DEPARTMENT OF MECHANICAL ENGINEERING

ANIL NEERUKONDA INSTITUTE OF TECHNOGY & SCIENCES

(UGC Autonomous & Permanently Affiliated to Andhra University)

PRAGNANAM BRAHMA

ANITS

CERTIFICATE

This is to certify that the Project Report entitled "**Application of Hybrid Variance Desirability Function Analysis(DFA) Approach for the Optimization ofnTurning Attributes of EN24 Steel**" being submitted by **N.Sahithi Sindhura (319126520034), K. Ahamed Husain (319126520017), A.Prasanna Kumar (319126520004), R.Dinesh (319126520040)** to the Department of Mechanical Engineering, ANITS is a record of the bonafide work carried out by them under the esteemed guidance of **Mr.G.Uma Maeshwara Rao.** The results embodied in the report have not been submitted to any other University or Institute for the award of any degree or diploma.

17.4.23

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THIS PROJECT WORK IS APPROVED BY THE FOLLOWING BOARD OF EXAMINERS:

1. **INTERNAL EXAMINER:** Neeharika 17/4/23

2. **EXTERNAL EXAMINER:** 17/4/2023

Application of Hybrid Variance-Desirability Function Analysis (DFA) approach for the Optimization of Turning Attributes of EN24 Steel

A Project report submitted in partial fulfilment of the requriemts for the award of degree of

Bachelor of Technology

in

Mechanical Engineering

Submitted by

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ABSTRACT

Producer’s today struggle greatly to choose the appropriate process settings in order to achieve several performance qualities during machining. The main goal of the optimization process is to reduce expenses and increase profits. When making judgements in the industrial sector, optimization is essential. The basic objective of the optimization process is to raise one or more process parameters while keeping other parameters within certain bounds. The current study aims to identify the influence of turning process parameters on surface roughness and material removed from the surface. The experiments on the material EN24 Steel were carried out using Taguchi's L16 Orthogonal array and PVD-coated tungsten carbide inserts. Using the desire function analysis (DFA) and analysis of variance (ANOVA) approaches, the optimal combination of process parameters was found.

Key Words: Material Removal Rate (MRR), Surface Roughness (Ra, Rz), Variance Desirability Function Analysis (DFA), Analysis of Variance (ANOVA).

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NOMENCLATURE

1. CNC: Computer Numerical Machine

2. NC: Numerical Control

3. HSS: High Speed Steel

4. DFA: Desirability Function Analysis

5: S/N Ratio: Signal to Noise Ratio

6: OA: Orthagonal Array

7: MRR: Material Removal Rate

8: d_i: Individual Desirability

9: $D_{g:}$: Composite Desirability

10: s: Speed

11: f: Feed

12: d: Depth of Cut

13: r: Nose Radius

14:SNR: Signal to Noise Ratio

15:R_a: Surface Hardness

CHAPTER 1

INTRODUCTION

1.1. Turning Operation

The machining process known as turning creates cylindrical pieces. It can be summed up as process for machining where material removal rate is considered.Turning can be done by

- Rotation of workpeice
- With a Single point cutting tool

Taper turning is the same as long as the tool is not angled to the axis position. Similar to this, in contour turning, the cutter's proximity to the axis of work is adjusted to create the required form.Though a single point cutting tool is stated, turning frequently uses multiple-tool setups, which are not excluded by the single-point tool requirement. Each tool in such a system functions independently as a single-point cutter.

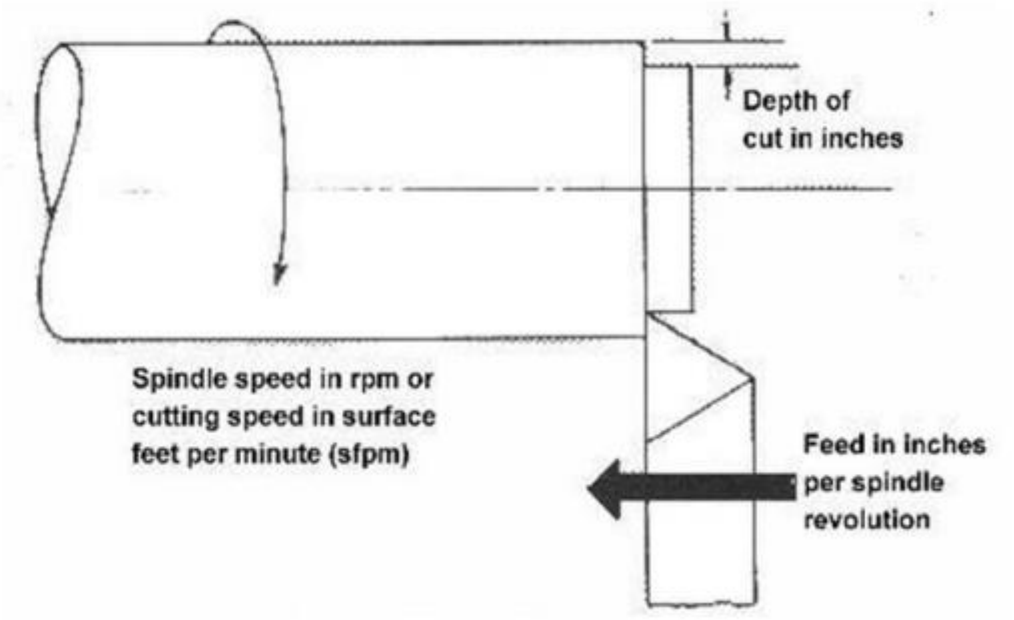


Figure.1.1 Turning Operations

1.2. Lathe Machine Operation.

The machine operations are divided into the following three major categories. The following lathe machine operations are carried out either by using a chuck or by holding the workpiece between centres:

- ➢ Turning Operation
- ➢Straight Turning
- ➢Rough Turning
- ➢Shoulder Turning
- ➢Taper Turning
- ➢Eccentric Turning
- ➢ Facing Operation
- ➢ Chamfering Operation
- ➢ Knurling Operation
- ➢ Theard Cutting Operation
- ➢ Filing Operation
- ➢ Polishing Operation
- ➢ Grooving Operation
- ➢ Spinning Operation
- ➢ Spring Winding Operation
- ➢ Forming

The following processes of lathe machine where holding of job in chuck,faceplate andangle plate:

- ➢ Drilling

➢ Reaming

➢ Boring

➢ Contour Boring

➢ Taper Boring

➢ Tapping

➢ Under Cutiing

➢ Interanl Thread Cutting

➢ Parting Off

1.2.1 The Operations performed with special attachments are

➢ Grinding

➢ Milling

Turning:

In all lathe operations, it is the most typical kind of operation. By removing extra material from the workpiece, turning creates a cylindrical surface with the desired length. The task was rotated at the proper speed while being held between the centre and a chuck. To provide the fees towards the headstock with the required depth of cut, the tool advances longitudinally. The quality on the surface is excellent.

Facing:

By feeding the workpiece perpendicular to the lathe axis, the length of the workpiece is reduced. This procedure flattens the end of the workpiece by reducing its thickness. Regular turning tools or facing tools can be used for this process. The tool's cutting edge should be positioned such that it is at the same height as the workpiece's centre**.**

Chamfering Operation:

It is the process of giving the edge of a cylindrical workpiece a bevelled surface. If the shaft ends are bolt ends, this process is carried out. Chamfering protects the operation by hands and prevents injury to the sharp edges. The bolt's chamfering makes it easier to screw on the nut.

Knurling Operation:

Giving a cylindrical workpiece's edge a bevelled surface is what it entails. This technique is done if the shaft ends are bolt ends. The chamfering shields the hands during operation and keeps the sharp edges from hurting anyone. The chamfering on the bolt makes it simpler to screw on the nut.

Thread Cutting:

External thread cutting refers to the process when threads or helical grooves are created on the surface of the workpiece. Internal thread cutting occurs when threads or helical grooves are created on the interior surface of the workpiece. The workpiece rotates on the lathe between the two centers, known as the live centre and dead centre.

To acquire the desired type of thread in this instance, the tool is moved longitudinally. The left-hand thread is obtained by moving the tool from the right to the left. The right-hand thread results from moving the tool from left to right.

In this instance, the lead screw drives the carriage. The lead screw is driven by two changing gears and the handle's rotation.

Grooving:

It involves lowering a workpiece's diameter over a very small surface. A tool with a groove does it. The parting-off tool is comparable to a grooving tool. To leave a small margin, it is frequently done near the end of a thread or close to a shoulder.

Forming:

Turning a convex, concave, or other uneven shape is what it is. The following technique can be used to form-turn:

- Using a tool of Forming.
- By combining longitudinal and cross feed.

- Tracing a template.

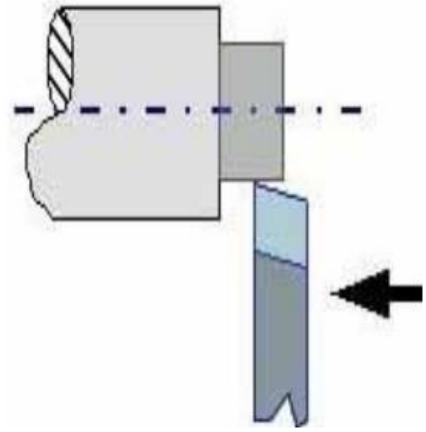


Figure 1.2 Producing a Cylindrical Surface

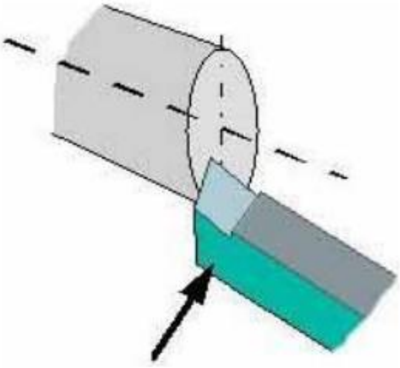


Figure 1.3 Producing a Flat Surface

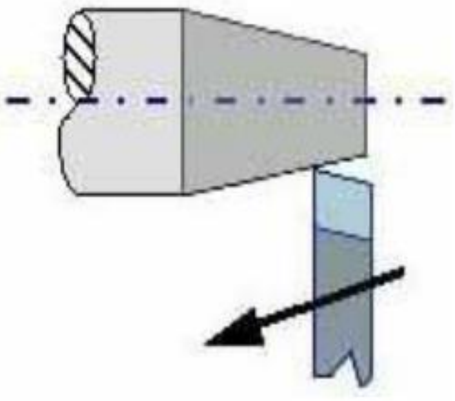


Figure 1.4 Taper Turning

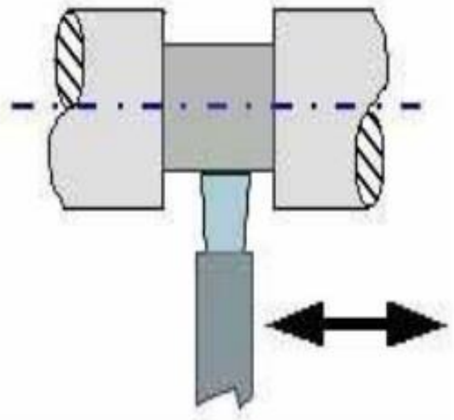


Figure 1.5 Parting Off / UnderCutting

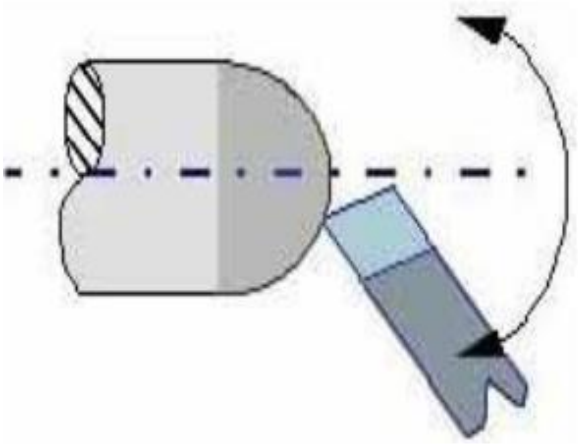


Figure 1.6 Radius Turning Attachment

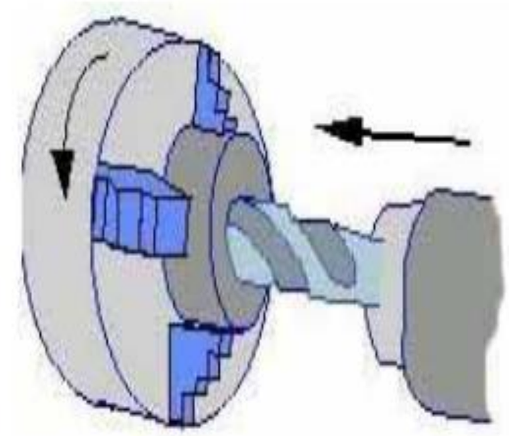


Figure 1.7 Drilling on a Lathe

Cutting Tools

Point cutting tool is the name of the tool used in the lathe. Two drills and files have only on cutting edge or tip instead of many tips and teeth.

As will be seen later, the turning tool cuts metal instead of cutting it. It also has relative workpiece motion. Cutting occurs, for example, when the tool moves within an obstacle while the workpiece is rotating.

Of course movement is important; For example, if you move too much at once, you may da-mage the device.

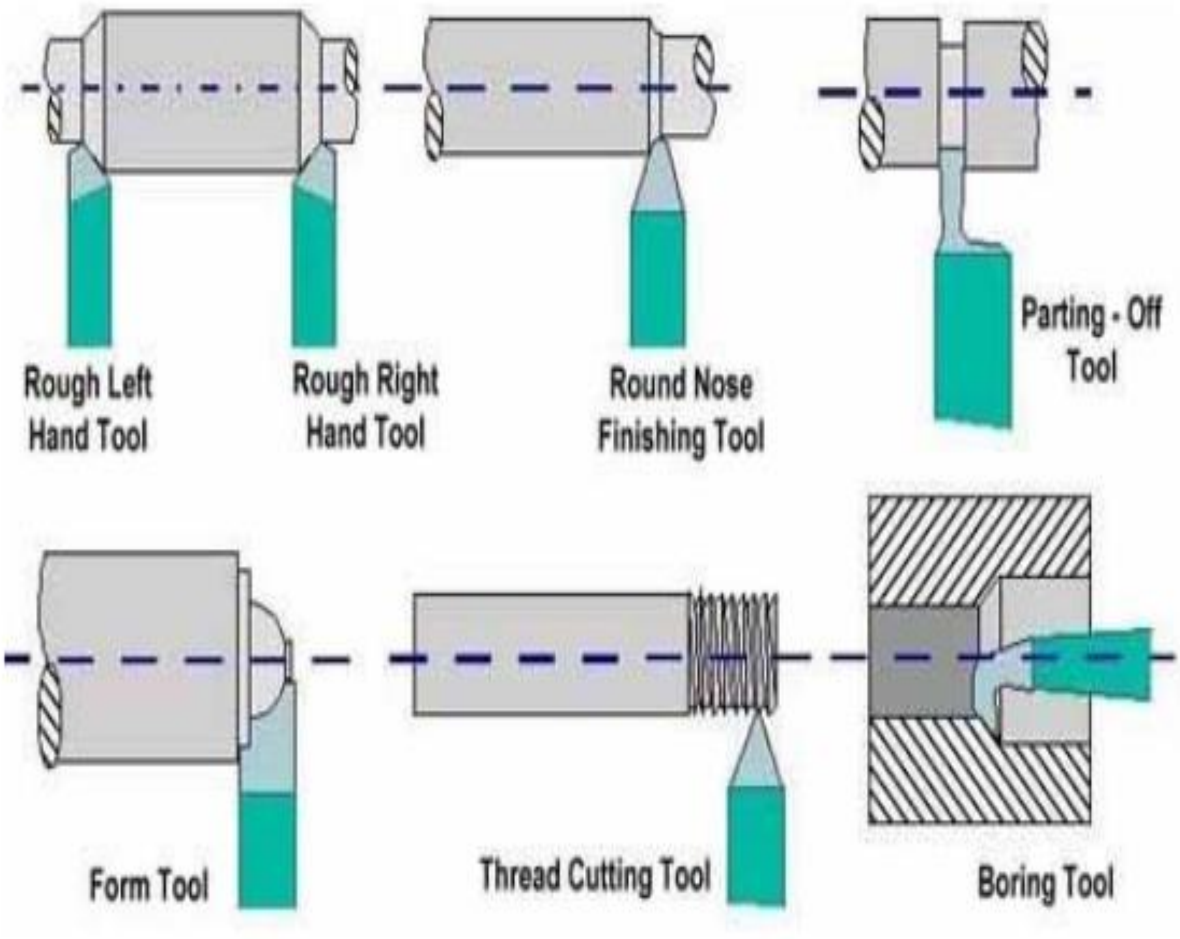


Figure 1.8 Types of Cutting Tool

The task at hand, the chosen machining operation, and the material to be cut will determine the type and design of the tools chosen. the ideal instrument in particular.

If the procedure is to be carried out in a cost-effective (i.e., productive) manner, the different face angles are crucial. There are many different tools used in the lathe, some of which are depicted in figure 1.8.

1.2.2 Tool Angles

Rake angle, clearance angle, and plan approach angle are the three crucial angles in the development of a cutting tool.

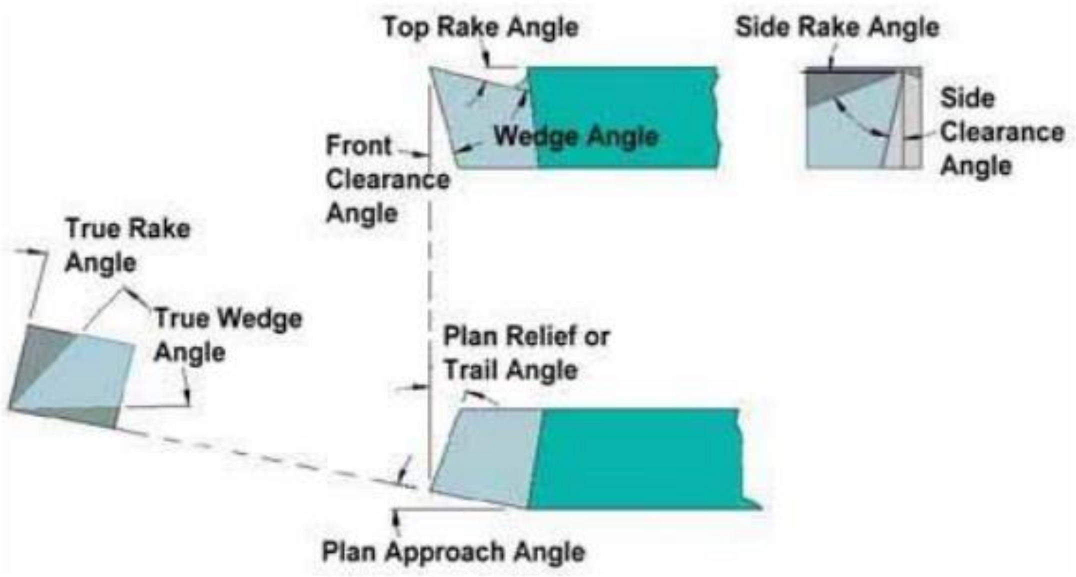


Figure 1.9 Main Features of a Single Point Cutting Tool

Rake Angle

Rake angle is the angle formed at the cutting edge of the tool between the top face and the normal to the work surface. Since the shear plane AB, depicted in Figure 1.9 , shrinks as rake ngle increases for a given depth of cut, the cutting force on the tool generally reduces as rake angle increases. The cutting motion will be improved by a large rake angle, but because the tool wedge angle is so weak, the tool would fail sooner. Therefore, a trade-off between sufficient strength and effective cutting action must be made.

Clearance Angle

The clearance angle is the angle formed between a tangent to the work surface that originates at the cutting edge and the flank or front face of the tool. To enable for cutting, all cutting instruments must have clearance. The amount of clearance should be kept to a minimum because too much space would weaken the tool rather than enhance cutting efficiency. In external turning, a front clearance angle of 6° is typical.

Plan Profile of Tool

The work's shape frequently determines the tool's plan shape, which also affects tool life and cutting performance. Two tools are shown in Figure 1.10, one where a square edge is preferred and the other where the steps in the work are finished with an angle or chamfer. The diagram demonstrates that the angled tool has a substantially longer cutting edge in contact with the job for the same depth of cut, reducing the load per unit length of the edge. The angle that the edge makes contact with the work should ideally be as large as feasible, but if it is, chatter could result.This angle, known as the Plan Approach Angle, should therefore be as large as possible without causing chatter.

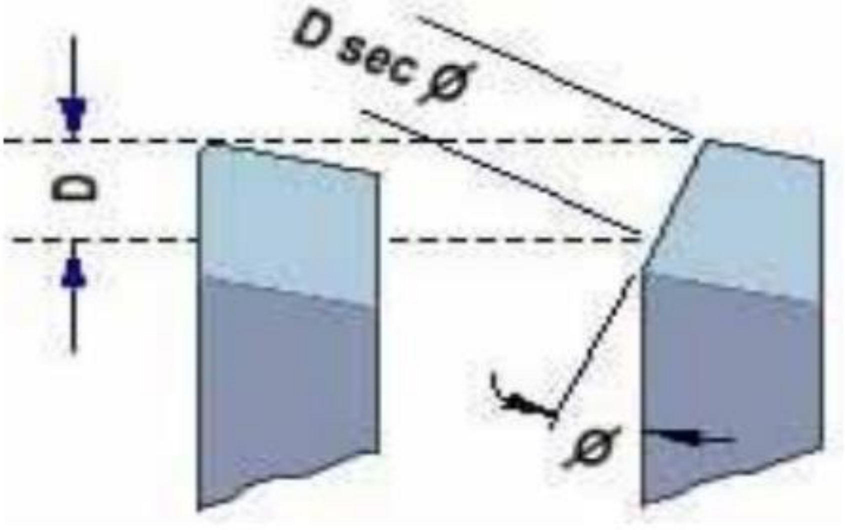


Figure 1.10 Plan Approach Angle

To provide space and minimise friction, the trailing edge of the tool is ground backward. A good general rule is to grind the trailing edge at 90° to the cutting edge. As a result, the approach angle will determine the Trail Angle or Relief Angle.

A narrow tool nose radius enhances cutting and lessens tool wear. Using a sharp point results in a poor finish and quick wear.

1.3. Basic Metal Cutting Theory

The typical image of cutting implies separating the object with a narrow knife or wedge. Although the tool will always be wedge-shaped in the cutting area and the cutting edge should always be sharp, the action when cutting metal is quite different, and the wedge angle will be far too great for it to be considered knife-shaped. Consequently, as the work is moved against the tool, a shearing motion occurs.

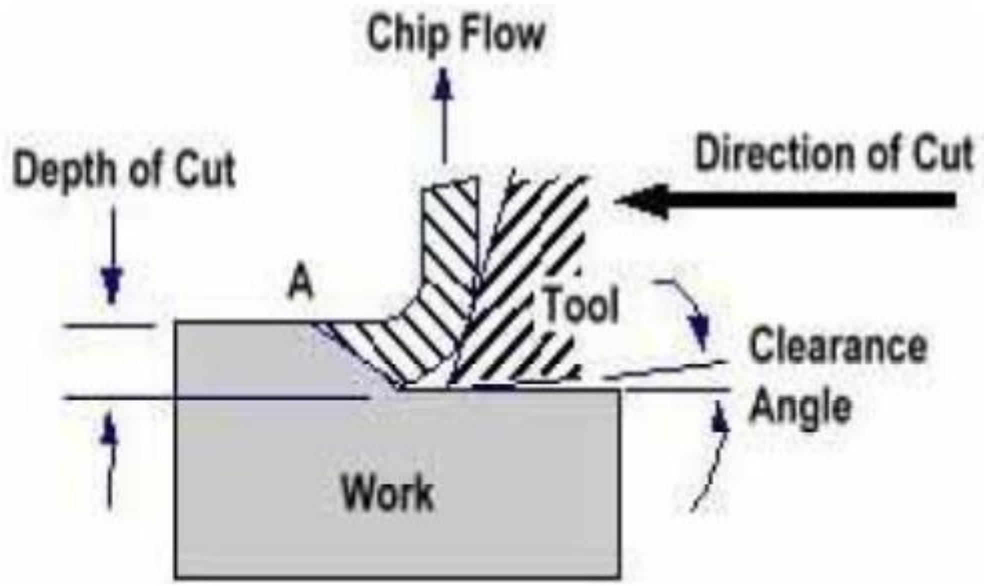


Figure 1.11 Basic Metal Cutting Theory

An object is moved against a stationary work piece in Figure 1.11. As the cut progresses, the chip exerts considerable pressure on the tool's top face, causing the shear plane AB to continuously be sliced. The same motion occurs when the workpiece is rotating and the tool is stationary, despite the fact that the Figure depicts a tool working in the horizontal plane with a stationary workpiece.

1.3.1 Chip Formation &Chip Breaker

The type of chip produced depends on the material being machined and the present cutting conditions. The type of tool being used, the machine's cutting speed, and the presence or absence of a cutting fluid are some of these variables.

Continuous Chip

This is typical when cutting most ductile materials, including mild steel, copper, and aluminium, leaving the tool as a long ribbon. It relates to proper tool angles, appropriate speeds and feeds, and the use of cutting fluid.

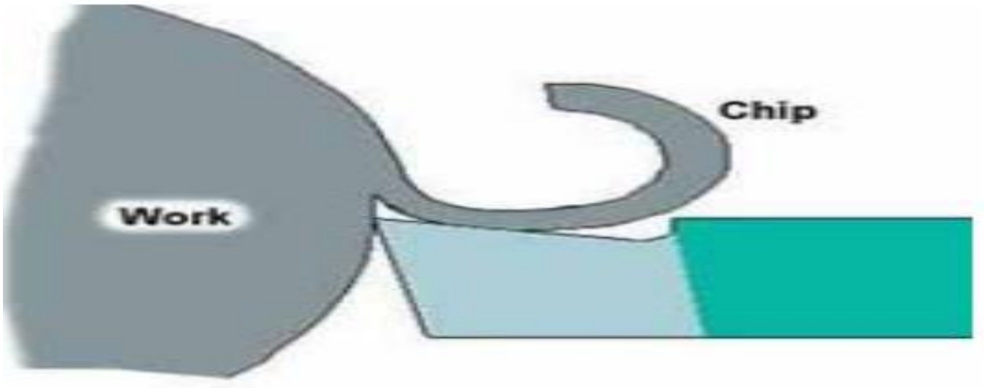


Figure 1.12 Continous chip

Discontinuous Chip

When fragile metals like cast iron and cast brass are cut with tools having narrow rake angles, little fragments of metal called chips result. In these conditions, this kind of chip is perfectly acceptable.

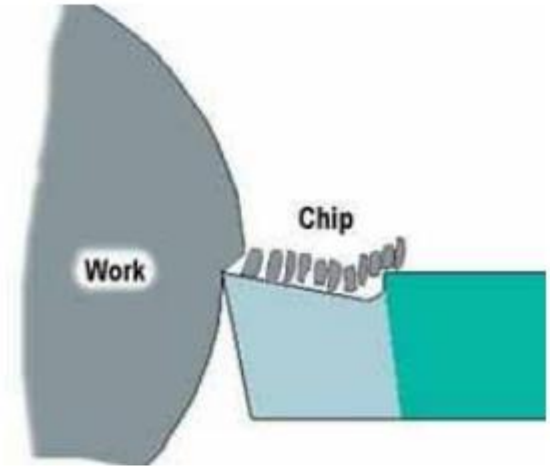


Figure 1.13 Discontinuous Chip

Continuous Chip with Built-up Edge

This is a chip to be avoided and is caused by small particles from the workpiece becoming welded to the tool face under high pressure and heat. The phenomenon results in a poor finish and damage to the tool. It can be minimized or prevented by using light cuts at higher speeds with an appropriate cutting lubricant.

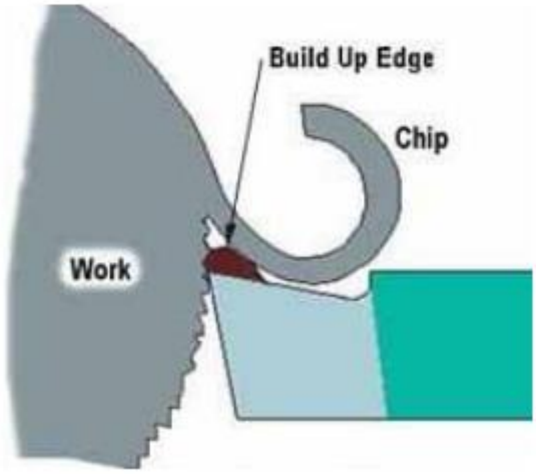


Figure 1.14 Continuous Chip with Buildup Edge

Chip Breaker

To prevent the chips from tangling around the cutting tool, a chip breaker is used to separate the continuous chip into pieces. Making a groove on the tool face a few millimetres behind the cutting edge creates the most basic type of chip breaker.

1.4. Cutting Parameters

The relative'speed' of the work piece's rotation and the 'feed' rates of the cutting tool coupled with the material to be cut must be given your significant consideration as you move on with the metal cutting process. This relationship is crucial if products are to be produced quickly, affordably, and accurately according to established standards for surface finish quality and precision. As a future supervisory or management level engineer, you need to pay close attention to these crucial characteristics and make sure you have a solid understanding of the variables at play.

1.4.1. Cutting Speed

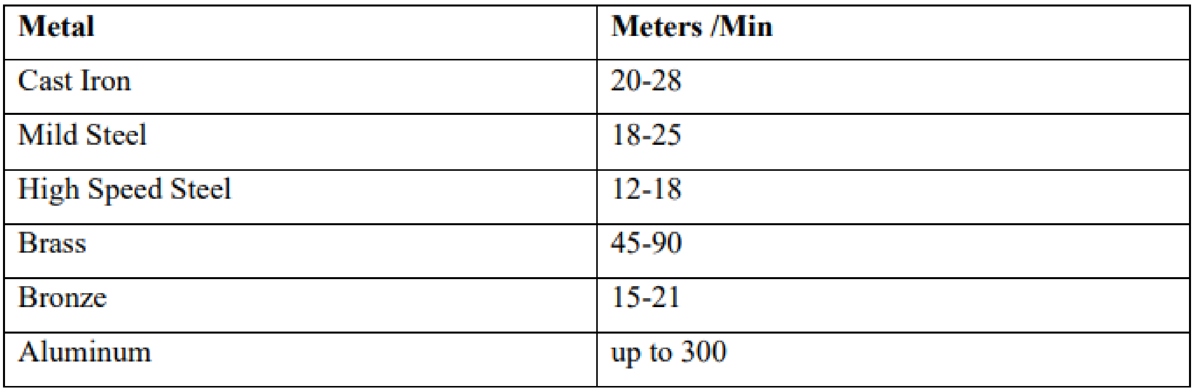
Every material has an ideal cutting speed, which is measured in metres per minute and is defined as the rate at which a point on the surface of the work passes the cutting edge or point of the tool. To determine the necessary spindle Speed,

$N = Cs\ X\ 1000/\ \pi d$

Where: N = Spindle Speed (RPM)

CS = Cutting Speed of Metal (m/min) d = Diameter of Work piece. Table 1 shows the cutting speed recommended for some common metals. It may be possible to exceed these speeds for light finishing cuts. For heavy cuts they should be reduced.

Table 1. Cutting Speed



Metal	Meters /Min
Cast Iron	20-28
Mild Steel	18-25
High Speed Steel	12-18
Brass	45-90
Bronze	15-21
Aluminum	up to 300

1.4.2. Feed

The amount of tool movement per workpiece revolution is referred to as "feed," and it mostly depends on the desired level of surface polish. A feed of up to 0.25 mm per revolution may be utilised to rough out a soft material. This should be lowered to a maximum of 0.10 mm/rev for harder materials. A finer feed is necessary for finishing than is advised.

1.4.3 Depth of cut

The depth of cut is the perpendicular distance measured from the machined surface to the uncut surface of the work piece.

1.5. Cutting Fluid & Lubricant

Maintaining precision, producing a good surface finish on the workpiece, and extending tool life are the goals in metal cutting.

•The deformation of the material ahead of the tool causes heat to be produced during the metal cutting operation.

• Resistance at the tool's point A lubricant can easily be used to minimise the heat produced by friction.

Deformation-related heat cannot be minimised, but it can be removed by a fluid. In order to reduce tool wear, improve surface smoothness, and tighten dimensional control, cutting fluids should be used.

However, correct cutting fluid selection, mixing, and application are commonly overlooked and misinterpreted in machining practise. It is essential to make sure that the cutting fluid is delivered directly to the cutting zone so that it can create a film at the tool's sliding surfaces in order for it to function as intended.

Cutting fluids in Common Use

Water:

Even though it has a high specific heat, it is poorly lubricated and promotes corrosion. During the grinding of tools, it serves as a cooling agent.

Soluble oils:

Oil won't dissolve in water, but emulsifying chemicals can be used to make it create an intimate mixture or emulsion. The oil is then suspended as tiny droplets in the water. These fluids cool well and have average lubricating capabilities. When using general purpose machines for light cutting tasks where high rates of metal removal are frequently secondary, soluble oils are ideal. There are numerous varieties of soluble oil available on the market, therefore it is important to adhere to the supplier's recommendations for the'mix''s' proportions.

Mineral Oils:

They are frequently found in manufacturing machines where high rates of metal removal are used and are used for heavier cutting operations because to their superior lubricating characteristics. Although mineral oils are excellent for steels, they shouldn't be used on copper or its alloys due to their corrosive nature.

Vegetable Oils:

They work well as lubricants but are rarely used since they can spoil and smell.

1.6. CNC Lathe

The utilization of electronic controls for their cutting tools is the primary way that numerical-control tracer lathes differ from hydraulically controlled tracer lathes. All tool movements during cuts, as well as all tool indexing, cross-slide operations, and changes in speed and feed, are pre-engineered and encoded on a punched tape for electronic control of all machine motions. The NC lathe has the advantages of low tool inventory and completely configurable cutting conditions. NC lathes can machine any cylindrical form for copying operations without the need for a template. However, compared to tracer lathes, NC machines can be rather pricey.

The usage of computers as controller units in NC systems at the beginning of the 1970s marked a significant leap in the theory behind machine tool numerical control. As a result, both direct numerical control (DNC) and computer numerical control (CNC) were created. Using a dedicated computer to perform part or all of the basic NC operations under the direction of stored instructions, computer numerical control (CNC) is a self-contained NC system for a single machine tool. A centralised computer can directly control a variety of machine tools thanks to DNC. For production systems, machine tools, welders, and laser beam cutters, CNC has become the more well-liked of the two methods of computer control due to its versatility and cheaper initial investment.

One objective of CNC systems is to minimise the remaining hardware and replace as much of the conventional NC gear with software as is practical. However, they always need some hardware in the controller that is particular to the individual machine. In such systems, functions can be exchanged between hardware and software in a variety of ways. This hardware must contain the servo amplifiers, transducer circuits, and interface components..

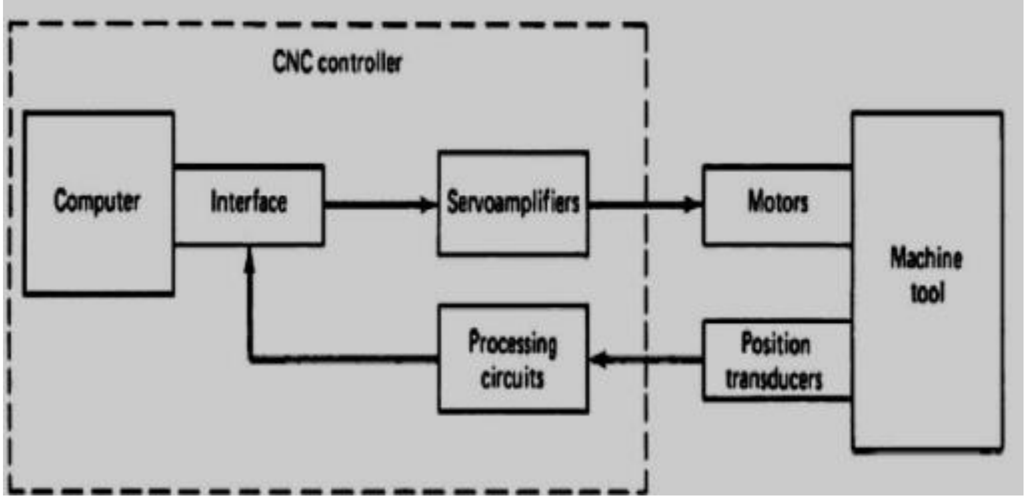


Fig. 1.15 Block diagram of a CNC machine

The software for a CNC system includes at least three important programmes: a supplement, a volunteer program, and a management programme. The part programme specifies both the cutting parameters, such as spindle speed and feed rate, and the geometry of the component being produced. The service program, which is also used to do system diagnostics, examines, edits, and fixes the part programme. The control programme creates signals that move the machine's axes of motion using the input data from the part programme.

The combined motion of the different axes creates the necessary route for the tool, which is a common feature in numerical control and robotics. The manipulator's far end, which could be a gripper, a welding gun, or a paint spraying gun, is referred to as the tool in robotics. The tool in numerical control is the cutting tool, such as a drill or milling cutter. Robot systems, however, are more advanced than CNC systems used in machine tools for the reasons covered in the next section.

For machine tools to function, the cutting edge's spatial location must be controlled. Usually, three control axes are enough. Robots must be able to control six axes of motion, also known as degrees of freedom, in order to control a tool's orientation and centre of gravity. While some robot systems employ more than six axes of motion, certain CNC machines use more than three. One typical example is a three-axis milling machine with a connected rotary table.

When a robot system has fewer than six axes, the wrist portion, however, only has fewer than three degrees of freedom.

1.6.1. Fundamentals of NC

The Electronic Industries Association (EIA) has defined numerical control equipment as a system in which actions are controlled by the direct injection of numerical data at some point. At least some of these data must be interpreted by the system automatically. The part programme in an NC or CNC system refers to the numerical data that must be retained on a disc or tape in order to produce a part. Blocks of information make up the part programme's structure. The numerical information needed to create one segment of the work-piece profile is contained in each block. The block has all the necessary data in coded form for processing a segment of the workpiece, including the segment length, cutting speed, feed rate, and more.

In contrast to a conventional machine tool, the operator's manual activities are replaced by the NC system. To create a part in conventional machining, an operator engages and disengages motorised slides that move a cutting tool along a workpiece. A skilled operator cuts shapes visually. Operators of NC machine tools do not, however, have to be proficient machinists. The only tasks required of them are to operate the tape reader, load and unload the workpiece, and monitor machine activities. The component programme now manages the majority of the mental tasks that the operator used to undertake.

To create the part programme for an NC machine tool, a part programmer is required. The assistant programmer must to have training and expertise in mechanical engineering. Understanding tools, cutting fluids, fixture design techniques, machinability information, and process engineering is essential. The component programmer must grasp how NC machine tools and machining processes operate and select the appropriate sequence of operations. There are two options: manually programming the part programme or using a computer-assisted language like the automatically programmed tool language. In part programmes for NC machines, the component dimensions are represented by integers. There are times when the dimensions of part programming for CNC machines are given in decimal numbers.

Each motion axis in NC and CNC machine tools has a unique drive mechanism in place of the traditional machine's hand wheel. Stepping motors, hydraulic actuators, or dc motors are examples of possible driving mechanisms. The machine and the required power needs decide the kind.

An axis of motion in numerical control is the direction that the cutting tool moves with respect to the workpiece. This movement is made possible thanks to the machine tool sliding. The three main axes of motion are the X, Y, and Z axes. The Z axis, which is perpendicular to both X and Y, creates a right-hand coordinate system. In a vertical drilling machine, for example, a +X instruction will move the worktable from left to right, a +Y instruction will move it from front to back, and a +Z instruction will move the drill up and away from the workpiece (as one faces the machine). With the X, Y, and Z axes, a right-hand Cartesian coordinate system is always produced.

Each axis of motion has its own unique control loop as well. In the control loops of NC or CNC systems, tachometers are used to measure velocity and encoders, or other position transducers like resolvers, are used to measure position. Following a comparison between the required position and the actual position, the controller generates an error. The control loop is of the negative feedback variety because it is designed to reduce mistake. Both continuous-path NC and CNC systems need to develop the ability for the individually driven axes to move in concert in order to achieve the tool's desired path. These coordinates are performed by interpolators. Systems for numerical control include hardware interpolators..

1.6.2. Advantages of NC Systems

It has been amply established that NC manufacturing requires fewer multifunctional NC machines, and in some circumstances, one operator may handle multiple machines. However, despite increased automation and mechanization, there may be a rise in the proportion of indirect to direct employees, which would boost overall employment in the industry. Naturally, output would also increase. So, rather than lowering labour costs, the gain really comes from increasing output per man-hour. The cost of handling has decreased, sometimes substantially, thanks to NC technology.

Despite a significant reduction in setup times, actual productive time has grown. By switching between operations as the workpiece is being machined, more time is saved. When using a traditional machine tool, operation must stop here to allow the operator to complete the next step. To make sure the material is not overcut, the operator periodically has to stop the cutting operation and measure the part dimensions. It is common knowledge that measurements typically eat up 70% to 80% of the workday. Operator weariness also slows down the manufacturing rate. Because precision is reproducible through numerical control, NC systems avoid these issues.

Numerical control produces higher-quality parts and makes it possible to accurately fabricate more complex designs without suffering from the typical accuracy loss experienced in conventional production. It can take a long time to make a product that needs a cut accuracy of 0.01 mm or better using traditional methods. It is state-of-the-art to achieve such accuracy in numerical control using single-axis motion, and it is maintained across the entire range of cutting speeds and feed rates. Additionally, numerical control enables the production of complex pieces that are unfeasible for conventional manufacturing. Manually carving complex contours in three dimensions is not doable. repeatable precision.

The following are advantages

- Complete flexibility
- Full Accuracy is maintained
- There is possibility of manucaturing contour parts
- Production time is very short
- Productivity can be achived highly.

1.6.3. NC Programming

Off-line programming methods, which can be either manual or computer-assisted (for instance, programming using the automatically programmed tool language), are used by the majority of NC and CNC machine tools. Writing a new piece of the programme while the machine is still running is known as offline programming. When a component of a programme is finished, it is frequently stored on a punched tape or floppy disc. After inserting the tape or disc into the machine tool controller at the machine shop, the part is subsequently manufactured. Manual portion programmes are made by programmers. The programmers must first choose the machining parameters and the appropriate sequence for carrying out the procedures. Based on this sequence, they compute the tool route and produce an expression.

N10

G01

X-52000

Y9100

F315

S717

T65432

MO3 (EB)

The letter and the number that follow it make up a word. Words like X and M03 are examples. The first letter of the word is a representation of the word address. The word addresses are shown as follows: Sequential number is denoted by N, preparation by G, dimensional words by X and Y, feed rate code by F, speed by S, tool code by T, other function by M, and end-of-block character by EB. Instead of being written, the EB character—often used as the carriage return code—is punched or coded, allowing a new line to begin immediately. The completion of the current reading and the need for the axis of motion to begin are both indicated by the EB character to the NC controller. The next block is read following the completion of this action.

1.7. Cutting Tools

Any tool that removes material from the workpiece through shear deformation is a cutting tool. Cutting is possible with single-point or multi-point tools. Single-point tools are used for turning, shaping, planing, and other processes that require the removal of material with a single cutting edge. Drilling and milling usually include the use of multipoint instruments. Grinding tools are multipoint tools. Each grain of abrasive, which serves as a tiny single-point cutting edge, shears a tiny chip. Cutting tools must be made of a material that is tougher than the material being cut and can withstand the heat generated during the metal-cutting process.

The primary categories of cutting tools are drills, reamers, taps, single point lathe tools, multipoint milling tools, and other kinds. These tools could all be ordinary items from a catalogue or custom equipment built to fulfil a specific production need.

The most typical error in tool selection is to prioritise cost savings over higher productivity and longer tool life in order to maximise tool life and minimise tool expense. To choose equipment for machining, an engineer or machinist needs to have a thorough understanding of the following:

- ➢ Shapes of starting and finished parts
- ➢ Hardness of Workpiece
- ➢ Tensile strength of Material
- ➢ Abrasiveness of material
- ➢ Type of chip
- ➢ Holding setup of work
- ➢ Capacity of speed and power of machine tool

A thorough review is needed to change any of about parameters.

Characteristics of Ideal Tool materials

- ➢ It should be hard than the workpiece which it is cutting
- ➢ Should be stable at high temperatures
- ➢ Resistance to shocks
- ➢ Wear Resistance
- ➢ Inertness

No single material for cutting tools possesses any of these qualities. Compromises between the various tool materials are created instead. For instance, a cutting tool constructed of ceramic has a great resistance to heat but a low resistance to shock and impact. Each newly developed and ever developing tool has a purpose for which it excels over others. Newer cutting tool materials have a tendency to reduce, but not completely eliminate, many of the uses of older cutting tool materials.

1.7.1. Single Point HSS Tool

When tool travel is restricted to straight-line movement, forms are frequently created on workpieces using single-point cutting tools. Additionally, single-point tools are used to remove the bulk of the metal during lathe turning. Single-point tools can be made from solid tool steel bars that have the proper cutting edge completed on one end, or they can be made from less expensive stock that has a carbide or other cutting material tip, or insert. Brazing, soldering, welding, or mechanical retention techniques can all be used to secure the implant. Brazed, soldered, and welded inserts are typically disposable, but mechanically held-in inserts can be sharpened again when they become dull from use.

Design

To help engineers create single-point tools, standard angles are shown and labelled in Fig. 1.16. The relationships between the nose radius, side rake angle, end cutting edge angle, side cutting edge angle, and end relief angle are depicted in this diagram.

Back Rake Angle

It is the angle, measured perpendicular to the side of the shank or holder, between the cutting face of the tool and the shank or holder. The angle is positive if the slope from the cutting point to the shank is downhill; the angle is negative if the slope is uphill..

Side Rake Angle

It is the angle, measured perpendicular to the side of the shank or holder, between the cutting face of the tool and the shank or holder. According to Fig. 1.16, an angle is positive if it slopes away from the cutting edge and towards the side of the shank on the opposite side of the shank, and it is negative if it slopes upward.

End Relief angle

It is typically measured at right angles to the end cutting edge and represents the angle between the tool's end face and a line drawn from the cutting edge perpendicular to the base of the shank or holder.

Side Relief angle

The angle between the side flank just below the edge is typically measured at a right angle to the side flank and is created by drawing a line through the side cutting edge perpendicular to the tool or tool holder's base.

Cutting edge Angle

It is the angle formed by the tool's cutting edge and a line perpendicular to the shank's side. The angle formed between the side cutting edge and the exposed side of the shank or holder is known as the side cutting-edge angle or lead angle.

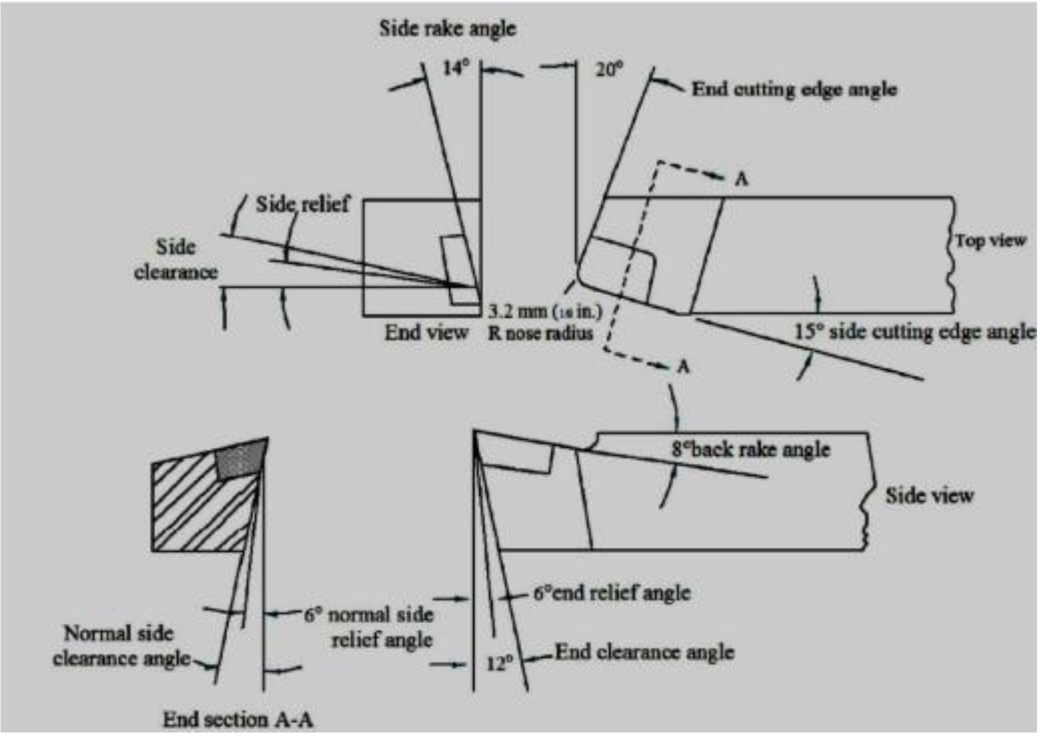


Fig.1.16 Single point cutting tool geometry

Nose Radius

It is the distance in radius between the cutting edges at the tool's end and its side. The nose contour, which is typically described as a radius, eliminates the tool's vulnerable corner, increases tool life, and enhances finish. For maximum strength or for use with abrasive cutting instruments, the radius may be big; however, for light feeds, it may be less. A radius that is too large may chatter, however the better the finish, the larger the radius that doesn't chatter.

The design of a tool determines how much force is required to turn it. The side rake angle has the biggest effect. Tool design is very important when turning using a tracer lathe, which uses one tool for all cuts. The bare minimum of passes is preferable, thus it is best to remove metal at the fastest rate possible while still preserving the necessary dimensions and quality standards. When only one cutting tool is utilized, the form of the tool is highly limited. The cutting edge's nose has a weak structure because tools typically need to have a cutting edge with a side angle of -3° and a minimum end angle of 30°.

1.8. Cutting tool materials

The rate of metal removal has accelerated, and with it the demand for heat-resistant cutting tools. High-speed steels were thus replaced by carbide, which was soon followed by ceramics and other extremely hard materials. High-speed steels, which cut four times quicker than the carbon steels they replaced, were created around 1900. High-speed steel is available in roughly 30 distinct variations, with the three most common types being tungsten, molybdenum, and molybdenum-cobalt based grades. Since the 1960s, when high-speed steel powder was first developed, it has been possible to manufacture drills, milling cutters, and form tools in almost limitless shapes. Tools made of high-speed steel may cut more quickly and last longer due to coatings, particularly titanium nitride. The corrosion-inhibiting titanium nitride provides a high level of surface hardness.

Today's industrial settings generally replace high-speed steels with carbide tools. Between three and five times faster than high-speed steels, these coated carbide and carbide tools cut. Cemented carbide is a powdered metal product made from fine carbide particles joined by a cobalt binder. Tungsten carbide, titanium carbide, tantalum carbide, and niobium carbide are the four main types of hard carbide. Different types of carbide have varying effects on the characteristics of cutting tools. For instance, a larger tungsten percentage reduces the strength of the tool while increasing wear resistance. Strength is increased but wear resistance is decreased when the cobalt content of the cobalt binder is higher. Solid round tools or carbide replaceable inserts are employed. Every carbide tool maker provides a selection for various applications.

It is essential to rely on the carbide providers to suggest grades for particular applications because there are no reliable guidelines for choosing carbide grade specifications. The distinct carbide product line is identified by manufacturers using an ANSI code. The carbide tools are all coated, with one exception. For the majority of applications, coated tools should be taken into consideration due to their quicker machining and longer life. A coating broadens the tool's potential use. These coatings are placed in numerous,.001-inch-thick layers, which are incredibly thin. Titanium carbide, titanium nitride, aluminium oxide, and titanium carbonitride are the primary coatings used on carbide inserts and cutting tools. Cutting tools made of ceramic are more brittle but also harder and heat resistant than those made of carbides.

The two primary categories of ceramic cutting tools are those made of alumina and silicon nitride. For the high-speed semi- and final finishing of ferrous and some non-ferrous materials, ceramics with an alumina basis are utilised.. Ceramics made on silicon nitride are usually used to process cast iron and super alloys more vigorously and roughly. Ceramic tools are made using materials that cover carbide types, such as titanium carbides and nitrides. In chemically reactive machining conditions, they are especially useful for final finishing, some turning, and some milling processes.

Cubic boron nitride and polycrystalline diamond are examples of ultra-hard tool materials. Their use is only permitted in carefully selected, cost-effective applications because their price can be 30 times that of a carbide insert.

Both the machining of non-ferrous metals and the cutting of abrasive materials like glass and some plastics employ polycrystalline diamond. Polycrystalline diamond inserts have outlasted carbide implants by up to 100 times in some high-volume applications. All cutting tools are "perishable," which describes their limited shelf life. Using rusted, worn-out tools until they break is not a smart idea. This safety hazard increases scrap, raises tool and part prices, and lowers productivity. Cutting tools can deteriorate in various ways besides breaking, such as:

➢ Edge and Flank Wear

➢ Top wear

➢ Chipping

➢ Built-up Edge

➢ Deformation

➢ Thermal Cracking

Both flank and edge wear are common, gradual forms of tool wear. This form of wear will quicken in extremely abrasive work materials, such some cast irons. Cratering, which happens frequently when long-chipping steels are machined, takes place beneath the cutting edge. The tool fails right away if the crater is big enough to touch the cutting edge. Utilizing tools made of tantalum carbide or titanium will prevent cratering.

Unpredictable tool failure occurs on the tool edge. Sometimes the separation of a high point on an edge is the first sign. Chipping can be avoided by using a stronger carbide grade, a different edge preparation, or a different lead angle. A built-up edge, which is a buildup of workpiece material on an insert's rake face, is possible.

These deposits may split, which would take particles of carbide out of the tool. Ductile substances like copper, aluminium, and softer steels contribute to this problem. The removal of built-up edge is facilitated by increased rake angles, faster cutting rates, and the application of high-pressure cutting fluid. Tool or insert distortion is brought on by heat accumulation. Without a microscope, deformation is difficult to observe yet is very detrimental to the machining process. By lowering the cutting speed or utilising a heat-resistant tool, deformation is typically prevented. When inserts undergo quick heating and cooling cycles, thermal cracking happens. Cutting interruptions and improper application of the cutting fluid are significant causes.

1.8.1. Characteristics of Tool Material

The following characteristics of a tool are necessary for effective cutting:

Hot Hardness

This refers to the capability of maintaining hardness under extreme heat. All cutting processes produce heat, which will eventually impair the tool's hardness and cutting capacity.

Strength and Resistance to Shock

At the start of a cut, the tool experiences a large shock loading as it bites into the task for the first time. It must, of course, be strong enough to withstand it.

Low Coefficient of Friction

As a result of the tool rubbing against the workpiece and the chip rubbing on the tool's top face, heat must be kept to a minimum.

1.8.2. Tool Materials in Common Use

High carbon steel has a carbon content between 1.4 and 1.4%, with chromium and tungsten added in small amounts to increase wear resistance. The steel is not recommended for modern machining processes, which often involve high speeds and heavy cuts, as it starts to lose its hardness at about 250° C.

High Speed Steel (H.S.S.)

Steel is a robust material with shock-resistant properties, with a hot hardness value of about 600° C. It is widely used by single point lathe cutting tools as well as multi point cutting tools like drills, reamers, and milling cutters.

Cemented Carbides

a substance created from tungsten powder that is incredibly hard. Typically, brazed or clamped tips are utilised on carbide tools. High cutting speeds and difficult-to-cut materials with HSS can both be easily machined using carbide-tipped tools.

Tools' lives In general, VTn =C represents the link between tool life and cutting speed.

V = cutting speed in m/min

T = tool life in min

C = a constant

For high-speed steel tools the value of C ranges from 0.14 to 0.1 and for carbide tools the value would be 0.2.

1.9 Cutting Parameters Effect on Responses

Surface finish, which influences both the cost of manufacture and the functionality of mechanical parts, is one of the most important quality elements in the manufacturing sector. Modern businesses have been attempting to produce high-quality goods fast and with the least amount of labour input. For that reason, automated and adaptable manufacturing systems using machine tools under computer numeric control have been introduced. Internationally, there have recently been numerous calculations focusing on surface roughness with the goal of enhancing product quality and machining effectiveness. Turning operations, particularly in the automotive and aerospace sectors, can be found to leverage this computation by increasing the alternative solution to obtain increased surface roughness.

Excellent turning surfaces can enhance strength properties like fatigue resistance, corrosion resistance, and temperature resistance. Additionally, a part's functional features like as friction, wear, light reflection, heat transmission, coating, and the ability to spread and retain lubricant are all impacted by the ultimate surface roughness. Tolerance-giving requires careful consideration of the tool geometry and cutting parameters that affect surface roughness. In order to achieve the needed quality, the desired finish surface is typically chosen and the relevant processes are chosen.

The surface roughness of a component is one of the most crucial factors to take into account when evaluating its quality because it affects all of the above-mentioned quality criteria. It has long received significant attention because it is an essential aspect of quality. It has evolved into a crucial design component in a variety of situations, such as those involving sections subjected to fatigue loads, accurate fits, fastener holes, and aesthetic requirements. Surface roughness is one of the most significant limitations on the usage of equipment and cutting settings in process planning.

Surface roughness, in general, refers to the vertical elevations made on the metal surface by tools or each grinding particle on a grinding wheel, such as grooves.

A wide range of industries and applications, including semiconductor thin-film uniformity, auto component wear, the effectiveness of medical implants, and the inspection of micro electromechanical systems, face serious challenges with surface roughness measurement. The effectiveness and usefulness of micro scale surface characteristics, particularly micro-inch surface roughness, is dependent on a wide range of products and systems, from high-end personal digital devices to upscale sunglasses. Without precision surface roughness metrology, many of the significant advancements in science and business during the past 50 years would not have been conceivable.

Surface roughness is most commonly measured using a value called Ra. Each peak and valley are compared to the mean line to calculate the average roughness, which is then averaged over the entire cut-off length.

1.9.1. Feed Rate and Depth of cut effect on surface roughness

As would be predicted, the roughness rises as the feed rate does. The feed markings also become more pronounced and evident on the roughness profiles. Roughness exclusively depends on nose radius and ceases to be feed rate dependent with lower feed rates. Increased micro roughness, or faults layered over the grooves made by chip removal, results from this. Comparatively speaking, the plastic flow component is larger. Similar to the preceding example, surface roughness is more influenced by feed rate than nose radius when feed rate is high and nose radius is low. Low feed rates result in a plastic flow that is in the opposite direction of the feed and has a higher height, which can also result in an increase in roughness. Higher feed rates were associated with reduced roughness, which is a similar distinction that has been documented.

Similar to this, material is ploughed rather than chipped at low input rates. This raises the possibility of an ideal feed rate. In contrast to what the theory predicts, roughness is really a function of the square of feed rate in practise. This could be caused by side flow or vibrations from tool use flattening the ridges. These effects are supported by the Fourier transformations. It is clear that the ploughing process produces a large number of harmonics at lower feed rates, which is in line with the explanations provided for the micro roughness at low feed rates.

1.9.2. Cutting speed and Nose Radius effect on Surface Roughness

At cutting speeds of up to 100 m/min, the surface finish degrades. The surface roughness of the machined work pieces appears to worsen for both grades as cutting speed is increased further. The increased friction at the point where the tool and the workpiece come into contact leads to an increase in the temperature in the cutting zone, which is what causes this. The material's shear strength and ductile behaviour are reduced as a result. Due to the duplex stainless steel's increased surface roughness and adhesive properties, it is exceedingly difficult for chips to separate from the work piece.

Due to a decrease in the tendency to produce built-up edges, surface roughness reduces when cutting speed is increased up to 100 m/min. Surface roughness, however, rises as cutting speed is increased more. This is explained by the fact that at faster cutting speeds of 120, 140, and 180 m/min, cutting tool nose wear increases. Additionally, it is obvious that when the cutting speed is set to 100/min, the lowest Ra of machined surfaces is reached.

1.9.3. Cutting Parameters effect on MRR

The volume of material removed divided by the machining time is known as the material removal rate, or MRR. The rate at which the cross-section area of material being removed moves through the work piece can be viewed of as the "instantaneous" material removal rate, which is used to compute MRR. Both the rate of material removal and the depth of cut fluctuate throughout the procedure. This might matter in certain situations. For instance, if you're interested in the workpiece and tool deflections brought on by cutting forces. The cutting force and, consequently, the deflections, will change over the course of the process because of the varying quantity of material being removed along the tapered shaft.

Let,

D_i = Initial Diameter of workpiece, mm

d = Depth of cut, mm

f = Feed, mm/rev

Volume of removed material in one revolution = $\pi D_i \times d \times f$ mm3

MRR = $\pi D_i \times d \times f \times N$ mm3 /min.

In terms of cutting speeds V in m/min;

MRR = $1000 \times v \times d \times f$ in mm3 /min

1.9.4. Cutting parameters effect on Machining time

The ideal equipment working schedule is chosen in order to optimise output, reduce the prime cost of the processed commodities, and preserve the necessary degree of quality. For instance, the typical machining time for metal-cutting machine tools is established using well-researched cutting parameters (depth of cut, feed, cutting speed, and number of passes). By utilising high-speed processing techniques and high-performance tools and equipment, machining times can be reduced. Machining time as a proportion of piece rate time for finishing a unit or one manufacturing activity rises as production gets increasingly automated and mechanised.

$L = l + l_1 + l_2$

l = Length of surface tube machined.

l_1 = Distance required for feeding the tool

l_2 = over travel of the tool at the end of each cut in mm

L = Distance travelled by the tool in the direction of the feed in single cut

f = feed mm/rev, N = rpm

Machining time = $L\ fN\ min$

1.9.5. Cutting parameters effect on machining force

When metal is machined at a particular speed, feed rate, and cut depth while utilising a particular lubricant, cutting tool material, and geometry, cutting forces are produced and power is required. Any of the variables can be modified to affect the forces, but because the engineer only defines the factors that lead to the forces, the change is indirect. Forces are important because they control how much the tools, work pieces, and work holders deflect, which has an impact on the ultimate component size. Forces also have an impact on the common machining phenomena of chatter and vibration.

In order to describe the machinery for a manufacturing operation, including the machine tool, cutting tool, and work holding devices, safely, it is obvious that the manufacturing engineer would need to be able to forecast forces (and power). The formula for calculating force is as follows:

F = k x d x f N

Where,

D = Depth of cut,mm

F = Feed per rotation in mm

K = Specific cutting energy coefficient

1.9.6. Cutting parameters effect on machining power

It might be conceivable to represent the energy per unit volume required to manufacture the chip, despite the fact that machine tools are often quantified in terms of power. By dividing the power input to the process, FcV, by the volumetric rate of material removal and multiplying the result by 33,000 to convert to horsepower, one can get unit (or specific) power values. The specific power, Ps, which measures the difficulties in cutting a given material, can be used to calculate the overall cutting power, P.

The specific power is the amount of power required to remove a unit volume in a certain amount of time. The link between the specific and overall powers is as follows:

Material removal rate, or MRR for short, is the volume of material removed in a specified period of time. The material removal rate is calculated by multiplying the uncut area by the speed at which the tool is moved perpendicular to the uncut region. Thus, the cutting parameters and the machine tool's kinematics control the rate of material removal. There are a number of established sources that can provide precise power numbers for a variety of materials.

Machine tools are unfortunately not entirely effective. Some power is lost owing to component wear, friction, and other causes before it reaches the tool.

Cutting power is a crucial factor, particularly in the event of difficult procedures, as it enables:

➢ Select and spend money on a machine whose power output is suitable for the job at hand. Find the cutting conditions that allow the machine's power to be utilised as effectively as possible while taking into account the tool's capacity.

➢ Find the cutting conditions that allow the machine's power to be utilised as effectively as possible while taking into account the tool's capacity.

CHAPTER 2

LITERATURE REVIEW

Harish Kumar et al [1] Tests on the MS 1010 were carried out using an HSS tool on a CNC lathe in a dry environment. The input factors used are speed,feed,depth of cut with surface roughness serving as the analyses' output characteristic. Taguchi approach was used by them and ANOVA to analyse the data. They discovered that DOC is the least important parameter for MS1010 speed, which is the most important parameter for surface roughness..

M. Kaladhar et al [2] used Taguchi L16 orthogonal array and ANOVA to conduct experiments on turning of AISI 304 austenitic stainless steel with PVD coated insert to optimise MRR and Surface Roughness. They discovered that for Surface Roughness, feed and nose radius are the two most important parameters. Similar to this, for Material Removal Rate, feed is the second-most important parameter after depth of cut.

N.E. Edwin Paul et al [3] have tested EN8 material on a Taguchi L9 orthogonal array using a CNC lathe. ANOVA and SNR ratio were employed to analyse the data. According to the findings, the feed has a bigger impact on surface roughness, followed by cutting speed and depth of cut, which have the least impact.

Anupam et al [4]. Steel grade AISI 52100 with a hardness of 55 HRC is machined with new carbide tools with his HSN2 coating with thickness of 12mm. S,f,d are considered input process parameters .A response surface methodology isused to refine the cutting parameters and a confirmation test is used to validate it. Cut speed has been found to be the parameter that most influences output response.

Adil et. al [5]. This study's goal is to identify the ideal cutting speed, feed rate, and cut depth for CNC turning in order to maximise material removal rate. Aluminum ENAC-43400 is CNC turned utilising carbide-tipped tools. The ANFIS model is used to optimise MRR for CNC turning.

Qinge Xiao et. al [6]. For various settings, energy-aware parametric optimisation is generalised in this article. created a two-layer knowledge-driven strategy by combining data mining (DM) and fuzzy logic theory. A modified association rule mining technique is developed in the first stage to find empirical knowledge. A fuzzy inference engine is developed to achieve preliminary optimisation based on this knowledge. An iterative procedure is used in the second stage to fine-tune the turning parameters in order to accomplish Pareto optimisation and decrease the amount of energy and machining time used, respectively. The findings of the simulation indicate that this procedure has a significant deal of potential to increase the energy and time efficiency of turning systems.

Miroslav Radovanovic et. al [7] Turning operations employing AISI 1064 steel in multiple passes for roughing and one pass for finishing with carbide cutting tools have been evaluated in terms of material removal rate and machining cost. The study focuses on a multi-pass roughing optimisation problem with five machining constraints (cutting force, torque, power, tool life, and cutting ratio), three influencing variables (depth of cut, feed rate, and speed), and two objectives (material removal rate and machining cost). An optimisation problem for single-pass finishing is looked at. It has two goals (material removal rate and machining cost), four variables (tool nose radius, depth of cut, feed, and cutting speed), and three machining constraints (surface roughness, tool life, and cutting ratio).

Dhiraj K. Patel et. al [8] investigation of the variables influencing the rate of material removal, power consumption, and surface roughness of EN-19 steels during Taguchi technique turning operations. The authors (NR) have recorded four distinct machining parameters: spindle speed (N), feed (F), depth of cut (D), and nose radius. The Taguchi technique is widely used by the authors to extract the influential parameter from the weighted components.

Massimo Fornasier et. al[9] examined the effect of lowering the settings. Al-SiC-Gr hybrid composite turning parameters include cutting rate, feed rate, cut depth, and the combined equal weight percentage of SiC-Gr particles. The authors used the Response Surface Methodology to develop a second order quadratic model in order to identify the influencing factor over the measured output response surface roughness. The surface roughness parameter Ra was measured by the authors for each of the 18 unique trials conducted using the RSM approach and the Design Expert software. They used the Mitutoyo Surf test SJ-201 to accomplish this. Following the assessment of surface roughness, ANOVA is performed to ascertain the relative contributions of all the affecting elements.

Davis et al. [10] conducted an experimental investigation to determine the best cutting parameters for turning EN24 steel, including feed rate, spindle speed, and depth of cut. In this investigation, turning operations are performed on EN24 steel using a carbide P-30 cutting tool in a dry environment to combine the parameters at their ideal levels. The Signal-to-Noise ratio and Analysis of Variance are used in order to concentrate the execution characteristics in turning operation. According to the investigation, no variable is seen to be extremely large. According to Taguchi approach, the support rate increased by Spindle speed and depth of cut are the perfect combination of factors when converting EN24 steel with a carbide cutting tool in dry cutting.

Makadia and Nanavati [11] employed Design of Experiments to examine the impact of key turning factors on the surface roughness of AISI 410 steel, including feed rate, tool nose radius, cutting speed, and depth of cut. Regarding the aforementioned factors, a scientific expectation model of the surface unpleasantness has been developed. Response Surface Methodology (RSM) has been used to examine how these parameters affect initial unpleasantness. The generated forecast condition shows that the primary factor followed by instrument nose sweep effects the surface discomfort is the nourish rate. It was discovered that the surface discomfort increased with the expansion of the bolster and decreased with the expansion of the instrument nasal range.

Verma et al. [12] analysed the best cutting circumstances to achieve the lowest surface roughness while turning ASTM A242 Type-1 Alloys Steel by the Taguchi method. According to Taguchi approach, cutting speed plays a crucial role in reducing surface roughness by 57.47%, followed by bolster rate by 16.27%. According to the experiments, the surface harshness is less affected by the depth of cut. The results obtained by this method will be helpful to other studies for similar types of research and may shed light on future investigations into device vibrations and cutting powers.

Aslan et al. [13] carried out an experimental investigation using Taguchi methodology to determine the best cutting parameters. Additionally, they also used the effect by combining the parameters, specifically cutting velocity, sustain rate, and depth of cut, on two performance measures,(VB), and (Ra). These effects defined using an orthogonal approach and the analysis of variance (ANOVA). Each execution measure's ideal cutting parameters were obtained, and the relationship between the parameters and the execution measures was clarified using several straight relapses. Al2O3-based production materials for earthenware are used because they are among the best materials for making cutting tools for machining solidified steels.

Nalbant et al. [14] employed the Taguchi approach to determine the best cutting settings for turning's surface roughness. The execution qualities in operations of turning AISI 1030 steel using TiN covered instruments are concentrated using the orthogonal exhibit, the flag to-commotion proportion, and study of fluctuation. The effects of surface unpleasantness on three cutting characteristics, specifically embed sweep, bolster rate, and profundity of cut, are improved.

C Ibrahim et.al. [15] conducted tests to determine how cutting parameters affected surface roughness while utilising CVD multi-layer coated cemented carbide tools to machine AISI304 and AISI316 steels. The outcomes demonstrated a strong correlation between cutting speed and surface roughness.

Sunil Kumar Sharma et al. [16] In order to evaluate the parametric complex to carry out acceptable surface roughness lower is better, material removal rate higher is better of the AISI 8620 steel while turning on a CNC lathe trainer, it has been determined that Taguchi optimisation approach pair with grey relational analysis has been used. ANOVA is used to locate the most important element during turning operation after determining the best process parameter settings for turning operation. As the P-value in this study is less than 0.05, it is determined that the feed rate is the most important factor for both the surface roughness and the rate of material removal. According to the results of the ANOVA analysis, cutting speed and depth are not significant.

Y Sahijpaul et.al. [17] Experimented that when turning EN8 steel, the impact of cutting settings on surface roughness was examined. They came to the conclusion that the feed rate is the factor that affects surface roughness the most.

S R Bheem et al. [18] examined how the turning of a metal matrix composite affected the rate of material loss and the surface roughness. Results showed that the feed, followed by the depth of cut and speed, had the greatest influence on surface roughness.

G Shivam et.al. [19] conducted experiments on a CNC lathe using MRR and SR as outputs and cutting speed, feed, and depth of cut as process parameters. The factors that have the greatest influence on surface roughness and rate of material removal, respectively, are cutting speed and depth of cut.

S Devendra et al. [20] a study was conducted by him to look at how the nose radius affected surface roughness during dry CNC turning of Al 6061. The parameter that has been found to have the greatest impact on surface roughness is nose radius.

Shreemoy Kumar Nayak, et al. [21] AISI 304 austenitic stainless steel was turned dry employing experiments using multi-objective Grey relational analysis, and the machinability properties of material removal rate, cutting force, and surface roughness were investigated. According to the Taguchi L27 orthogonal array, experiments were performed. According to the mean of the overall Grey relationship grade, feed has a significant impact on Material Removal Rate (MRR), followed by cutting pressures, surface roughness, speed, and depth of cut.

Dipti Kanta Das et al. [22] Using a Grey based Taguchi (L9 orthogonal array) and regression methodology, it was investigated to determine the ideal combination of cutting process parameters during hard machining of EN 24 steel with coated carbide insert. According to the findings, the feed is thought to be the parameter that affects Surface

Roughness parameters Ra and Rz the most. Regression analysis for surface roughness was used to construct the prediction models, which are sufficient and significant.

M. Kaladhar et al. [23] based on Taguchi and Utility principle, have improved multi-characteristic response for turning AISI 202 austenitic stainless steel utilising a CVD coated cemented carbide tool on CNC TC. This idea has been applied to the optimisation of process variables like speed, feed, depth of cut, and nose radius, as well as the selection of numerous performance traits like surface roughness and material removal rate. To plan experiments, Taguchi's L8 orthogonal array was chosen. The analysis of the experimental results revealed that in order to simultaneously maximise MRR and minimise Ra, a combination of greater levels of cutting speed, depth of cut, and nose radius and lower levels of feed is required. They conducted an ANOVA for both the multi-response scenario and individual quality factors.

Bharat Chandra Routara et al. [24] had researched a case study involving CNC end cutting of UNS C34000 medium leaded brass that applied the utility idea and Taguchi method to a multi-objective optimisation problem. A multi-response optimisation problem has been transformed into a single response optimisation problem using utility theory, where overall utility degree acts as the model single objective function for optimisation. They combined the utility notion with the Taguchi methodology to forecast the ideal process parameter setting. Finally, validation runs have confirmed the best setting.

B.Singarvel et al. [25] Following experimental study, the ideal machining parameters for turning EN25 steel with CVD and PVD coated carbide tools were assessed using the Taguchi-based utility concept in conjunction with Principal Component study (PCA). This method has been used to minimise surface roughness, increase cutting power, and maximise material removal rate all at once. They discovered that the machining parameters for this experiment, as determined by the ANOM data, were a cutting speed of 244 m/min, a feed rate of 0.10 mm/rev, and a depth of cut of 1.0 mm using a CVD coated tool. The coated tool was the most important parameter, followed by cutting speed, according to the ANOVA results.

Hari Vasudevan et al. [26] had researched a hybrid Taguchi methodology-utility-fuzzy multi-objective optimisation algorithm.Four process parameters chosen for the investigation, and R_a, cutting force, and MRR were chosen as quality performance metrics. To conduct their studies, they used a Taguchi L27 orthogonal array. GFRP/Epoxy tubes made of woven fabric and manufactured by hand layup were finished turning with a Poly Crystalline Diamond (PCD) tool. Using a Mamdani type fuzzy inference system, the utility values of the three performance measures were combined into a single Multi Performance Characteristics Index (MPCI).

Kishan Choudhuri et al. [27] Using the Taguchi and Utility principle to optimise the turning of Aluminum 6061 utilising a Carbide cutting tool on a CNC TC for a variety of performance variables, including surface roughness and material removal rate. To plan experiments, Taguchi's L9 orthogonal array was chosen. The experimental results demonstrated the necessity of combining greater feed rates, deeper cuts, and slower spindle speeds in order to simultaneously maximise MRR and minimise surface roughness.

R. Jayadithya et al. [28] Using three machine parameters—pulse on time (TON), pulse off time (POT), wire feed, and one work piece parameter—work piece thickness—experiments have been undertaken to measure reactions including cutting speed, surface roughness, and dimensional deviation. The Taguchi's L9 orthogonal array was chosen to gather data on the procedure with fewer experimental runs. An optimisation problem with many responses cannot be solved using the conventional Taguchi approach. Utility theory has been used to get over this restriction. To determine the significant impact of the process factors during the WEDM process, an ANOVA analysis was also performed. Finally, a confirmation test was performed to validate the outcomes of the experiment.

Ravinder Kataria et al. [29] have compared various multiple response optimisation approaches for AISI O1 tool steel turning operations. As input process parameters, they chose nose radius, speed, feed, and depth of cut; as quality parameters, they chose material removal rate and surface roughness. The Taguchi method was used to optimise single responses. Weighted signal-to-noise ratio (WSN), grey relational analysis (GRA), utility concept, and technique for order preference by similarity to ideal solution (TOPSIS) method have all been used for multi-response optimization, and the effectiveness of each has been assessed. For WSN, GRA, Utility Concept, and TOPSIS, the ideal process parameter settings were A1B3C2D3, A2B1C1D2, A2B3C3D2, and A2B2C3D3, respectively.

Nithyanandhan T. et al. [30] to determine the best process parameter setting, it has been researched how process parameters affect material removal rate (MRR) and surface finish. And the influence of cutting parameters during machining is also examined using the analysis of variance (ANOVA).

CHAPTER 3

METHODOLOGY

3. 1. Taguchi Method

Dr. Genichi Taguchi has created a methodical statistical approach to product and process improvement. The method places a strong emphasis on bringing the quality issue upstream, to the design stage, and on defect prevention through process improvement. Taguchi has emphasised again how crucial it is to reduce variance as the main strategy for raising quality. The entire loss suffered by society as a result of a product's failure to operate as intended and as a result of unfavourable side effects, including running costs, is how Taguchi defines a product's quality level. From the moment a product is supplied to the customer, some loss is inevitable, and smaller loss yields more desirable products. To compare different product designs and manufacturing techniques, it is crucial to measure this loss. Using a quadratic loss function, this is accomplished. The producer often defines a target value for the performance characteristic and a tolerance range around it when performing manufacturing quality control. Any performance characteristic value that falls within the tolerance range of around 3 is considered a desirable product. The goal value of the performance characteristic is the focus when using the loss function as a measure of quality, and deviations from that value are punished. A bigger quality loss occurs with a larger departure from the goal value.

3.1.1. Signal-to-Noise (S/N) ratio

In the taguchi technique, the terms "signal" and "noise" refer to the desired value (mean) and the unwanted value (standard deviation), respectively, for the output characteristic. The S/N ratio gauges how sensitive the controlled quality characteristic under investigation is to uncontrolled external influencing factors (noise factors). Therefore, Taguchi measures the quality characteristic deviating from the desired value using the S/N ratio. Depending on the kind of characteristic, there are primarily two S/N ratios accessible; Better and Better and Better and Better

Smaller-the-Better

The smaller is better quality characteristic can be given as

$$\frac{S}{N} = -10\, log_{10}[y^2]$$

Higher-the-Better

The smaller is better quality characteristic can be given as

$$\frac{S}{N} = -10\ log_{10}\left[\frac{1}{y^2}\right]$$

Here y is the response value.

3.2 Desirability Function Analysis (DFA)

The Taguchi approach can only be used to analyse the process parameters for a single performance characteristic; to get over this problem, the present work uses a multi-objective optimisation technique called Desirability function analysis (DFA). DFA can be used to analyse multiple performance variables simultaneously. Derringer and Suich (1980) first proposed this methodology. The method converts an estimated response into a scale-free value termed desirability by using an objective function, D(X), referred to as the desire function. The ideal ranges run from 0 to 1 (correspondingly, least desirable to most desirable). The ideal parameter circumstances are thought to be the factor settings that have the highest overall desirability.

3.2.1. Procedure of Desirability Function Analysis (DFA)

STEP 1: Use the Derringer and Suich formula to determine the individual desirability (di) for the relevant responses. According on the qualities of the answer, the desirability functions come in three different forms. In those we are usig smaller the better form.
The other forms are Nominal the better and Larger the better.

STEP 2: Using the following equation (k), the individual desirability ratings have been added together to determine the total desirability.
Here, Dg stands for overall desirability, di for each quality characteristic's individual desirability, and n for the total number of responses.

$$D_g = (d_1 * d_2 * d_3 \dots\dots\dots\dots d_n)^{\frac{1}{n}}$$

Here, D_g = Overall Desirability

STEP 3: The ideal parameter and its level should be identified. A greater product quality is implied by the higher composite desirability value**.**.

STEP 4: Analysis of variance (ANOVA) for the parameter that has the greatest impact. The relative significance of parameters is established through ANOVA**.**

STEP 5: Utilizing the ideal level of the design parameters, the final phase is predicting and verifying the quality attributes.

CHAPTER 4

EXPERIMENTAL DETAILS

4.1.Selection of Work Material

For turning operations, long EN24 steel rods that were cut into equal-length pieces using a power hacksaw were used. A 40mm length was used for the turning process. The table below provides information about EN24's composition and characteristics.

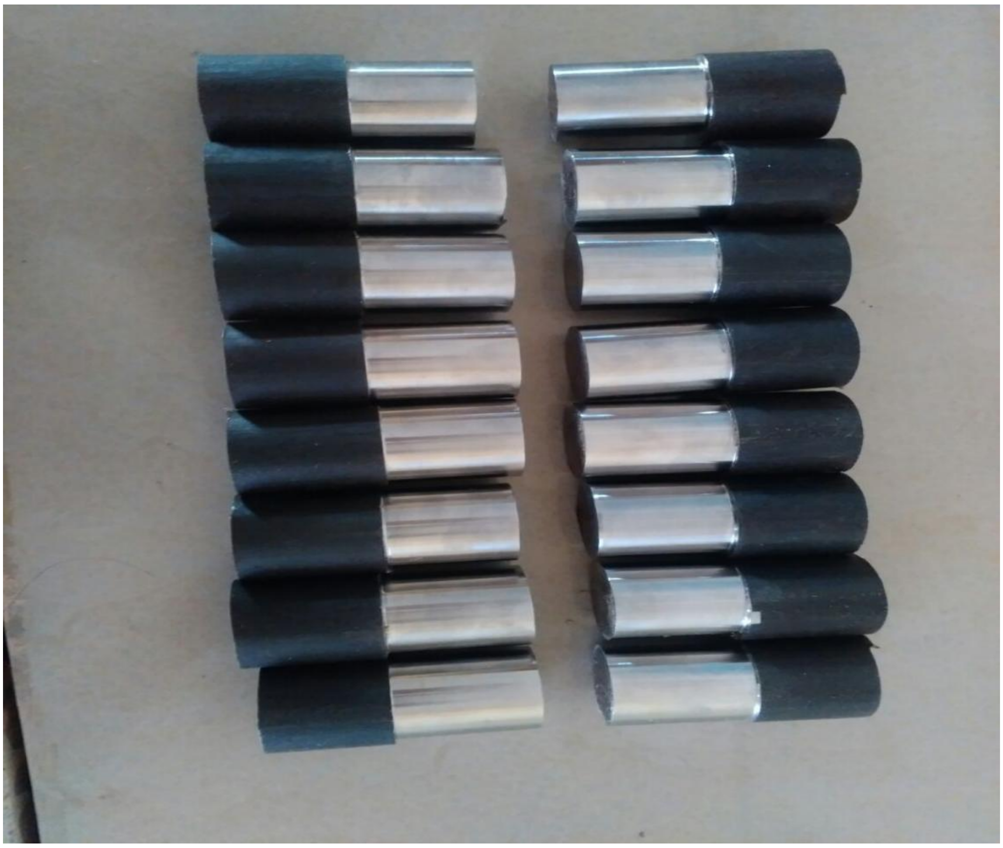


Figure 4.1: EN24 turned workpieces

Table 4.1. Chemical composition of EN24 steel

S.NO	ELEMENT	COMPOSITION
1	Carbon	0.36-0.44 %
2	Manganese	0.45-0.70 %
3	Silicon	0.10-0.35 %
4	Sulphur	0.04%
5	Phosphorus	0.04%
6	Chromium	1.00-1.40 %

7	Nickel	1.30-1.70%
8	Molybdenum	0.20-0.35%

Table 4.2. Mechanical Properties of EN24 STEEL

Size mm	Tensile Strength N/mm²	Yield Stress N/mm²	Elongation	Impact Izod J	Impact KCV J	Hardness HB
63 to 150	850-1000	680 min	13%	54	50	248/302

4.2. Selection of the Process Parameters and Their Levels

In an unusual process, choosing the proper combination of process parameters and defining the parameter range are crucial steps. Small variations in the process parameters will have a negative impact on the accuracy and surface roughness of the machined components. In general, there are two categories of process parameters.

- Fixed parameters
- Controlled parameters

In this present work the tool geometry, work piece hardness and its mechanical properties and environmental conditions are taken as fixed parameters which will not be changed throughout the investigation, whereas cutting speed, feed, depth of cut and nose radius are considered as the controlled parameters are used to change for each experiment by Taguchi approach. The selected process parameters for the experiment with their limits, notations and units are given in table 4.3

Table 4.3 Levels of Process Parameters

Parameter	LEVEL 2	LEVEL 2	LEVEL 3	LEVEL 4
s, Rpm	1500	2000	2500	3000
f , mm/rev	0.05	0.1	0.15	0.2
d , mm	0.3	0.6	0.9	1.2

r, mm	0.4	0.8		

4.3. Selection of Orthogonal Array (OA)

With a very small number of experiments, Taguchi created a design known as an orthogonal array that is used to examine the whole design space. Taguchi's standard L16 has been selected for the four parameters with mixed levels, and it is shown in table 4.4.

The Taguchi Orthogonal Array (OA) design is one type of generic factorial design. Using one of Dr. Genichi Taguchi's design matrix is an extremely fractional orthogonal design that takes requirements into account. Balanced orthogonal Taguchi arrays take into account all levels of each factor. Despite the design's fragmented appearance, this enables the elements to be assessed independently. Three separate characteristics (cutting speed, feed, and depth of cut) are taken into account at three different levels in this study. Therefore four-level design that also takes into account the L16 orthogonal array in addition to the other three components**.**

Table 4.4 L16 Orthogonal Array

S.no	s	f	d	r
1	1500	0.05	0.3	0.4
2	1500	0.1	0.6	0.4
3	1500	0.15	0.9	0.8
4	1500	0.2	1.2	0.8
5	2000	0.05	0.6	0.8
6	2000	0.1	0.3	0.8
7	2000	0.15	1.2	0.4
8	2000	0.2	0.9	0.4
9	2500	0.05	0.9	0.4
10	2500	0.1	1.2	0.4
11	2500	0.15	0.3	0.8
12	2500	0.2	0.6	0.8

13	3000	0.05	1.2	0.8
14	3000	0.1	0.9	0.8
15	3000	0.15	0.6	0.4
16	3000	0.2	0.3	0.4

The fig 4.2 below represents CNC Turret lathe on which our experiments are conducted.

Figure 4.2: CNC turning machine

The next process after machining is Surface Roughness Test.We have conducted the surface roughness test using the below machine shown in figure 4.3.

Figure 4.3: Surface Roughness Tester.

CHAPTER 5

RESULTS & DISCUSSIONS

5.1. Experimental Results of the Responses

A total of 16 experiments were carried out to determine the best cutting settings for turning EN24 bars based on various performance criteria. The product of speed, feed, and cut depth yields the material removal rate (MRR), which is expressed in cm3 per minute. Each machined component's surface roughness characteristics were measured using a surface tester at three separate points, with the average serving as the final value. Table 5.1 shows the outcomes that were attained.

Table 5.1. Outputs

S.NO	MRR,cm^3/min	R_a, µm	R_z, µm
1	0.023	0.247	1.259
2	0.090	0.39	1.799
3	0.203	1.354	4.956
4	0.360	1.649	6.029
5	0.060	0.574	2.933
6	0.060	0.488	2.467
7	0.360	0.688	2.933
8	0.360	0.685	2.902
9	0.113	0.344	1.568
10	0.300	0.444	2.109
11	0.113	1.037	3.796
12	0.300	1.059	5.062
13	0.180	0.61	2.773
14	0.270	2.192	5.486
15	0.270	0.676	2.817
16	0.180	1.235	4.798

5.2. Results of Desirability Function Analysis (DFA)

Higher the better and lower the better features can be used to determine the individual desirability (di) values of the responses, respectively. The composite desirability (Dg) can be calculated from the individual desirability ratings, and the values are shown in table 5.2.

Table 5.2. INDIVIDUAL DESIRABILITY (di):

S.NO	MRR	R_a	R_z	D_g	SNRA1
1	0.0000	1.0000	1.0000	0.0000	-80.0000
2	0.1988	0.9265	0.8868	0.7246	-2.7977
3	0.5341	0.4308	0.2249	0.6369	-3.9187
4	1.0000	0.2792	0.0000	0.0000	-80.0000
5	0.1098	0.8319	0.6491	0.6151	-4.2204
6	0.1098	0.8761	0.7468	0.6313	-3.9954
7	1.0000	0.7733	0.6491	0.9043	-0.8733
8	1.0000	0.7748	0.6556	0.9057	-0.8604
9	0.2671	0.9501	0.9352	0.7729	-2.2370
10	0.8220	0.8987	0.8218	0.9239	-0.6872
11	0.2671	0.5938	0.4681	0.6499	-3.7426
12	0.8220	0.5825	0.2027	0.7261	-2.7797
13	0.4659	0.8134	0.6826	0.8001	-1.9374
14	0.7329	0.0000	0.1138	0.0000	-80.0000
15	0.7329	0.7794	0.6734	0.8596	-1.3143
16	0.4659	0.4920	0.2581	0.6484	-3.7625

5. 3. Taguchi Analysis

In terms of composite desirability (Dg), the challenging multi-objective problem has now been reduced to a single objective problem. It is common knowledge that the better the numerous performance attributes, the higher the composite desirability. In order to determine the best possible combination of process parameters and to understand how cutting parameters affect the numerous replies, Taguchi’s higher-the-better characterstics has been applied. Table 5.3 provides the Dg's average values.

Table 5.3. Taguchi Analysis: Dg versus s, f, d, r:

Level	**speed**	**feed**	**Depth of cut**	**Nose radius**
1	-41.679	-22.099	-22.875	-11.567
2	-2.487	-21.870	-2.778	-22.574
3	-2.362	-2.462	-21.754	
4	-21.754	-21.851	-20.874	
Delta	39.317	19.636	20.097	11.008
Rank	1	2	3	4

Figure 5.1 depicts the main effect plot for the composite desirability (Dg) values for the S/N ratio. The primary effect plot yields the speed, feed, depth of cut that produce the multi objective function with the best possible efficiency at 2500 rpm, 0.15 mm/rev, and 0.6 mm, respectively.

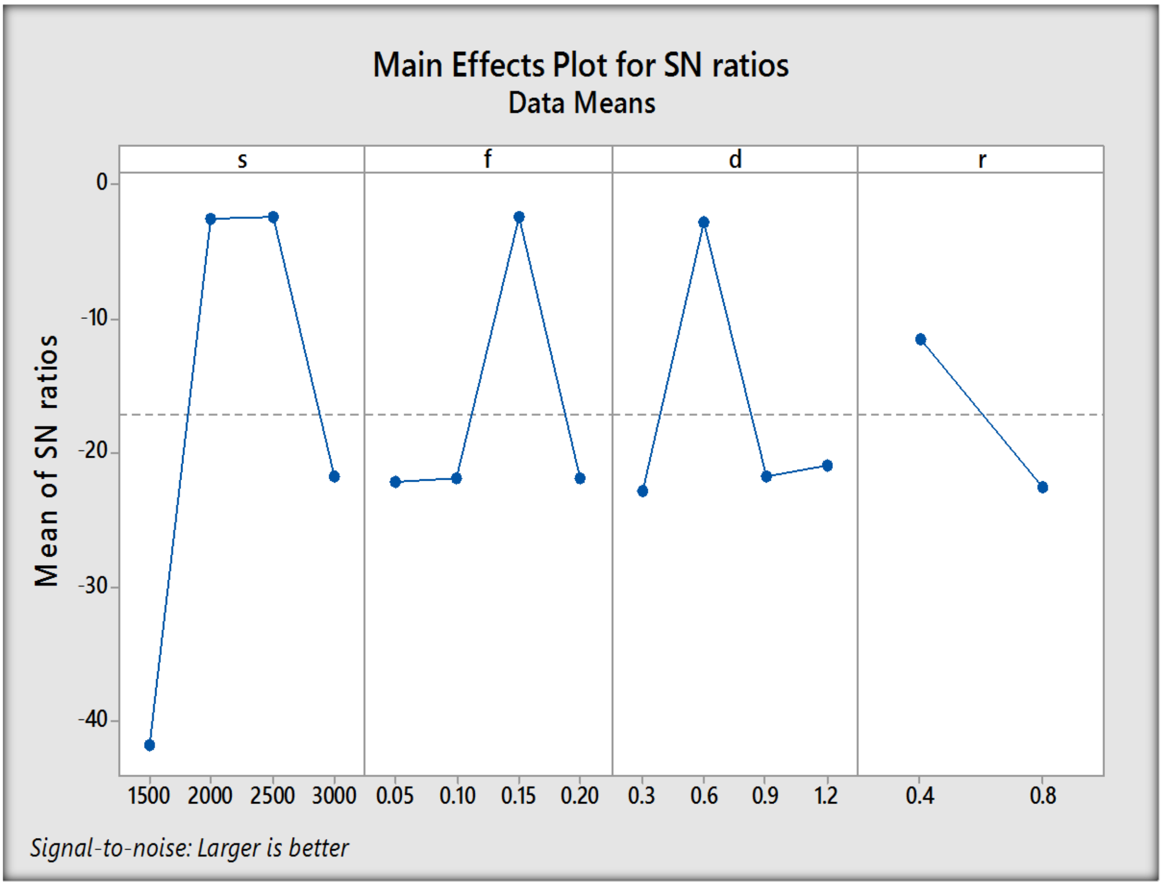


Figure 5.1. Main Effect Plot for S/N Ratios of D_g

5.4. ANOVA Results

ANOVA is a technique for allocating the variability of an output response to various inputs. Investigating which design parameter significantly impacts the performance characteristics is the goal of statistical ANOVA. This is done by dividing the contributions from each machining parameter and error into the overall variability of the composite desirability value, which is quantified by the sum of the squared deviations from the total mean of the composite desirability value. It is evident from the findings in Table 5.4 that Speed is a highly impacting element.

Table 5.4 Results of D_g in ANOVA

Source	**DF**	**Adj SS**	**Adj MS**	**F-Value**	**P-Value**
Model	12	1.33771	0.111476	1.62	0.383
Linear	4	0.39610	0.099024	1.44	0.399
s	1	0.13539	0.135393	1.97	0.255
f	1	0.04905	0.049050	0.71	0.461
d	1	0.00001	0.000007	0.00	0.993
r	1	0.13631	0.136307	1.98	0.254
Square	3	0.45367	0.151223	2.20	0.268
s*s	1	0.37808	0.378075	5.49	0.101
f*f		0.04645	0.046447	0.67	0.472
d*d	1	0.02915	0.029146	0.42	0.562
2-Way Interaction	5	0.56437	0.112874	1.64	0.363
s*f	1	0.00766	0.007660	0.11	0.761
s*d	1	0.05666	0.056661	0.82	0.431
s*r	1	0.07463	0.074630	1.08	0.374
f*d	1	0.36794	0.367939	5.34	0.104
f*r	1	0.08534	0.085338	1.24	0.347
Error	3	0.20663	0.068877		
Total	15	1.54434			

CHAPTER 6

CONCLUSIONS

➢Taguchi Analysis is an afforadable alternative than other optimization techniques.

➢ The current study uses MINITAB software to generate the design of experiments matrix using the ANOVA approach and to provide the output with the maximum determined the influencing factors.

➢We have considered four process parameters.They are Cutting speed, Depth of cut, Feed, Nose radius.We have got Cutting speed has great effect on surface roughness than other parameters.

➢ In terms of increased tool life and decreased surface roughness, it was discovered that the parameter combination of speed 2500 m/min, feed 0.15 mm/rev, depth of cut 0.6 mm, and nose radius 0.4 mm produced outstanding results.

➢This study shows that EN24 Steel will get efficient turning by choosing these process parameters.

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