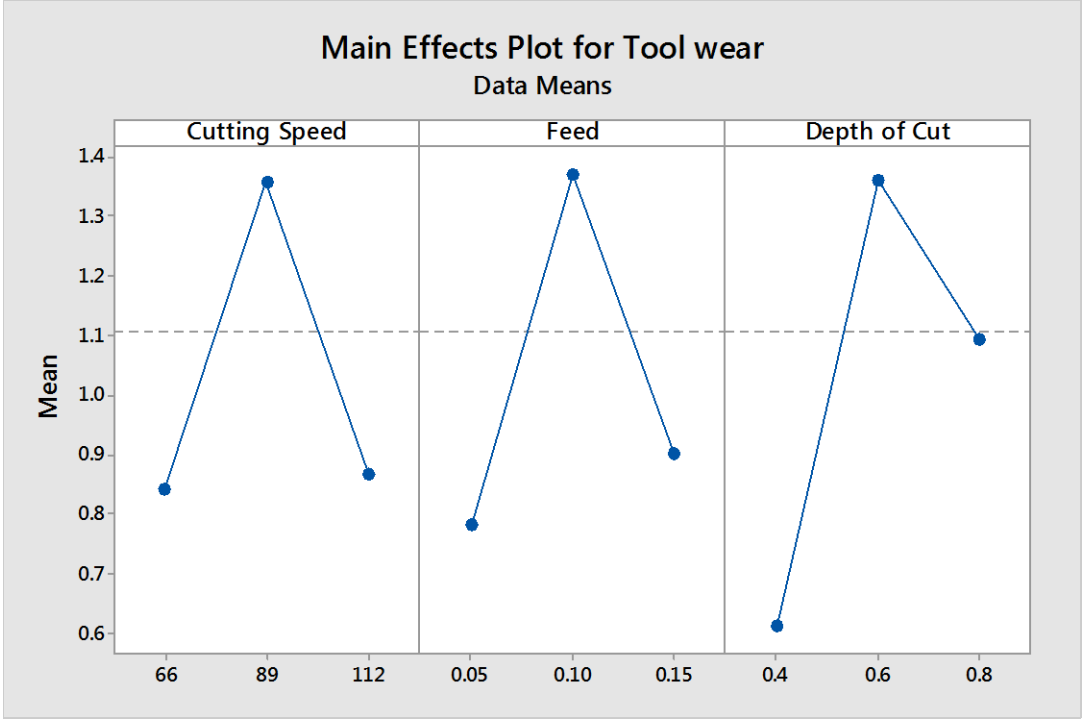
Ra's primary effects plot (Fig. 21) demonstrates how the surface roughness first drops off sharply as cutting velocity increases. It gradually rises with an increase in cutting velocity after a certain point. In the case of feed, the same thing occurs, but the increase after that specific point is particularly steep. Ra likewise decreases as the depth of cut increases up to a certain point, at which point it is discovered to sharply increase as the depth of cut continue to increase.



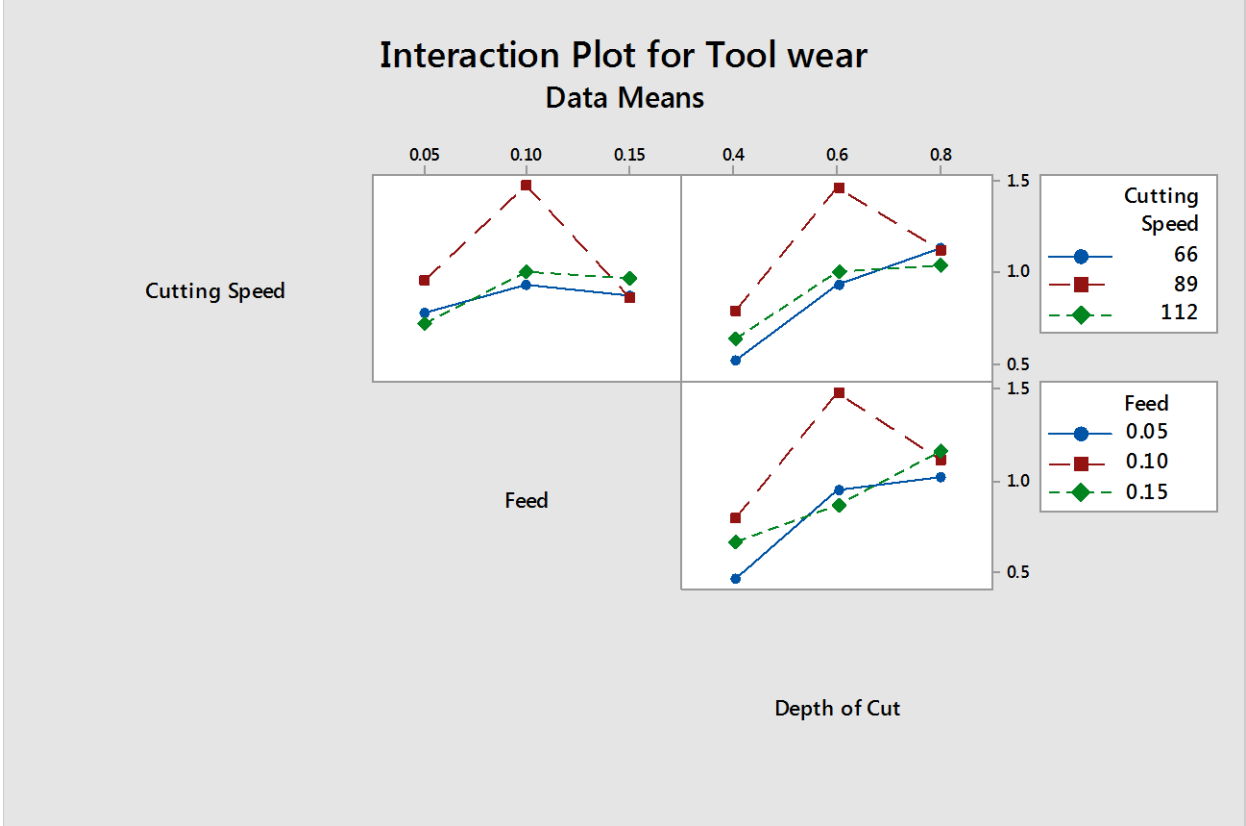
**Fig 24: Interaction plot for Ra**

**Table 8: ANOVA for Tool Wear.**

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	9	2.46551	0.273945	2.57	0.049
Linear	3	0.62221	0.207403	1.95	0.186
Cutting Speed	1	0.00154	0.001538	0.01	0.907
Feed	1	0.03648	0.036782	0.34	0.571
Depth of Cut	1	0.58419	0.584189	5.48	0.041
Square	3	1.80619	0.602063	5.65	0.016
Cutting Speed*Cutting Speed	1	0.12033	0.120332	1.13	0.313
Feed*Feed	1	0.20075	0.200745	1.88	0.2
Depth of Cut*Depth of Cut	1	0.13514	0.135143	1.27	0.286
2-Way Interaction	3	0.03711	0.012369	0.12	0.949
Cutting Speed*Feed	1	0.01178	0.011781	0.11	0.746
Cutting Speed*Depth of Cut	1	0.02344	0.023436	0.22	0.649
Feed*Depth of Cut	1	0.00189	0.001891	0.02	0.897
Error	10	1.06518	0.106518		
Lack-of-fit	5	0.8564	0.157088	2.81	0.141
Pure Error	5	0.27974	0.055948		
Total	19	3.53068			



**Fig 25: Main effects plot for Tool wear**



**Fig 26: Interaction plot for Tool Wear**

# RESIDUAL PLOTS

The residual plots for tool wear and surface roughness are shown in Figures 25 and 26, respectively.

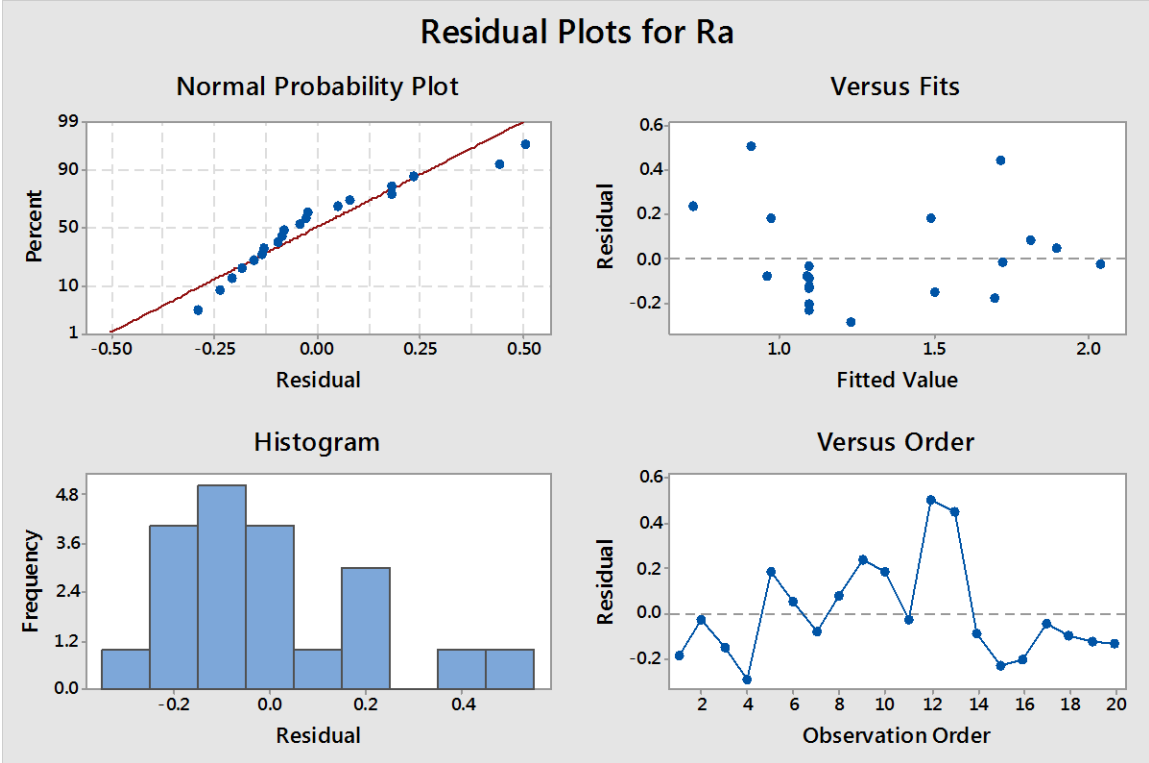
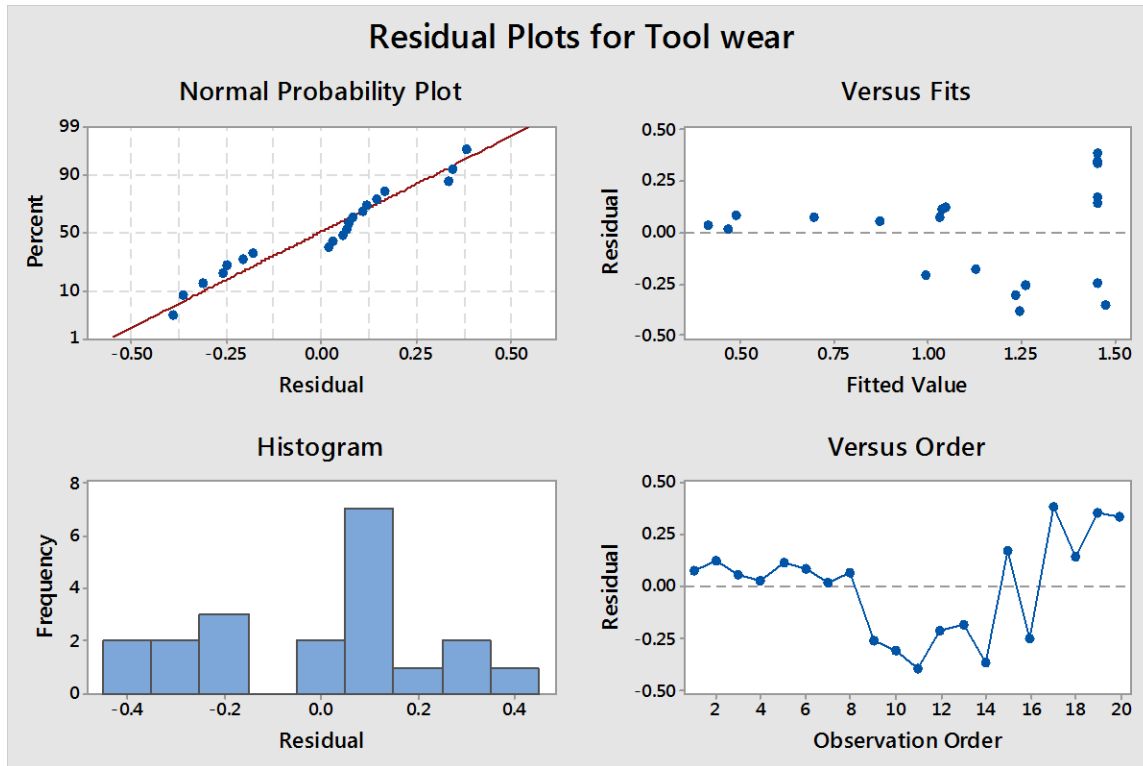


Fig 27: Residual Plots for Ra

The points in the normal probability plot that fall on a straight line indicate that the model is appropriate. It indicates that the errors are dispersed normally. Additionally, there is no evident trend in the plot of the residuals versus the projected response.



**Fig 28: Residual plots for Tool Wear**

Once more, the model is sufficient as evidenced by the points in the normal probability plot falling on a straight line. It is a sign that the errors are regularly distributed, which is what a good-fit model should have. Additionally, a virtually bell-shaped normal distribution may be seen in the histogram.

Additionally, there is no evident pattern in the plot of the residuals versus expected tool wear.

**Chapter 5**  
**CONCLUSIONS**

For the given tool-work combination and the chosen domain of the input machining parameters, RSM was effectively used to optimize the surface roughness and tool wear. ANOVA analysis was performed, and it was discovered that the only significant component affecting tool wear was the depth of cut. Feed is the most important factor determining surface roughness, followed by cutting speed and depth of cut. It was discovered that  $V_c$  (112 m/min),  $f$  (0.0540404 mm/rev), and  $d$  were the ideal operating conditions (0.4 mm). On the basis of empirical models for surface roughness and tool wear, predictions for output responses for the right applications can be made.

Plain carbide tool was used for machining surface roughness was measured using Taylor Hobson apparatus. The results were input into the Minitab 18 software for ANOVA and obtaining the regression equation. The regression equation obtained can be used to predict the  $R_a$  and tool wear for any other inputs. The relative significance of each parameter for  $R_a$  and tool wear in case of dry machining was analyzed.

### **5.1 SCOPE FOR FUTURE STUDY**

Initially, it was intended to conduct the experiment using a mist application of cutting fluid. The experiment was carried out in a dry cutting setting due to the mist application equipment not being available due to some restrictions. The same tool-work combination for the same domain of cutting parameters as those selected in the current study might be used in the future, and its effects on surface roughness and tool wear could be researched and analysed.

Cutting forces might be added as an output response in addition to surface roughness and tool wear, which would be another way to improve the current study. Attempts can then be made aimed at determining the best machining parameters such that several factors might be optimised through a single experimental attempt.

In order to improve the efficacy of the fitted model, any tool geometry parameter from among

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impacts on the output responses.

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# Optimization of machining Parameters in CNC machining of D2 Steel Using Taguchi Method

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## **Abstract**

The goal of this project is to machine D2 steel using CNC turning and to research the influencing parameters of surface roughness and MRR during machining materials. The MRR and Surface roughness of the CNC Turning process parameters of feed rate, depth of cut, spindle speed/rotational speed, and lubrication have been examined. For the experiments, a carbide tip tool was employed as a cutting tool. Taguchi's L18 mixed type orthogonal array experimental design was chosen for inquiry, and Taguchi's technique was used to optimise the design, as well as analysis of variance (ANOVA) to determine the relevance of process factors on the response variable.

## **I. INTRODUCTION**

Any manufacturing industry in the world strives to fulfil two key goals: quality and client requirements. In any industrial industry, machining is one of the most important metal processing procedures. Many process parameters influence the quality of metal cutting. The output responsiveness or performance qualities are influenced by these process factors. As a result, selecting the right process parameter is crucial in machining processes. Poor process parameter selection leads to non-optimal machine operation, resulting in poorer material removal rate, lower surface finish, longer machining time, shorter tool life, greater tool wear, and higher energy consumption, among other things. For example, there are numerous process parameters in a turning operation [cutting parameters, cutting tool parameters, work piece material (surface and temperature), ambient characteristics, and so on]. The turning operation is the most extensively utilised machining operation, and the current industrial condition necessitates researchers to develop improved process parameters to offer high-quality products while conserving energy. Various metrics like as feed and radial forces, Ra, tool wear, and work piece temperature are used to evaluate the machinability of materials in turning.

The current research focuses on machining stainless steel on a turning centre while optimising machining parameters.

Stainless steel is a low-density, corrosion-resistant, and long-lasting material with unique properties such as ease of joining, casting ease, high thermal conductivity, and formability.

D2 steel was chosen because it is widely employed in a variety of manufacturing industries for a wide range of applications.

Taguchi method, ANOVA methodology, fuzzy logic, and genetic algorithms are some of the optimization methods used.

algorithm and so on. ANOVA and the Taguchi technique are two of the most used approaches. The ANOVA is a statistical test that compares two groups



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The turning operation is a basic metal machining operation that is used widely in industries dealing with metal cutting [1]. The selection of machining parameters for a turning operation is a very important task in order to accomplish high performance [2]. By high performance, we mean good machinability, better surface finish, lesser rate of tool wear, higher material removal rate, faster rate of production etc. A fundamental metal machining technique that is frequently utilised in sectors that deal with metal cutting is turning [1]. To achieve excellent performance, choosing the right machining parameters for a turning operation is crucial [2]. High performance is defined as having good machinability, a better surface finish, lower tool wear, a higher rate of material removal, a higher rate of output, etc. The surface finish of a product is usually measured in terms of a parameter known as surface roughness. It is considered as an index of product quality [3]. Better surface finish can bring about improved strength properties such as resistance to corrosion, resistance to temperature, and higher fatigue life of the machined surface [4,5]. In addition to strength properties, surface finish can affect the functional behaviour of machined parts too, as in friction, light reflective properties, heat transmission, ability of distributing and holding a lubricant etc. [6,7]. Surface finish also affects production costs [3]. For the aforesaid reasons, the minimization of the surface roughness is essential which in turn can be achieved by optimizing some of the cutting parameters.

Tool wear is an inherent phenomenon in every traditional cutting operation. Researchers strive towards elimination or minimization of tool wear as tool wear affects product quality as well as production costs. In order to improve tool life, extensive studies on the tool wear characteristics