INVESTIGATION ON EFFECT OF CNC PARAMETERS ON SURFACE ROUGHNESS AND MRR ON EN31 STEEL USING HIGH SPEED TURNING OPERATION

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by

MOHD LARAIB

(Enrollment No. 1700101467)

Under the Supervision of

Dr. Mohd Faizan Hasan

Assistant Professor

DEPARTMENT OF MECHANICAL ENGINEERING
INTEGRAL UNIVERSITY, LUCKNOW
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This is to certified that **Mr. Mohd Laraib** (Enrollment No. 1700101467) has carried out the research work presented in this thesis entitled "**Investigation on Effect of CNC Lathe Machine Parameters on Surface Roughness and MRR on EN31 Steel Using High Speed Turning Operation"** for the award of **Dual Degree** from Integral University, Lucknow under my supervision. The thesis embodies result of original work and studies are carried out by the student herself and the contents of the thesis do not form the basis for the award of any degree to the candidate or to anybody else from this or any other university/Institution.

Signature of Supervisor

Dr. Mohd Faizan Hasan
Assistant Professor
Department of Mechanical Engineering
Integral University, Lucknow

Date:

Kursi Road, Lucknow - 226026 (U.P.) India
Phone : 0091 - 63900 11283, 84, 85
Website : www.iul.ac.in
E-mail : info@iul.ac.in
integraluniversity_inspiringexcellence
f integralunilko
integralunilko_official

DECLARATION

I hereby declare that the thesis titled "**Investigation on Effect of CNC Lathe Machine Parameters on Surface Roughness and MRR on EN31 Steel Using High Speed Turning Operation"** is an authentic record of the research work carried out by me under the supervision of Dr. Mohd Faizan Hasan, Department of Mechanical Engineering at Integral University, Lucknow. No part of this thesis has been presented elsewhere for any other degree or diploma earlier.

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Name-Mr. Mohd Laraib

Enroll. No. 1700101467

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Mohd Laraib

Enrollment No. 1700101467

ABSTRACT

Regression analysis has been applied in this research to improve the machining settings for the CNC turning of EN-31 steel using carbide cutting tool. L18- orthogonal array conceived and carried out the experiments. Cutting speed, feed rate, and depth of cut were taken into account as machining factors in order to maximize the surface roughness and material removal rate. Statistical software called Minitab 18 was used to generate the ANOVA. Following the ANOVA and regression analysis, a comparison between dry and wet machining is conducted. While DOC and Surface Roughness are negatively correlated, meaning that as DOC increases, Ra decreases, speed and feed are directly correlated with Ra. All three parameters were discovered to be proportional in the case of MRR, meaning that MRR rose as speed, feed, and DOC increased. The projected values obtained using the Response Surface Methodology are contrasted with the results of the experiments. Response Surface Methodology is used to analyze the effects of input parameters on outcomes. According to the findings, cutting speed and depth of cut are the two factors that have the greatest impact on surface roughness, while feed is the only significant component that has an impact on tool wear. To be the cut's depth. The top three parameters that were most effective for performing the machining were are displayed in the results section and were acquired via the Response Surface Optimizer.

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Chapter 1

1.1 INTRODUCTION

In the process of machining, unwanted metal is taken out of the raw material in the form of chips in order to shape the finished product as needed. Subtractive manufacturing refers to a group of procedures that have numerous controlled, common criteria for material removal. Three categories are used to group machining processes. A fundamental metal machining process that is frequently utilised in sectors that deal with metal cutting is turning. In order to achieve excellent performance, it is crucial to choose the right machining settings for a turning process. High performance is characterized by good mach inability, improved surface finish, decreased tool wear, increased material removal rate, increased production rate, 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 the product. Improved strength characteristics, such as resistance to corrosion, resistance to temperature, and longer fatigue life of the machined surface, can be attained with a better surface finish. The functional behavior of machined parts can be influenced by surface finish in addition to strength characteristics. Examples include friction, light reflection, heat transmission, ability to distribute and hold lubricant, and others. Costs of production are also impacted by surface finish. For the reasons described, it is crucial to minimize surface roughness, which can be done by optimizing some of the cutting settings. Every traditional cutting operation has a natural problem called tool wear. Because tool wear impacts both product quality and production costs, researchers work to eliminate or reduce it. In-depth research on tool wear characteristics must be done in order to increase tool life.

Machining parameters including cutting speed, feed, depth of cut, etc., tool material and its properties, work material and its properties, and tool geometry are some of the elements that determine tool wear and surface roughness. The product quality and tool life may significantly change with even minor adjustments to the following requirements. 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 fulfill the increased need for better product quality, lower production costs, and faster production rates in the modern world, companies and researchers must priorities optimization. Optimization procedures make considerable use of statistical design of experiments. The practice of organizing experiments in a way that allows suitable data to be analyzed using statistical techniques is known as statistical design of experiments. bringing about reliable and impartial conclusions. 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. When Neseli et al. employed the RSM method using the input variables nose radius, approach angle, and rake angle, they discovered that 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 tool nose radius. To determine the ideal cutting parameters, Yang and Tarng applied the Taguchi method. According to a study by Bouacha, cutting speed and feed rate are the two factors that have the most influence on a product's surface finish. Halim discovered that the depth of cut has the greatest impact on tool wear, with other variables appearing to be inconsequential. The goal of the current study is to optimise 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. Machining and non-machining methods are two different types of manufacturing processes. The removal of material from metal through cutting action is what is referred to as the machining process. Nearly 90% of engineering components need to be machined. The most widely used cutting method is turning. Maintaining the components' quality in terms of surface finish is crucial. speed and feed profundity of cut are the information parameters which specifically influence the execution of the cutting device. One of the client's most important specialty requirements is surface complete. To improve tribological performance, a logically adequate surface finish is desired. Characteristics, the item's weakness, consumption antagonism, and it fashionable intrigue. The superficial unappealingness and device wear also depends on information characteristics including speed, feed rate, and cut depth. from now on it is It's crucial to choose the ideal balance of cutting tempo, feed rate, and cut depth to ensure equipment life, material The part's surface and evacuation rate can be advanced. Therefore, simplifying cutting parameters, In order to maximize material evacuation rate and minimise surface area, cutting velocity, feed, and depth of cut are used. unappealingness of the component Steel of the EN-31 steel grade is a frequently used substance. The literature review served as the primary source of inspiration for the topic selection, which is optimising cutting parameters for lathe machining of EN-31 steel. Since EN-31 steel is utilised in many industries, including the automotive industry, the turning process and parameter optimization are crucial. In this study, turning operations on EN-31 steel with plain carbide are shown. The Taguchi L9 technique was used to optimise the input parameters for surface roughness, MRR, and tool wear.

EN-31 Steel

EN31 is a quality high carbon alloy steel which offers a high degree of hardness with compressive strength and abrasion resistance. Typical applications for EN31 steel include taps, gauges, swaging dies, ejector pins, ball and roller bearings. It is a good quality steel for wear resisting machine parts and for press tools which do not merit a more complex quality.

Forging

Heat slowly and begin forging at 1000-1050°C. Allow sufficient time at the forging temperature for the steel to be thoroughly soaked through. Re heat as necessary and does not forge below 850°C. After forging EN31 steel, cool slowly preferably in a furnace.

Annealing

EN31 is usually supplied in the annealed and machine able condition. Re-annealing will only be necessary if the steel has been forged or hardened. To anneal, heat the EN31 steel slowly to 800-810°C, soak well and allow cooling in the furnace.

Hardening

Heat slowly to the hardening temperature of 800-820°C. Maintain until thoroughly soaked through. Plenty of time must be given for this soaking and then quench in oil.

Tempering

Temper according to the purpose for which the tools are required, generally between 150°C and 300°C. Soak well at the selected temperature and soak for at least one hour per 25mm of total thickness. Cool slowly in air.

Heat Treatment

Heat treatment temperatures, including rate of heating, cooling and soaking times will vary due to factors such as the shape and size of each EN31 component. Other considerations during the heat treatment process including the type of furnace, quenching medium and work piece transfer facilities. Please consult your heat treatment provider for full guidance on heat treatment of EN31.

1.2 OBJECTIVES OF PRESENT WORK

The material removal rate is of great importance for cutting forces and temperatures, spindle power, deflections, dimensional and form accuracy of the work piece, and surface integrity**.**

- To study the influence/effect of machining parameters of speed, feed and depth of cut, on the surface roughness of machined material.
- To determine optimum machining parameter settings for tool/work combination so as to increase the material removal rate.
- To determine optimum machining parameter settings for the tool/work combination so as to minimize the surface roughness.

2.1 LITERATURE REVIEW

Santos 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.

Venkata Ramana 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 .

W. B. Sai et al.(2003) have shown that an increase in cutting speed causes a higher decrease of the time of the second gradual stage of the wear process. This has been due to the thin coat layer which has rapidly peeled off when high-speed turning. This investigation included the realization of a wear model in relation to time and to cutting speed.

Y. Huang et al.(2009) have focused on the direct machining steel parts at a hardened state, known as hard turning have offered a number of potential benefits over traditional grinding in some applications. In addition, hard turning has several unique process characteristics, e.g., segmented chip formation and microstructural alterations at the machined surfaces, fundamentally different from conventional turning. Hard turning has been therefore, of a great interest to both the manufacturing industry and research community. Development of super hard materials such as polycrystalline cubic boron nitride (known as CBN) has been a key to enabling hard turning technology. Although various tool wear mechanisms, or a combination of several, coexist and dominate in CBN turning of hardened steels, it has been suggested that abrasion, adhesion (possibly complicated by tribochemical interactions), and diffusion may primarily govern the CBN tool wear in hard turning.

H. Chelladurai et al.(2010) have shown that cutting tool wear has been a critical phenomenon which influences the quality of the machined part. In this paper, an attempt has been made to create artificial flank wear using the electrical discharge machining (EDM) process to emulate the actual or real flank wear. The tests were conducted using coated carbide inserts, with and without wear on EN-8 steel, and the acquired data were used to develop artificial neural networks model. Empirical models have been developed using analysis of variance (ANOVA). In order to analyze the response of the system, experiments were carried out for various cutting speeds, depths of cut and feed rates. To increase the confidence limit and reliability of the experimental data, full factorial experimental design (135 experiments) has been carried out. Vibration and strain data during the cutting process are recorded using two accelerometers and one strain gauge bridge. Power spectral analysis have been carried out to test the level of significance through regression analysis. Experimental results were analyzed with respect to various depths of cut, feed rates and cutting speeds.

Rajesh Singh et.al. (2018): 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.

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Raman B Magdum et.al.(2015) In this research the use of0materials for tool & process parameters for forces in turning for selected9range 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.

M. U. Ghani et al.(2011) have presented results of an investigation into the tool life and the tool wear behavior of low content CBN cutting tools used in hard turning of hardened H13 tool steel. The finite element method experiments involved measuring the cutting forces, cutting temperatures, tool wear, and the contact area. Using the measured cutting forces and the contact area in the orthogonal cutting model. The temperatures history from the analysis was matched with the experimental data have estimated the fraction of heat entering the tool for both conventional and high speeds. The heat partition into the tool was estimated to be around 21–22% for conventional speeds, whereas for high-speed turning, it was around 14%. The tool wear, however, was found to be dominated by chipping for both cutting speeds and could be reduced considerably by reducing the amount of heat entering the tool.

The following chapter discusses research on the turning process that has been published and aims to optimise 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 utilised to find the best answer, with the Response Surface Method as its primary focal point.

2.2 The Turning Operation

A common metal machining process that is performed in sectors that deal with metal cutting is turning. 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 axis of rotation of the work piece at a constant rate during a turning operation. Unwanted material is removed in the form of chips, creating a cylindrical or more complex profile. This operation is carried out in a Lathe Machine either manually under operator’s supervision, or by a controlling computer program. 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. The basic turning operation with the motions involved is shown in Fig and Fig , figures from. Fig shows a single point cutting tool and its nomenclature.

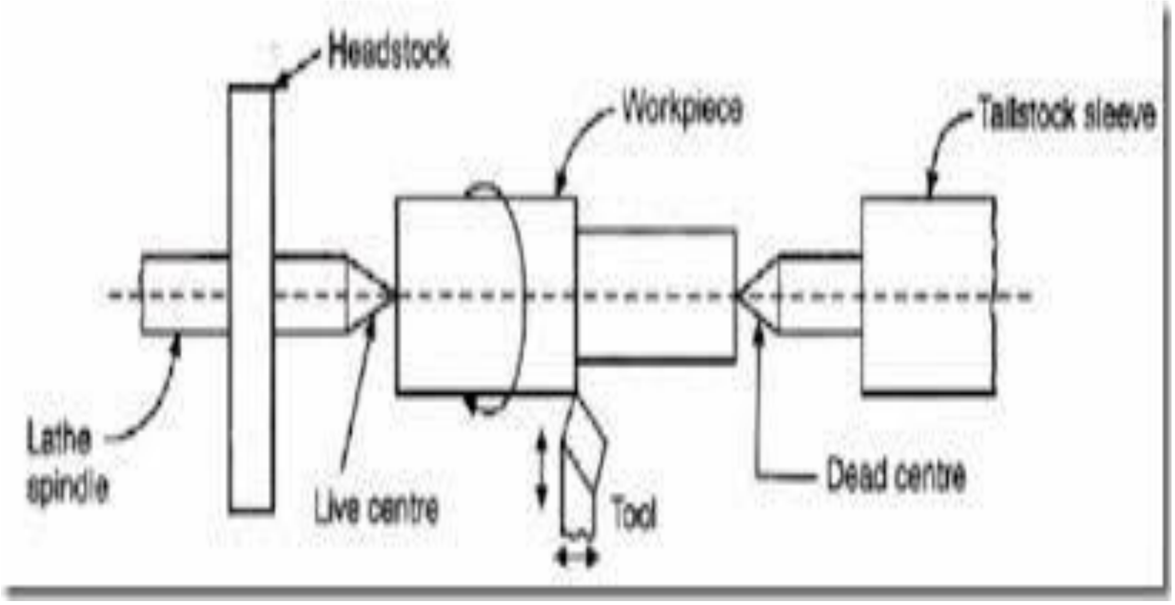


Fig 1: turning operation in CNC Lathe Machin

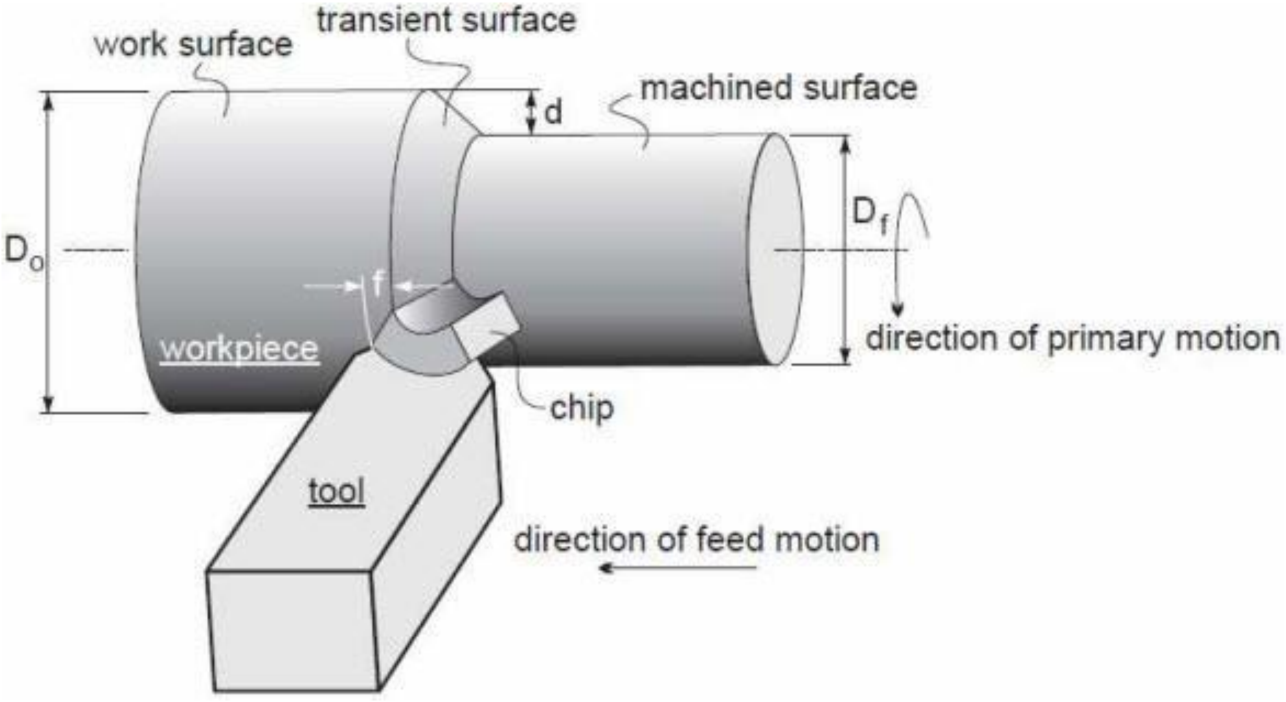


Fig 2: Turning operation of Motion

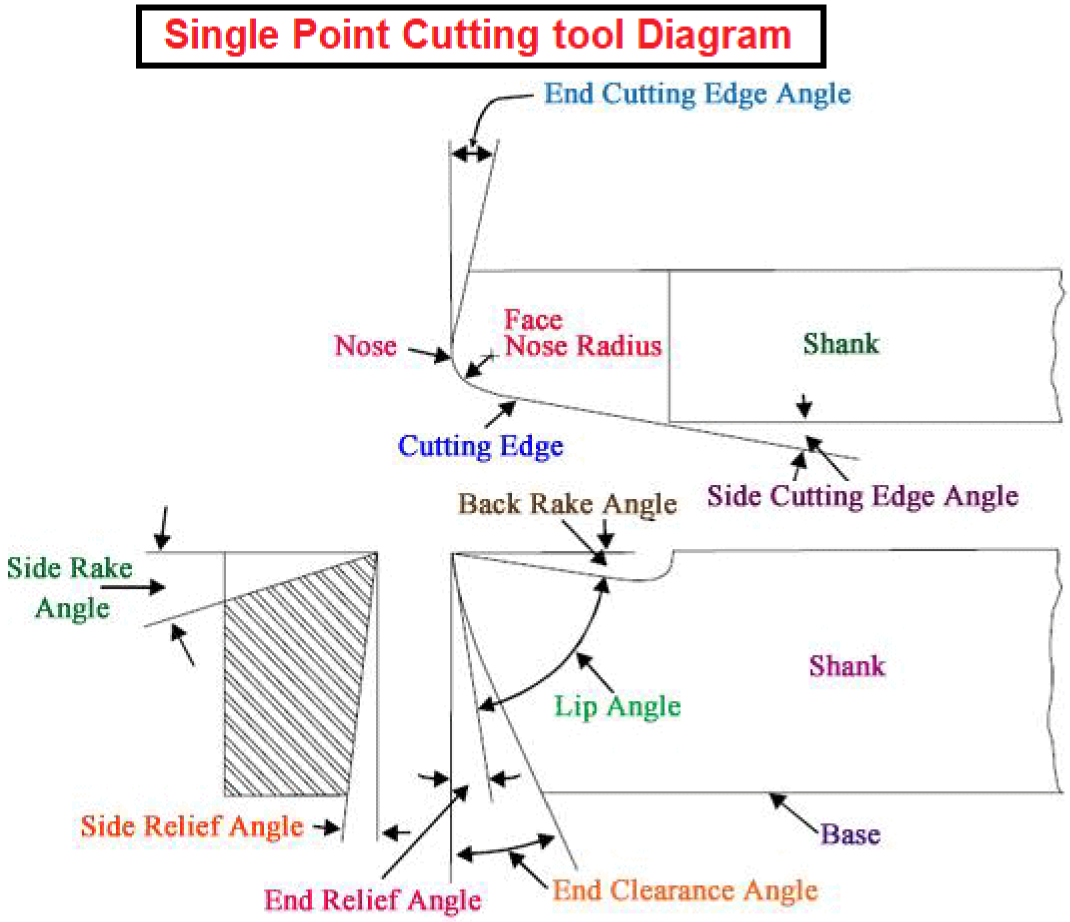


Fig 3: In turning and its nomenclature Single point cutting tool use

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 4 from. These three parameters are combined to provide material removal. Surface roughness and tool wear are two other input characteristics that affect the output parameter; however these latter two are the easiest for the operator to alter while the operation is still in progress.

2.3.1 Cutting Speed

The rate at which the work piece's uncut surface moves past the cutting tool 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 expressed in terms of the number of rotations the work item makes each minute, or rpm. The cutting speed V c (in m/min) is stated if the spindle speed is „N“ rpm.

$$\mathbf{V_c =} \frac{\pi D N}{1000}$$

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." Typically, it is also stated as the spindle speed in mm/min as

$$\mathbf{F_{m}=fN}$$

where, f=Feed in mm/rev

N=Spindle speed in rpm

2.3.3 Depth of cut

The distance between the recently 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 works, the thickness is removed from both sides, resulting in a diameter reduction that is double the depth of cut.

$$\mathrm{D} = \frac{d1 - d2}{2}$$

where, D_1=Initial

diameter of job

D_2=Final

diameter of job

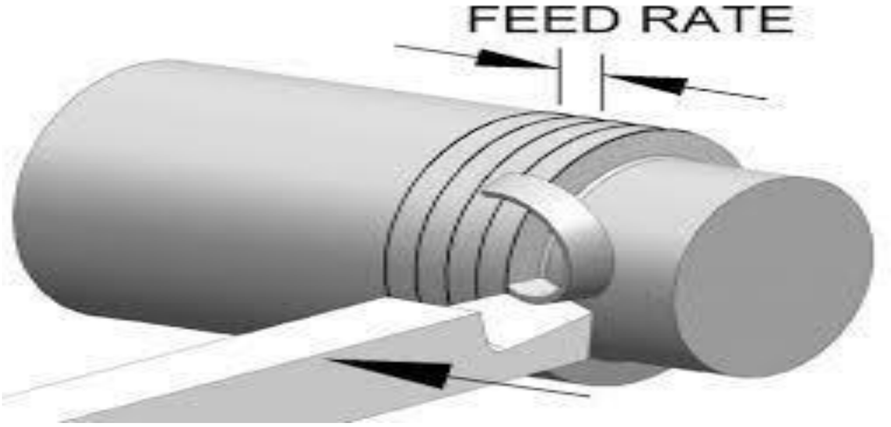


Fig 4: Machining parameters adjustable

2.4 Cutting tool

Tool wear is a significant phenomenon in metal cutting. The manner and pace of tool wear are influenced by a variety of factors. The most important factors that influence wear include tool temperature, material type and hardness, grade and condition of the work piece, abrasiveness of the material's micro components, tool shape, feed, speed, and cutting fluid. The relative importance of these factors affects the kind of wear pattern that manifests. The volume of tool material lost on the contact surface as a result of interactions between the tool and the work piece is referred to as tool wear in machining. Tool wear is specifically described by wear rate, which is significantly influenced by temperature, pressures, and induced relative sliding speed at the contact interface. High surface loads and rapid surface temperatures result from the chip sliding along the tool rake face at a high speed while applying a very high normal pressure to this face, subjecting metal cutting tools to highly demanding circumstances. Due to the presence of hard particles in the component microstructure or, more severely, when interrupted cutting is being done, the forces may be variable. Cutters are therefore required.

- Strength at elevated temperatures
- High toughness
- High wear resistance
- High hardness

2.4.1 Insert Cutting Tool

The actual cutting edge is so often included in cutting tool inserts, which are exchangeable attachments. Applications for cutting tool inserts include:

Fig 5: Inserts cutting tool Various shap

2.4.2 Material Insert

Cutting tool inserts are frequently made of silicon nitride, high-speed steel, ceramic, cobalt, diamond PCD, micro grain carbide, and carbide. Coatings contribute to longer insert life and increased wear resistance. Titanium nitride, titanium carbonitride, titanium aluminum nitride, aluminum titanium nitride, aluminum oxide, chromium nitride, zirconium nitride, and diamond are some coatings for cutting tool inserts. 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.

2.4.3 Insert Coating

Assembling hard, wear- and abrasion-resistant coatings on cutting tools (such as drill bits, milling cutters, cutting tool inserts, taps, reamers, etc.) and shaping tools has been done by the coating section of STATON for almost 20 years (e.g. forms, matrices, shear and bending tools, etc.). Arc evaporation and magnetron sputtering are two cutting-edge processes used to apply the coating. Thin films, including multilayer coatings, nano composites, TiN, TiCN, TiAlN, CrAlSiN, TiAlN, and TiAlN, have a significant impact on a tool's performance and physical characteristics.

The coated tools only come in the following sizes: length (diameter) = 600 mm; weight = 50kg.

2.5 Material removal rate

The material removal rate (MRR), which is measured when conducting machining operations such utilizing a lathe or milling machine, is the amount of material removed per time unit (frequently per minute). The material removal rate increases with the amount of material removed per minute. You can achieve this thanks to a single digit called the MRR. It provides a clear indication of your cutting effectiveness and profitability. The MRR stands formaterial removal rate. The MRR increases as your cutting settings increase. In other words, the MRR is the amount of residue that is produced per unit of time during a cutting operation as a direct result of the removal from the work piece. The depth of the cut times the width of the cut times the feed rate can be used to compute the rate of material removal in a work process. Commonly expressed as cubic centimetre per minute (cm3/min) , the material removal rate. [3]

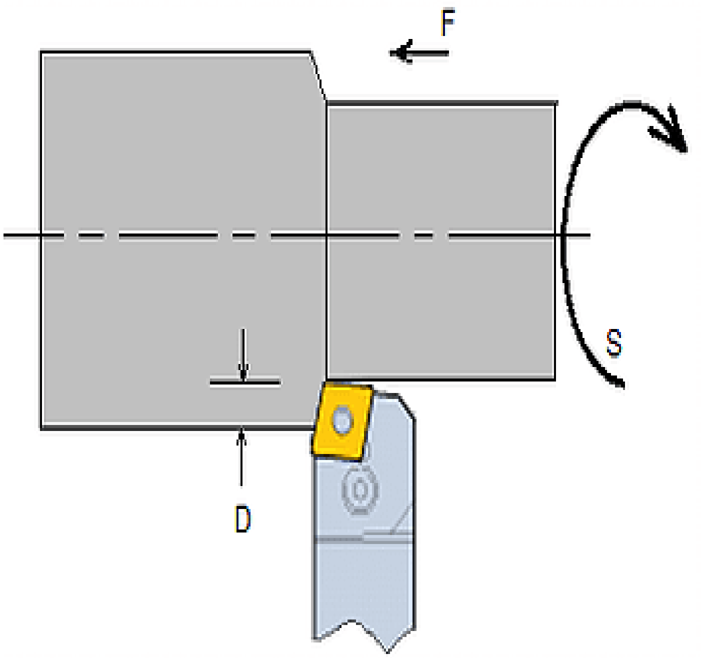


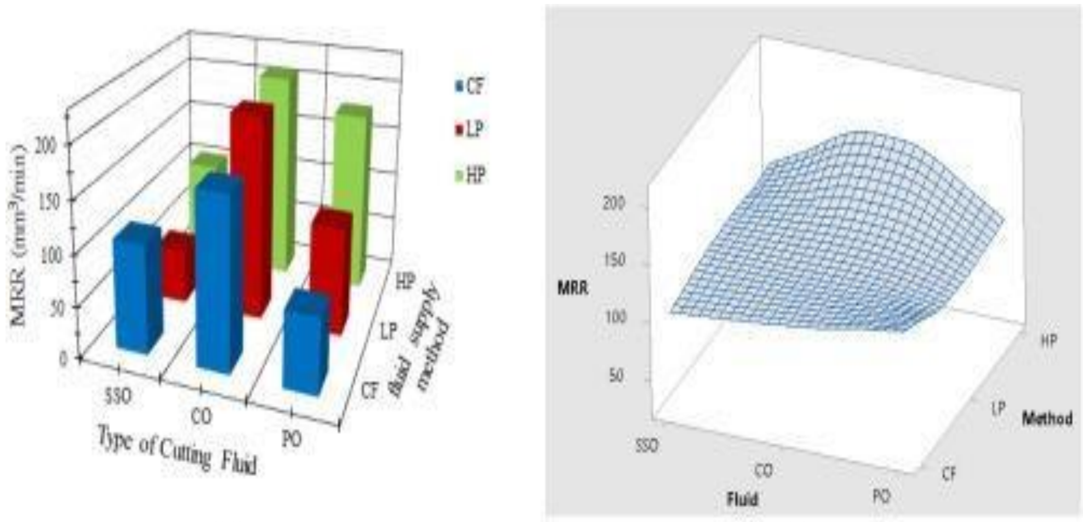
Fig 6 Material Removal Rate operation

The amount of material removed per unit of time, or material removal rate (MRR), is directly related to process productivity. This needs to be optimised in roughing operations and large batch production. However, it is a factor that should be placed on hold in finishing procedures, bringing roughness and precision to the fore. Since MRR is often very low for finishing, low cutting rates and feeds per tooth are typically used for low roughness. There are a few ways to evaluate the MRR (Q), the following one is for the instantaneous calculus:

$Q = V_c * A_c$

2.5.1 Effects on material removal rate

In the process of surface grinding, high MRR is preferred. For a particular set of parameters, it reflects the unit amount of material eliminated. Surface grinding produces burr-like chips that are too tiny to be removed directly from the surface of the material. Due to the high temperature, it frequently becomes stuck in the deep surface troughs and rewelds. Aside from parametric influence, the efficacy of the cooling method's burr evacuation propensity is what causes the change in MRR. A is a representation of the 3D bar graphs for the impacts of cutting fluid type and supply technique on MRR for a 0.3 mm depth of cut. Plots show that as compared to a typical flooding system, vegetable oil-based MWFs with a pressurised spray cooling system achieved higher MRR. It is explained by the fact that due to the reduced density of vegetable oils, high-velocity droplets when they impinge on a surface of a material tend to remove the trapped and rewelded burrs by an effective splashing effect. Improved MRR is the result of having a new surface to grind on. The cumulative response behaviour of the MRR under the influence of the fluid and method is shown. The maximum MRR was created by a castor oil-based MWF with a high-pressure system, as can be seen. Additionally, in order to achieve greater MRR, the use of vegetable oil-based MWFs and pressurised spray cooling systems becomes crucial. Additionally, these outcomes are consistent with data from statistical and optimization evaluations, which revealed that castor oil and an HP system, produced the best MRR.



(A) (B)

Fig 7. Effect of MRR

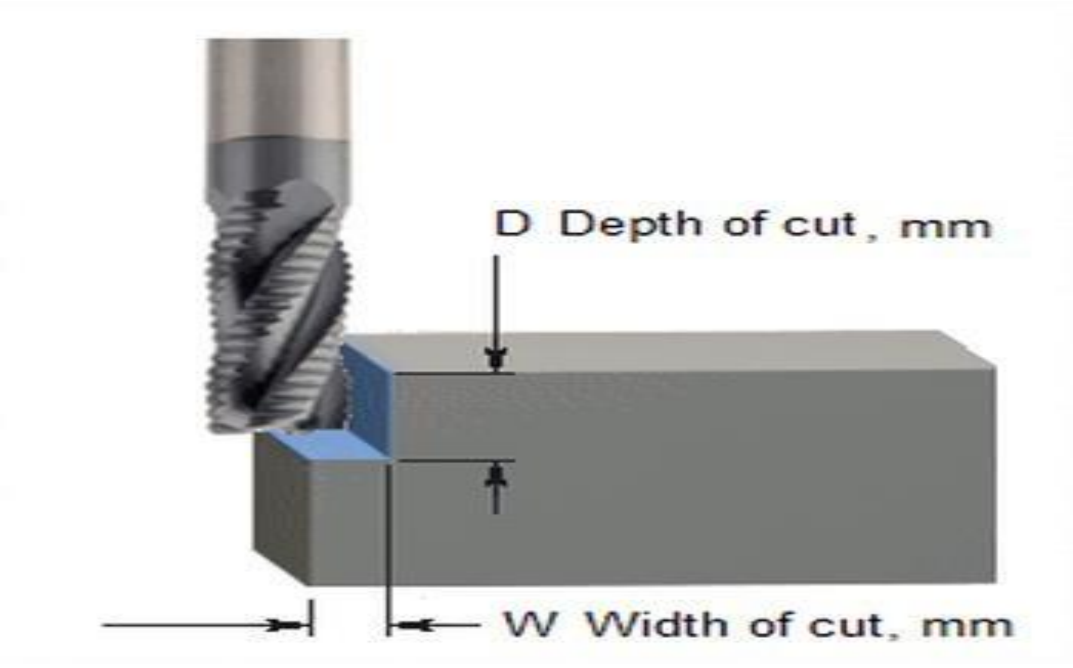


Fig 8 MRR Cutting Operation

2.6 Surface Roughness

Surface abrasion Ra is frequently used to describe surface roughness. Cutting at a low-chip load is crucial for obtaining a good surface finish and high precision in micromilling operations. If machining tolerance is to be less than 1 m, this feed per tooth and the cutting depth should be kept below 1 m. When the ratio of chip load to tool edge radius is below a threshold point, a significant ploughing phenomenon will manifest. Surface roughness is most significantly influenced by chip load because surface roughness worsens as chip load increases. 22 However, when high feed and depth of cut are used, surface roughness diminishes due to dynamic behavior (low vibration). With increasing chip load, the roughness of a micro milled surface decreases until embedded built-up edges (BUEs) are noticeable.

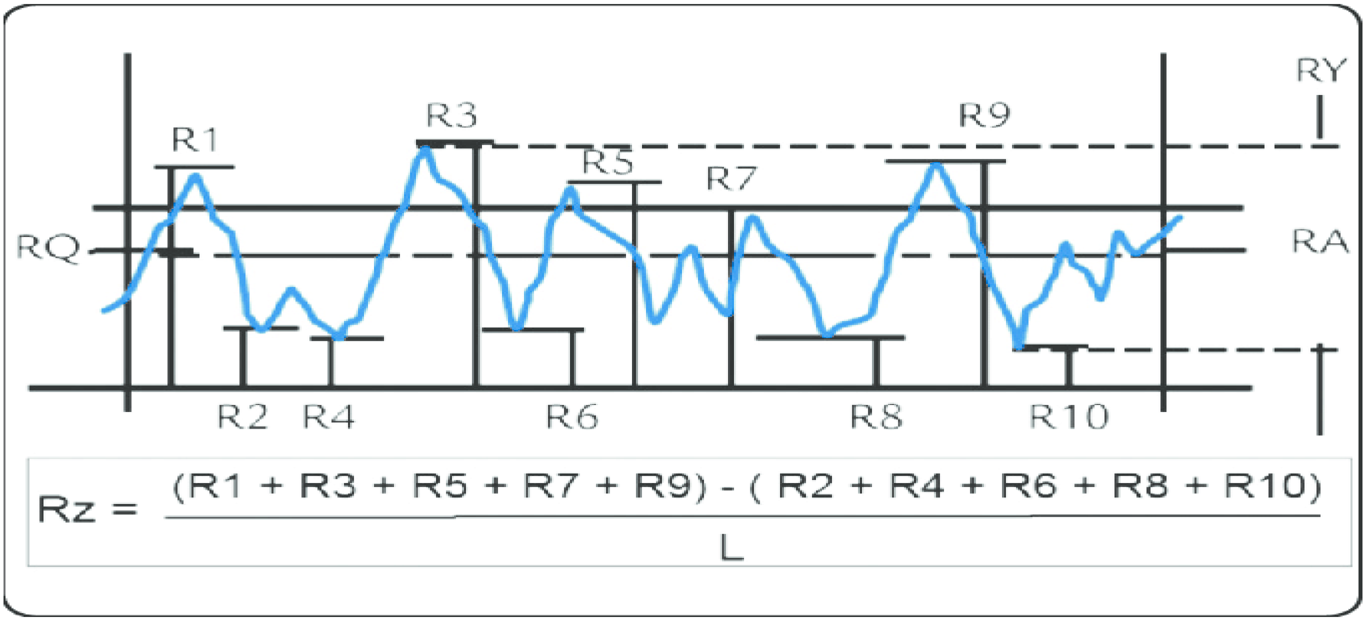


FIG 9 Characteristic observations of surface roughness from the Surfanalyzer profilometer

Typically, using instruments referred to as profilometers, the surface roughness is assessed directly. The Profilometer is a stylus probe instrument that uses a motor drive to move the stylus positioned in the pick-up unit across the machined surface. The output of the pick-up is received, rectified, and amplified. The average height of the roughness is then reported digitally. The Taylor-Hobson Talysurf is one of the popular varieties of profilometers on the market. Carrier modulation is the basis for how it functions.

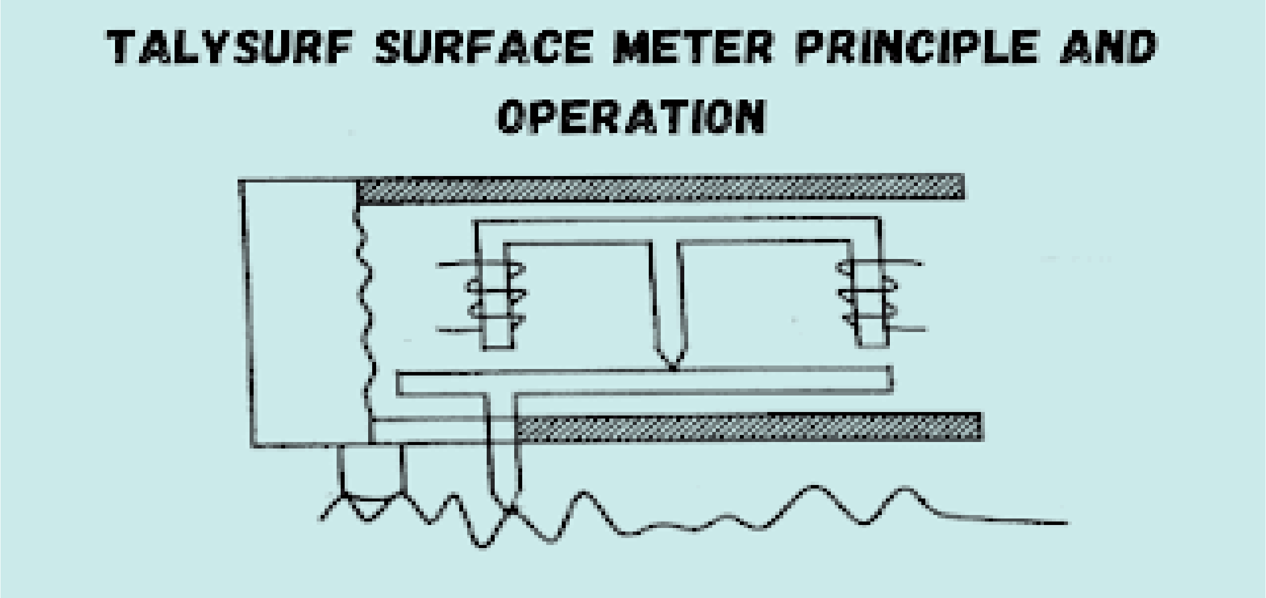


Fig 10 Talysurf Surface Meter Operation

The two outer legs of the E-shaped stamping are wrapped in coils that conduct alternating current. An oscillator is created by these two coils and two additional resistances. Alterations in the air gap between the armature and the stamping brought on the stylus movements modulate the amplitude of the alternating current. The signals are demodulated by the demodulator so that the current is only directly proportional to stylus vertical displacements. The output is supplied into a recorder, which creates the numerical output and records it.

CHAPTER 3

3.1 Design Of Experiments

A systematic, effective strategy called design of experiments (DOE) enables scientists and engineers to investigate the link between several input variables (also known as factors) and important output variables (aka responses). It is a methodical process for gathering information and developing discoveries.

Use of DOE when

- To identify whether a particular factor—or a group of factors—has an impact on the answer.
- To ascertain whether variables interact when influencing the response.
- To simulate how the reaction behaves in relation to the components.
- To enhance the reaction.

3.2 Response Surface Methodology (RSM)

The theoretical model that connects some controllable variables (factors) to a response is frequently either unavailable or extremely complex. Information about the relationship between the causes and the response in this situation should be gathered empirically. The Box and Wilson-developed Response Surface Methodology (RSM) is a set of mathematical and statistical methods for studying situations similar to the one being asked using an empirical model. More specifically, its goals are as follows:

- To produce knowledge in the relevant experimental field.
- To accurately gauge experimental variability (pure error).

- To ensure that the suggested model and the experimental data are adequate (to make it easy to detect the lack of fit). To as accurately and precisely as possible predict the observed reaction at locations inside the experimental domain where no trials were conducted.
- To offer step-by-step plans for carrying out experiments with various alternatives in response to the findings.
- To continue operating at a high level of efficiency within the constraints of time, money, and any other real-world constraints.
- To facilitate the easy detection of outlier data.
- To eliminate ambiguity and enable decision-making in uncertain situations. RSM clearly encompasses much more than model fitting and model analysis. In fact, RSM, taken in its broadest sense, has taken centre stage in industrial experimentation. 2In the book written by Box and colleagues3 (Part C. Sequential investigation and discovery),For n “ number of measurable in put variables, there sponse surface can began–

  $Y=f(x_1,x_2,x_3,x_4…x_n)+\varepsilon$ …………………..1

  Where the random error and x 1 through x is n are the independent input parameters. The variable that needs to be optimised is Y, which is the output or response.

  The response function in a turning operation with three input variables can be expressed as –

  $Y= f(x_1,x_2,x_3)+\varepsilon$ ……………………..2

Where,x_1=log V_c ,x_2=log f ,and x_3=log d. Y=log Ra and is the mirror .

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.

The first order or linear multiple regression model, for instance, can be utilized. –

$Y=\beta_0+\beta_1x_1+\beta_2x_2+\beta_3x_3+\varepsilon$ …………3

For better approximation, interaction terms can be included–

$Y=\beta_0+\beta_1x_1+\beta_2x_2+\beta_3x_3+\beta_{12}x_1x_2+\beta_{13}x_1x_3+\beta_{23}x_2x_3+\varepsilon$ ……………4

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

$Y=\beta_0+\beta_1x_1+\beta_2x_2+\beta_3x_3+\beta_{11}x_1^2+\beta_{22}x_2^2+\beta_{33}x_3^2+\beta_{12}x_1x_2+\beta_{13}x_1x_3+\beta_{23}x_2x_3+\varepsilon$ …………..5

Since there are some attractive designs available for fitting quadratic models, such as Central Composite Design (CCD) and Box-Behnken Design, the quadratic model provided in Equation 9 istypically used in RSM situations.

3.3 Central Composite Design (CCD)

A Box-Wilson The Central Composite Design, often known as "a central composite design," consists of a canter -pointed embedded factorial or fractional factorial design that is supplemented by a collection of "star points" that enable curvature estimate. The distance between the design space's centre and a star point is || > 1 if the distance between the centre and a factorial point is 1 unit for each factor. The exact amount of relies on the number of components involved and some desired design features.

Similar to how the number of counterpoint runs the design must have relies on certain design-essential attributes.

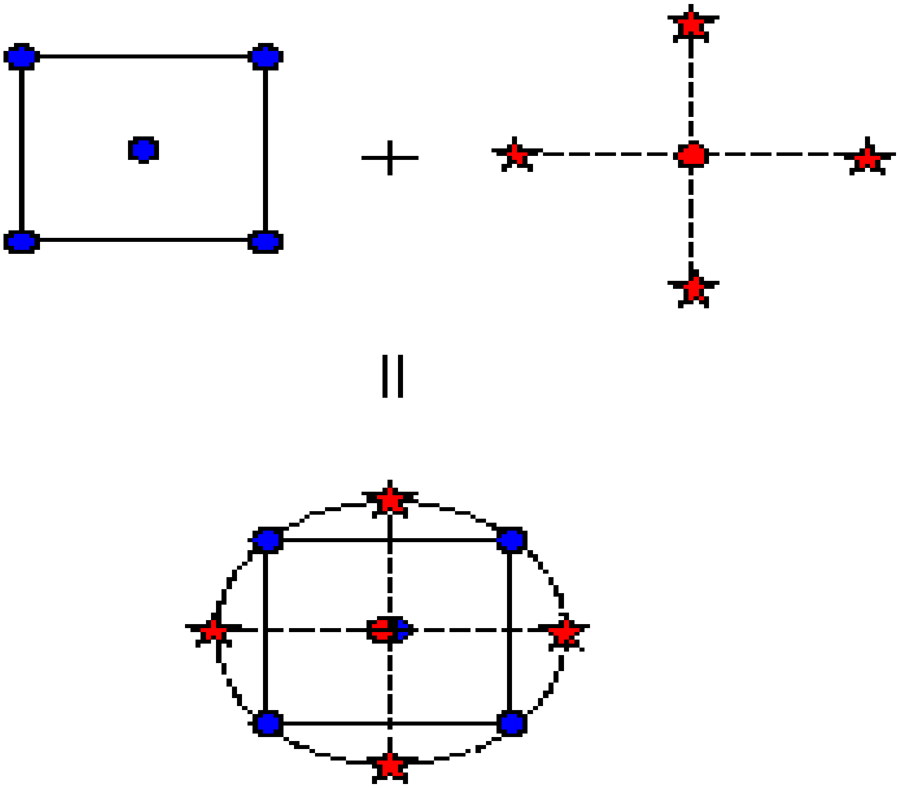


Fig11: The Development of a Central Composite Design for Two Factors

There are usually twice as many star points in a central composite design as there are design factors. For each factor in the design, the star points symbolize new extreme values (low and high). The characteristics of the three types of central composite designs are compiled in Table . The links between these variations are depicted in Figure . The variability of an experimental design's coefficient estimates and, in turn, the variability of the response estimate serve as indicators of the design's quality. Iso-variance per rotation is a crucial feature (rotatability). This indicates that the prediction error is the same for all points that are spaced the same amount from the domain's centre. In comparison to the orthogonal design at the domain's centre, the rotatable design offers a less precise estimation.

This is where the rotatable and orthogonal design comes in.The values of and the number of points at the centre for the selected attributes are provided by the processing programme for the creation of trials. An illustration of a response variable shown as a function of the independent variables is called a response surface. A dependant or response variable can be better understood through this experiment than it can be through a two-level factorial or fractional-factorial design. Each independent variable in a three-level factorial design contains a centre point in addition to high and low points, necessitating three experiments. Because of the third factor level, this is known as a three-level factorial design. The number of experiments is significantly increased by the third component.

Chapter 4

4. Materials And Methods

4.1 Work Material

The final experiment's work piece was made of EN31 steel. A high-grade high-carbon alloy steel called EN31 that provides high levels of hardness, compressive strength, and abrasion resistance is of good quality.

Table 1 Chemical Composition EN 31 Steel

ELEMENT	COMPOSITION
Carbon	0 .90-1.20%
Chromium	1.0-1.60%
Manganese	0.3 – 0.70%
Sulphur	0.050 % max
Silicon	0.10-0.35 %

En31 steel is frequently used in products like taps, gauges, swaging dies, ejector pins, and ball and roller bearings. It is a decent grade of steel for press tools and wear-resistant machine parts that don't require a more sophisticated quality.

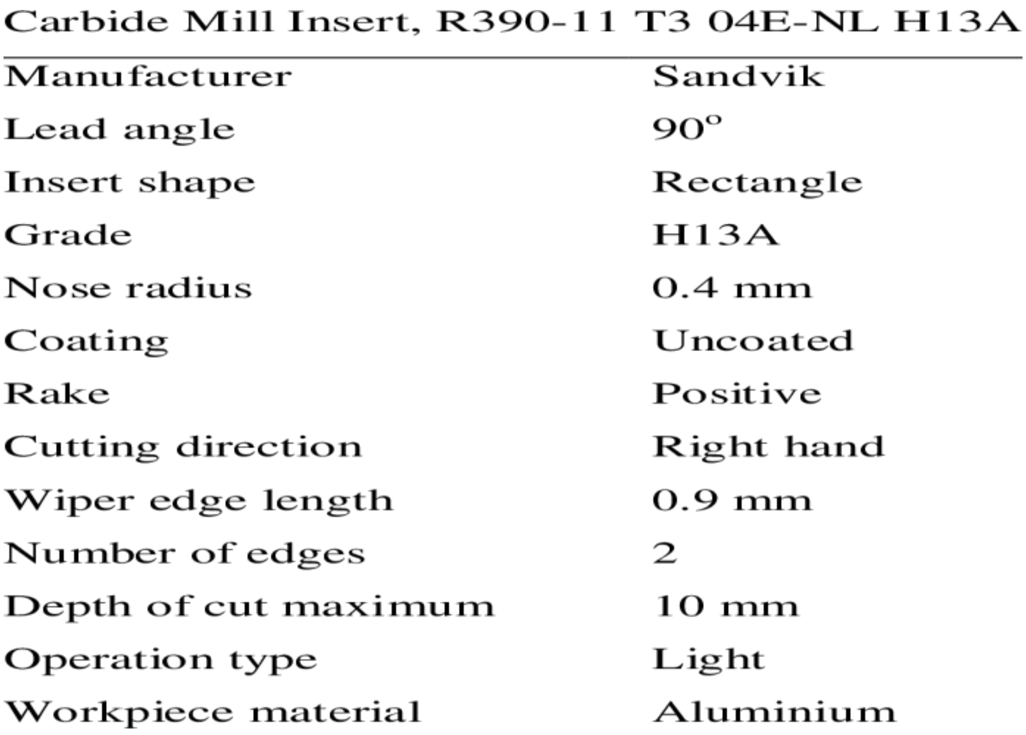
Table 2 EN31 Steel: EN 31 Steel Mechanical Properties

Density	7.81 g/cm3
Melting point	1424°C
Hardness, (quenched in water from 150°C tempered)	64 Matrix
Poisson’s ratio	0.27-0.30
Elastic modulus	190-210 GPa

4.2 Tool Insert Material

Compared to other materials like HSS, carbide tools have a high wear resistance, allowing the user to use the tool for longer periods of time and at higher speeds. Compared to their steel equivalents, carbide tools offer better value for the money. Hardened steel can be machined with carbide tools. Tools made of carbide are chemically inert.

Table 3 Specification of Cutting Tool



Carbide Mill Insert, R390-11 T3 04E-NL H13A	
Manufacturer	Sandvik
Lead angle	90°
Insert shape	Rectangle
Grade	H13A
Nose radius	0.4 mm
Coating	Uncoated
Rake	Positive
Cutting direction	Right hand
Wiper edge length	0.9 mm
Number of edges	2
Depth of cut maximum	10 mm
Operation type	Light
Workpiece material	Aluminium

Typically, carbides develop at temperatures above 1500 °C. Carbides often have high melting points and are very stable. Carbides can be categorised as covalent, interstitial, or salt-like.

Fig 12 Selection of Cutting Tool

Fig13: Set of cutting inserts used for experimentation

4.3 Experimental Setup And Initial Preparation

In the production process known as CNC turning, material bars are held in a chuck and rotated while a tool is being fed to the piece to remove material until the required form is attained. Subtraction machining is another name for the process, which involves removing material in order to create the required shape.

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.

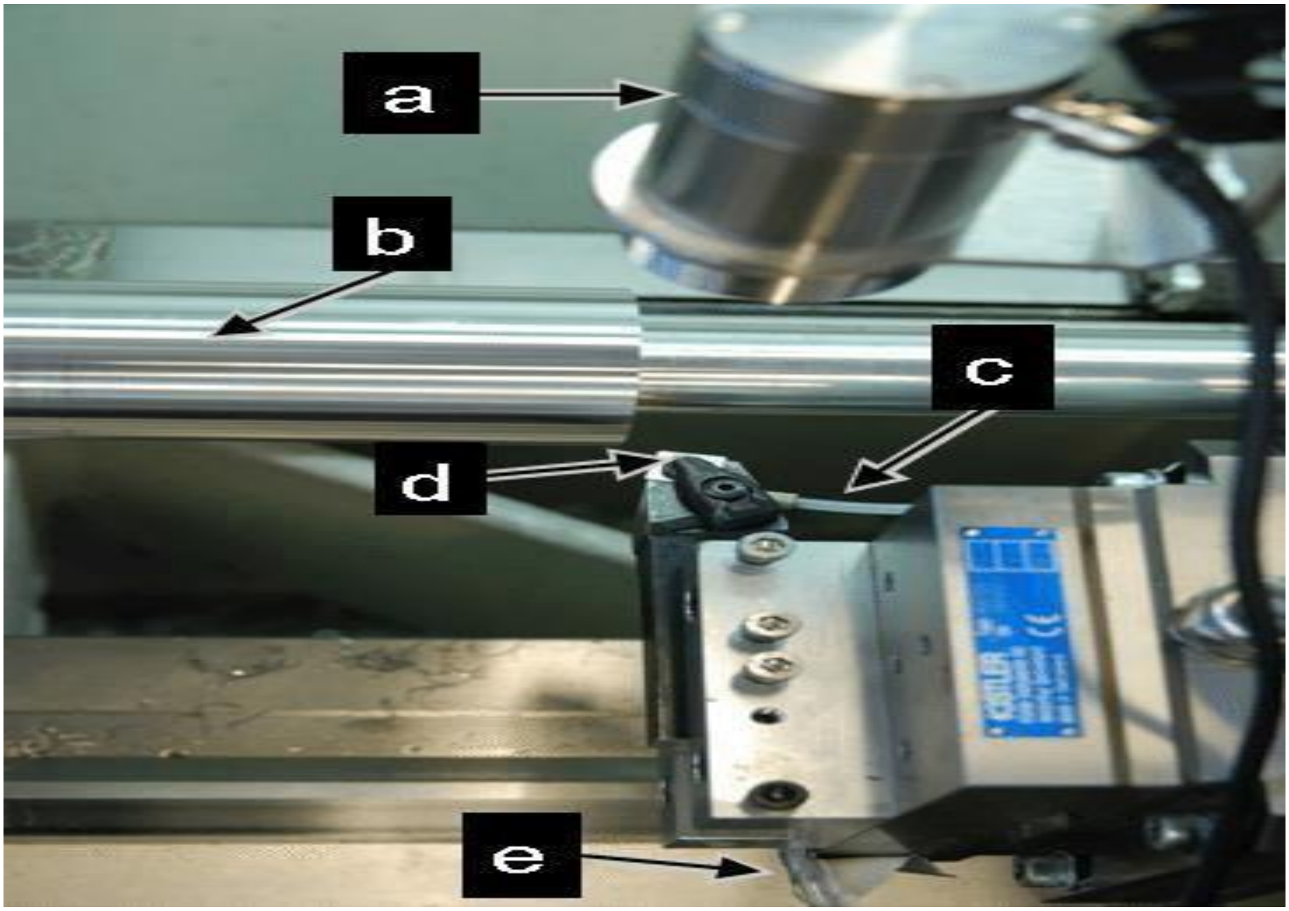


Fig14: Setup for Experimental

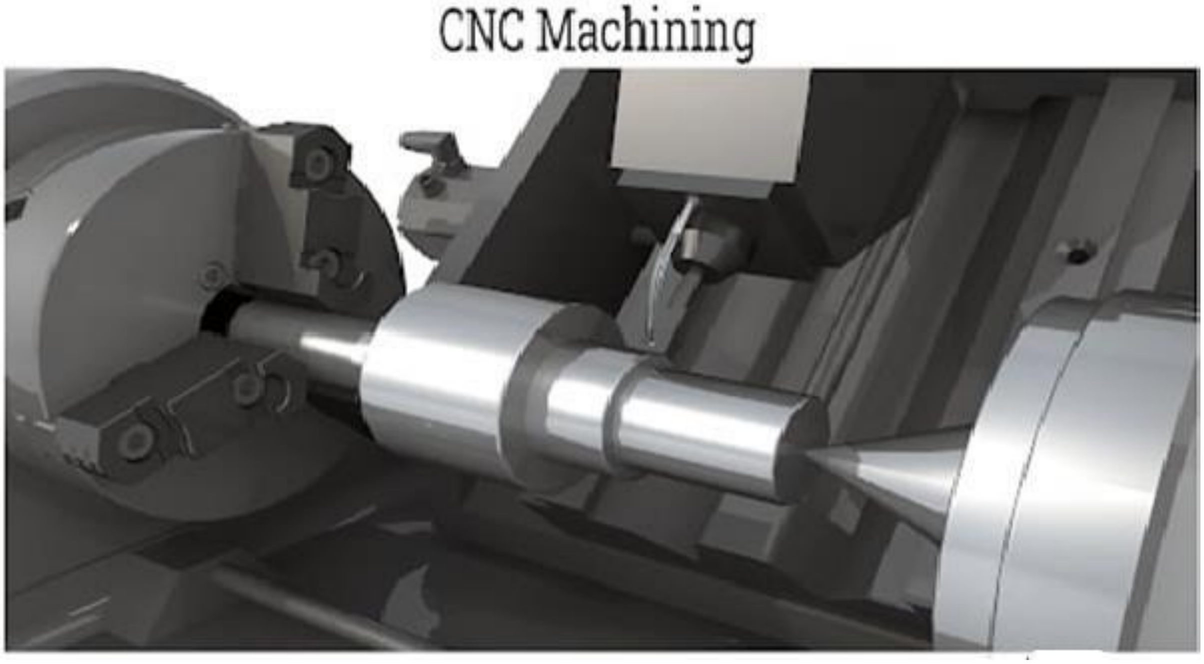


Fig15: Mounting of work piece and tool

4.4. Cutting Condition

Short cutting times, extended tool lives, and great cutting precision are the ideal cutting conditions. It is required to choose effective cutting conditions and tools based on the work material, hardness, shape, and machine capability in order to achieve these conditions. The testing method included both dry and wet cutting environments. Both dry and wet cutting techniques are used during machining. 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 work best at higher cutting temperatures obtained during dry cutting.

4.5 Measurement Of Surface Roughness

- Talysurf is a surface metre that uses an electronic principle to measure surface roughness. It includes a stylus and a skid-type instrument for measuring the product's surface.
- Compared to other types of surface metres, this type of talysurf surface metre incorporates an electronic means that is precise and highly accurate.
- The measuring head has a diamond stylus on it that is extremely pointed. The stylus in the talysurf surface metre has a very small tip radius of 0.002 mm and works with a motor to move the skid on the surface.
- The stylus in this instrument points out the surface's profile, and any deflections are turned into electric current to identify the readings of the object. It consists of stamping on top of the armature, which has coils on both sides, which together form an oscillator. In this surface metre, the armature on the stamping is fixed, and when the stylus vibrates as a result, the air gap created by the fixed armature creates a change in the amplitude of the current flowing through a coil, which causes the output to demodulate. The surface is measured by an electronic system that is built into the device.

Fig16:Talysurf setup for measuring surface roughness

FIG 17 Taylor Hobson Talysurf Reading shown display

4.6 Measurement Of Materials Removal Rate

The material removal rate is defined as the amount of material removed from the workpiece per unit of time. The material removal rate can be calculated using the volume of material removed or the weight difference between the material before and after machining. It is a gauge of how swiftly or slowly the machining speed is moving because micro-EDM is normally a very slow procedure. Goals for accuracy and surface finish must be achieved while machining productivity is raised. The MRR is significantly impacted by the process parameters. Increasing the discharge voltage, peak current, pulse duration, duty cycle, and pulse interval will result in higher MRR. In addition to these electrical parameters, some non-electrical features and material variables have a substantial impact on MRR.

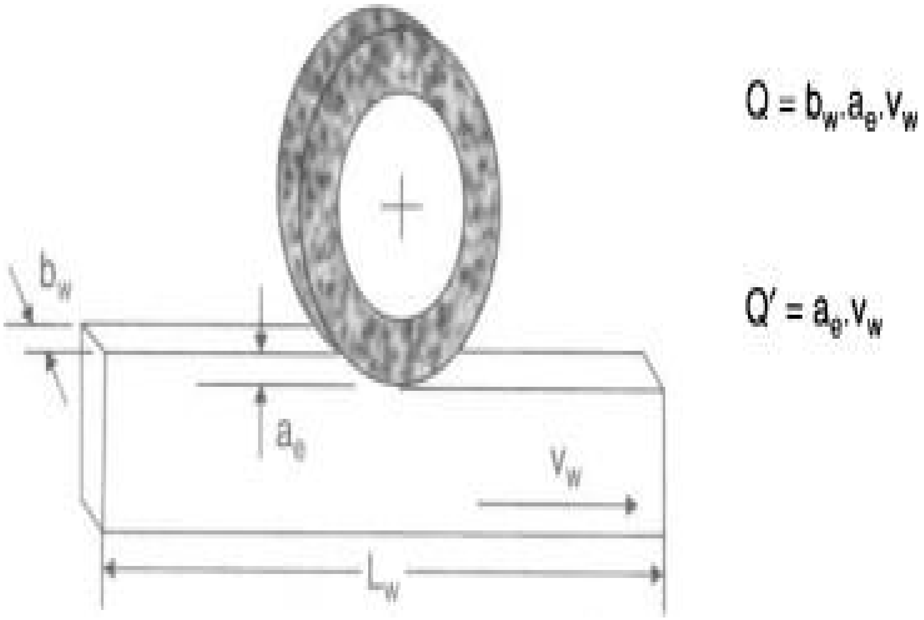


Fig 18 Material Removal Rate Parameter shown

4.7 Process Parameter

The following table (Table4) shows the levels of the cutting parameters chosen.

Code	Parameter	Level 1	Level 2	Level 3
A	Cutting Speed(m/min)	53	74	98
B	Feed (mm/rev)	0.22	0.33	0.44
C	Depth of cut (mm)	1	1.2	1.4

Table 4 Table of Cutting Parameters

4.8 Layout Of Experiment

The experiment layout was obtained in accordance with the 3- level with 3- parameters of Total L18 orthogonal array run.

Table 5 Experimental Observation

Sl. NO	**Weight before machining(gms)**	**Weight after machining(gms)**	Wt_b-Wt_a	**Machine time(sec)**
1	877.0	856.2	20.8	49.36
2	876.2	868.2	8	35.49
3	868.5	855.3	13.2	28.32
4	865.2	855.2	10	25.88
5	816.5	798.2	18.3	19.22
6	866.1	855.0	11.1	15.66
7	866.0	855.0	10	18.54
8	868.2	855.2	13	14.65
9	866.3	848.2	18	11.21
10	876.6	870.0	6.6	49.23
11	862.1	847.2	14.9	35.21
12	862.0	838.6	23.4	28.63
13	869.3	860.4	8.9	26.54
14	856.2	838.0	18.2	18.56
15	892.4	872.2	20.0	14.24
16	864.0	851.6	12.4	17.25
17	899.0	889.0	10	13.54
18	863.0	851.3	11.7	11.53

Table 6 L18 Orthogonal Array

Run	**Lubrication**	**Speed (m/min)**	**Feed (mm/rev)**	**DOC (mm)**	**Length (mm)**	**Ra (micron meter)**	**MRR (mm3/min)**
1	Dry	53	0.22	1	50	0.9493	1986.254
2	Dry	53	0.33	1.2	50	1.4654	3799.165
3	Dry	53	0.44	1.4	50	1.5862	3690.2541
4	Dry	74	0.22	1	50	1.2354	3214.6354
5	Dry	74	0.33	1.2	50	1.7652	7963.2569
6	Dry	74	0.44	1.4	50	1.2101	6985.3754
7	Dry	98	0.22	1	50	1.6354	5247.3614
8	Dry	98	0.33	1.2	50	0.8234	6254.3165
9	Dry	98	0.44	1.4	50	0.9898	1354.2142
10	Wet	53	0.22	1	50	0.9987	1175.3549
11	Wet	53	0.33	1.2	50	1.5754	1180.3214
12	Wet	53	0.44	1.4	50	1.8672	2944.3582
13	Wet	74	0.22	1	50	1.5354	7025.3671
14	Wet	74	0.33	1.2	50	1.8694	3254.1265
15	Wet	74	0.44	1.4	50	0.9968	6957.3548
16	Wet	98	0.22	1	50	1.3542	7756.3598
17	Wet	98	0.33	1.2	50	0.9685	3965.1469
18	Wet	98	0.44	1.4	50	0.9963	7069.3587

Chapter 5

5. Results And Discussions

5.1 Experimental Results

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

Table 7 L18 Response table

Run	Lubrication	Speed (m/min)	Feed (mm/rev)	DOC (mm)	Length (mm)	Ra (micron meter)	MRR (mm3/min)	SNR OF Ra	SNR of MRR
1	Dry	53	0.22	1	50	0.9493	1986.254	0.6458	66.2365
2	Dry	53	0.33	1.2	50	1.4654	3799.165	2.9856	71.5637
3	Dry	53	0.44	1.4	50	1.5862	3690.2541	3.4452	71.3245
4	Dry	74	0.22	1	50	1.2354	3214.6354	1.1212	70.4125
5	Dry	74	0.33	1.2	50	1.7652	7963.2569	4.6523	78.3965
6	Dry	74	0.44	1.4	50	1.2101	6985.3754	0.5624	77.3251
7	Dry	98	0.22	1	50	1.6354	5247.3614	3.9672	74.8531
8	Dry	98	0.33	1.2	50	0.8234	6254.3165	2.5674	76.1243
9	Dry	98	0.44	1.4	50	0.9898	1354.2142	0.4568	82.6534
10	Wet	53	0.22	1	50	0.9987	1175.3549	0.8685	60.8974
11	Wet	53	0.33	1.2	50	1.5754	1180.3214	3.2614	69.5621
12	Wet	53	0.44	1.4	50	1.8672	2944.3582	4.9874	77.1421
13	Wet	74	0.22	1	50	1.5354	7025.3671	3.5487	70.2142

14	Wet	74	0.33	1.2	50	1.8694	3254.1265	5.2345	76.8695
15	Wet	74	0.44	1.4	50	0.9968	6957.3548	0.8563	76.7546
16	Wet	98	0.22	1	50	1.3542	7756.3598	2.5364	72.2131
17	Wet	98	0.33	1.2	50	0.9685	3965.1469	1.6524	76.8957
18	Wet	98	0.44	1.4	50	0.9963	7069.3587	0.3541	80.5321

5.2 Results and Discussions

The L18 orthogonal array was directed, and yield reactions, such as material ejection rate and surface unpleasantness, were resolved. Here, the test data was evaluated, and machining parameters were improved using Taguchi optimization techniques (table 6).

In Fig., the main impact plots for material removal rate reveal that feed rate, depth of cut, and rotational speed all have a direct effect on material removal rate. The MRR grows as the feed rate, depth of cut, and rotational speed are increased, as well as via observation. For dry conditions, the best specifications are a cutting speed of 98 m/min, a feed rate of.44 mm/rev, and a DOC of 1.4 mm.

Main Effects Plot for SN Ratio

Data Means

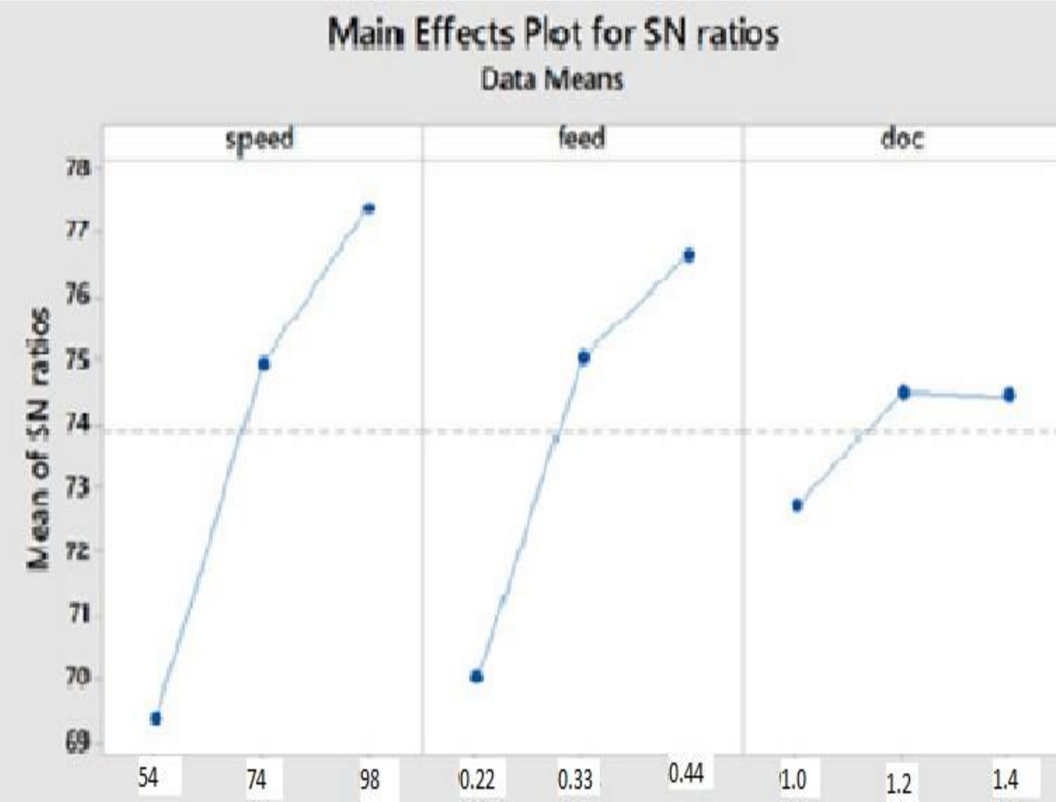


Fig 19 Main Effect Plot For Material Removal Rate

Fig -20. Display how information parameters affect surface roughness. It is implied that increasing feed rate and cutting rate increases surface discomfort, increasing depth of cut decreases surface harshness, and that machining under coolant conditions can reduce surface unpleasantness. The ideal setting parameters for achieving lower Ra have been identified as cutting rate of 98 m/min, feed rate of.44 mm/rev, and DOC of 1.4 mm for dry condition.

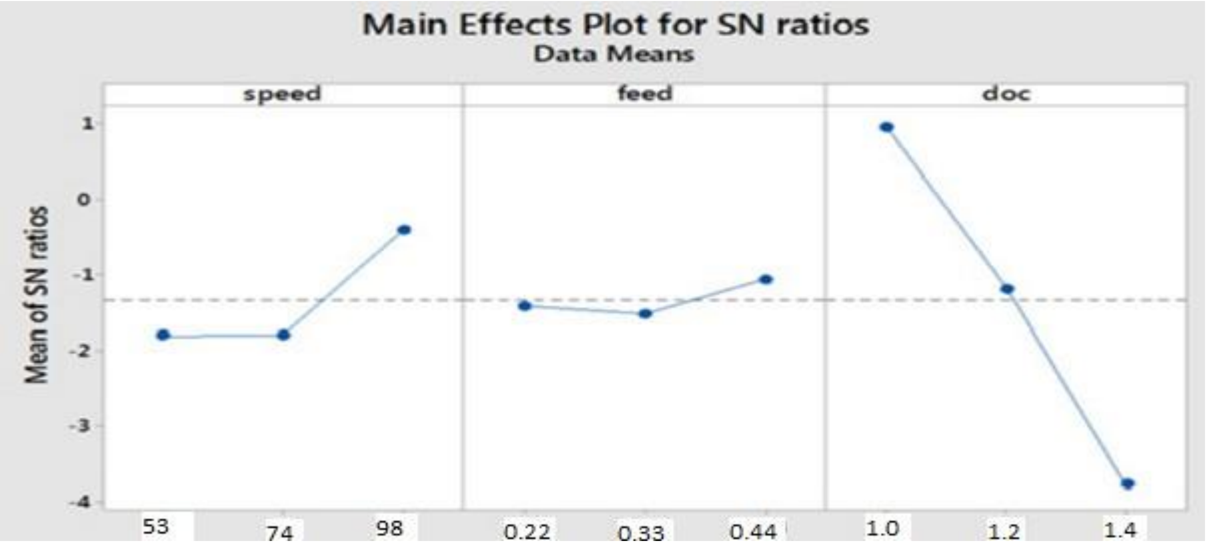


Fig 20 Main effect plot for surface roughness

CHAPTER 6

6. Conclusions

6.1 Conclusions

The machining was done with a simple carbide tool. The Taylor Hobson equipment was used to calculate MRR and assess surface roughness. The data was entered into the Minitab 18 programmers to do an ANOVA and calculate the regression equation. For any other inputs, the regression equation produced can be used to estimate the Ra and MRR .In both wet and dry machining; the relative importance of each parameter for Ra and MRR was investigated.

The S/N ratio response graphs for wet and dry situations were found to be similar. The speed and feed were exactly proportional for Surface Roughness, but DOC was inversely proportional. i.e., as the population grows, Ra drops when DOC lowers. In the case of MRR, all three parameters were shown to be proportionate, meaning that as speed, feed, and DOC increased, so we get MRR.

6.2 Scope for future study

Consider the following ideas for potential future research projects:

i) WE using an alternative substance, such as oil.

ii) Making use of different wire types including coated wires made of copper, tungsten, and other materials.

iii) Utilizing a scanning electron microscope to examine the WEDM's surface roughness.

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Investigation on Effect of CNC Parameters on Surface Roughness and MRR on En31 Steel Using High Speed Turning Operation

Mohd Laraib[1] Mohd Faizan Hasan[2]
[1]Research Scholar [2]Assistant Professor
[1,2]Department of Mechanical Engineering
[1,2]Integral University, Lucknow, U.P., India

Abstract— The test is carried out on EN 31 steel with a carbide insert. Face central composite design is used to define the number of experiments and the layout of process parameters. Spindle speed, feed, and depth of cut are the input parameters, and they are changed on three levels response MRR and Surface Roughness are utilized to make an empirical link between the inputs and responses. Analysis of variance was used to verify the results response. Surface Roughness and MRR predict the following values: as compared to data from experiments the effects of input factors on responses are investigated using Surface Roughness and MRR as a response Tool undergoes multi-objective optimization of turning process parameters.

Keywords: Surface Roughness, MRR, High Speed Turning Process, EN31 Steel

I. INTRODUCTION TO VARIOUS MACHINING PROCESSES

Machining is a metal removal process in which excess material is removed from raw material in the form of chips to get the desired shape of the result. Subtractive manufacturing, refer to a group of methods that share numerous common, controlled parameters for material removal. There are three types of machining processes.

- The main method of moving metal against the cutting tool in turning operations is to rotate the work piece. The lathe is the most common machining tool used in turning.
- Milling procedures involve rotating the cutting tool to bring the cutting edges into contact with the work item. In milling processes, milling machines are the most used machining tools.
- Drilling procedures involve bringing a revolving cutter with cutting blades on the lower extremities into contact with the work piece to create or refine holes.

A. High Speed Turning Operation:

The removal of metal from the outside diameter of a spinning cylindrical work piece is known as turning. Turning is a technique for reducing the diameter of a work piece to a certain size and producing a smooth finish on metal. It can be defined as the machining of an exterior surface in its most basic form:

- With the rotatable work piece.
- Using a single-pointed cutting tool and
- The cutting tool should be fed parallel to the work piece's axis and at a distance that will remove the work's outer surface.

B. Process Parameters of High Speed Turning Operation:

1) Speed:

The spindle and the work piece are always mentioned when talking about speed. Their rotational speed is indicated by the number of revolutions per minute (RPM). The surface speed, or the rate at which the work piece material moves past the cutting tool, is the most significant aspect for a given turning process.

$$V = \pi DN/1000 \, m/min$$

Where, V = cutting speed,
D = Initial diameter of work piece (m)
N = Spindle speed (RPM)

2) Feed:

The cutting tool is always referred to as the feed, and it is the rate at which it moves along its cutting path. The feed rate on most power fed lathes is proportional to the spindle speed.

$$F = f N \text{ mm/min}$$

Where,
F = Feed,
f = Feed rate,
N = Spindle speed

3) Depth of Cut:

It refers to the thickness of the layer being removed from the work piece, or the distance between the work's uncut and cut surfaces.

$$\text{Depth of Cut (DOC)} = D1\text{-}D2/2$$

Where,
D1 = Initial Diameter,
D2 = Final Diameter

4) EN31 STEEL:

EN31 is a high-quality high-carbon alloy steel with high hardness, compressive strength, and abrasion resistance.

II. LITERATURE REVIEW:

1) Santosh Kumar et.al (2017): The Taguchi method and regression analysis were used in this study to optimise the machining parameters when turning EN-45 spring steel with a simple carbide cutting tool. Taguchi's L16 orthogonal array was used to plan and conduct the experiments. The Taguchi technique (Minitab) was used to optimise the input parameters speed, feed, and depth of cut for maximum material removal rate (MRR), minimum tool wear (TW), and minimum surface roughness (SR) The regression analysis, which is a set of equations for the output parameter as a function of the input variables, was created
2) Venkata Ramana et.al.(2014): Taguchi's technique for determining machining conditions is linked to Taguchi's strong emphasis on instrument wear. The elements chosen in this study include cutting speed, machining feed rate condition, and carbide device material type. When titanium alloys are machined under various oil circumstances, it is revealed that the base amount oil produces increasingly better results when compared to dry and overwhelmed grease situations. The ANOVA method reveals that cutting speed has a greater impact on improving hardware wear rate [6].

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In the process of machining, unwanted metal is taken out of the raw material in the form of chips in order to shape the finished product as needed. Subtractive manufacturing refers to a group of procedures that have numerous controlled, common criteria for material removal [20]. Three categories are used to group machining processes. A fundamental metal machining process that is frequently utilised in sectors that deal with metal cutting is turning. In order to achieve excellent performance, it is crucial to choose the right machining settings for a turning process. High performance is characterised by good machinability, improved surface finish, decreased tool wear, increased material removal rate, increased production rate, 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 the product. Improved strength characteristics, such as resistance to corrosion, resistance to temperature, and longer fatigue life of the machined surface, can be attained with a better surface finish. The functional behaviour of machined parts can be influenced by surface finish in addition to strength characteristics. Examples include friction, light reflection, heat transmission, ability to distribute and hold lubricant, and others. Costs of production are also impacted by surface finish.For the reasons described, it is crucial to minimise surface roughness, which can be done by optimising some of the cutting settings. Every traditional cutting operation has a natural problem called tool wear. Because tool wear impacts both product quality and production costs, researchers work to eliminate or reduce it. In-depth research on tool wear characteristics must be done in order to increase tool life. Machining parameters including cutting speed, feed, depth of cut, etc., tool material and its properties, work material and its properties, and tool geometry are some of the