EFFECT OF CUTTING FLUIDS ON TURNING OPERATION OF Ni-Al-Br (C95500) ALLOY

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

Bachelor of Technology
in
Mechanical Engineering

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CERTIFICATE

This is to certify that the Project Report entitled **"Effect of Cutting fluids on Turning Operation of Ni-Al-Br (C95500) Alloy"** being submitted by **G. Sai Kiran (319126520136), G. Tirupati Rao (320126520L20), K. Shanthi Kumari (319126520147), V. Vasu (319126520165)** to the Department of Mechanical Engineering, ANITS is a record of the bonafide work carried out by them under the esteemed guidance of **Mr. K. Naresh Kumar.** The results embodied in the report have not been submitted to any other University or Institute for the award of any degree or diploma.

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ABSTRACT

Nickel aluminum bronze C95500 alloy is widely used in various industrial applications due to its high strength, excellent corrosion resistance, and good wear resistant properties.However, machining of these materials with cutting tools generates more heat at the contact between tool and workpiece and leads to premature tool wear and poor surface finish. To overcome these issues, cutting fluids are often used in machining operations. The aim of this study is to investigate the effect of different types of cutting fluids on the machinery operations of nickel aluminum bronze C95500 alloy during turning process. The study was conducted using a variety of cutting fluids, including water- soluble cutting fluid (WSCF), mineral oil-based cutting fluid (MOCF), and vegetable oil-based cutting fluid (VOCF) under minimum quantity lubrication (MQL). In this work, various effects of cutting parameters like speed, feed, and depth of cut on HSS (High Speed Steel) under dry and wet conditions are observed. Theobservations made from this study are temperature, cutting forces, viscosity of cutting fluids, Surface roughness, material removal rate during machining of alloy steel. The Experiment was conducted based on Taguchi design of experiments L9 orthogonal array. A computer operated dynamometer set up was attached to the lathe machine for measuring the cutting forces. Three different fluids behavior was analyzed during machining. Two methods Taguchi, and Topis are used as optimization techniques for prediction of best data from the experiment. The most influencing parameter after performing the experiment was calculated using mini tab software Taguchi design of experiments and best experiment for three types of oils used is determined using Topsis optimization. Finally, the best cutting fluid for minimization of cutting forces and improving the tool life was suggested in the conclusion. This method used in the present study can be effectively employed in various industries for improving the machining characteristics of high alloy steels.

Keywords: *Ni-Al-Br alloy, Cutting forces, Finekut 56 oil, Hydraulic oil, Xtraa coolant oil, Taguchi, Topsis.*

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CHAPTER - 1

INTRODUCTION

In this chapter, concept of turning is defined. The adjustable cutting parameters, lathe machine and cutting fluids role in machining process are discussed.

1.1 TURNING OPERATION

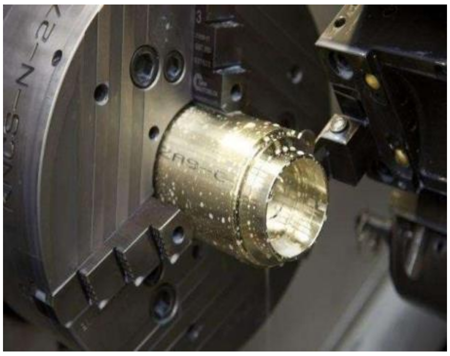


Figure 1.1 Turning Operation

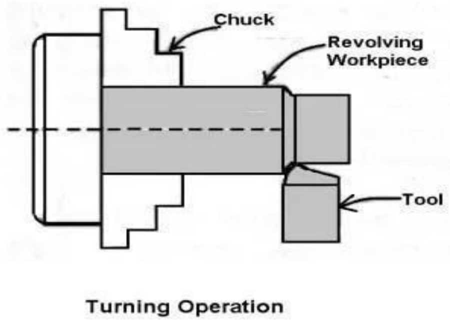


Figure 1.2 Turning in 2D View

The process of turning involves machining, which is a way to remove materials to create rotational components. The turning method requires the use of a turning machine or lathe, a workpiece, a fixture, and a cutting tool. The workpiece is a pre-shaped material that is held securely by the fixture, which is then attached to the turning machine, and rotated at high speeds. Usually, a single-point cutting tool is used as the cutter, although some operations may employ multi-point tools. The cutting tool feeds into the rotating workpiece, and as a result, it removes material in the form of small chips to shape the desired outcome.

Turning is a process that is utilized to create rotational parts that are typically axi-symmetric and possess a variety of features such as holes, grooves, threads, tapers, diameter steps, and even contoured surfaces. Turning is often employed to produce parts that are required in limited quantities, such as custom-designed shafts and fasteners, particularly for prototypes. Additionally, turning is frequently utilized as a secondary process to supplement or refine features on parts that were made using a different process. The process of turning can provide high tolerances and surface finishes, making it ideal for the addition of precise rotational features to a part that has already been formed with a basic shape.

1.2 ADJUSTABLE CUTTING PARAMETERS IN TURNING

Speed, feed, and depth of cut are the key factors in any turning operation, and they can be directly controlled by the operator. Although material and tool selection also impact the process, the operator can adjust these three factors on the machine.

1.2.1 Speed:

Speed in turning refers to the rotation of the spindle and workpiece, stated in revolutions per minute (rpm). However, the crucial aspect is the surface speed or the rate at which the workpiece material moves past the cutting tool, expressed in meters per minute (m/min). This varies with the diameter of the workpiece, even if the rotation speed remains constant.

$$V = \pi DN/1000$$

Here,

v is the cutting speed in turning in m/min,

D is the initial diameter of the work piece in mm,

N is the spindle speed in r.p.m.

1.2.2 Feed:

Feed pertains to the cutting tool, referring to the speed of its advancement along the cutting path, often proportional to spindle speed. It is expressed as millimeters per revolution (mm/rev) on power-fed lathes.

$$F_m = f \times N \text{ (mm/min)}$$

Here,

F_m is the feed in mm per minute, f -Feed in mm/rev and

N - Spindle speed in r.p.m.

1.2.3 Depth of Cut:

Depth of cut is the thickness of the layer being removed from the workpiece in one pass, expressed in millimeters. It is noteworthy that the workpiece diameter reduces by twice the depth of cut since the layer is being removed from both sides.

$$DOC = (D1-D2)/2$$

Where,

DOC- Depth of cut in mm

D1 - Initial diameter of the work pieced

D2 - Final diameter of thework piece

1.3 Single Point Cutting Tool

Single point cutting tools are widely used in lathes, planers, and shaper machines for cutting operations. These tools are categorized as either left-handed or right-handed. A tool is considered right-handed if its cutting edge is located on the right side when viewed from the point end.

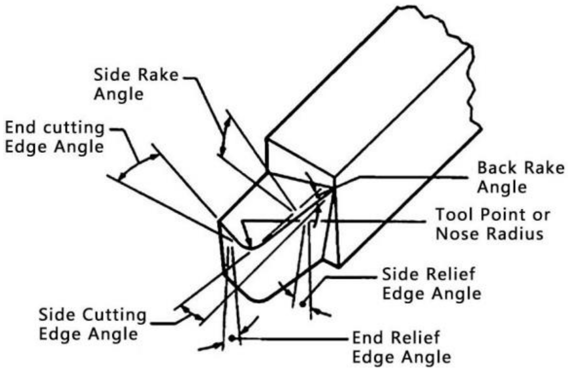


Figure 1.3 Tool geometry of single point cutting tool

This specification is according to the American Standards Association (ASN) Systems.

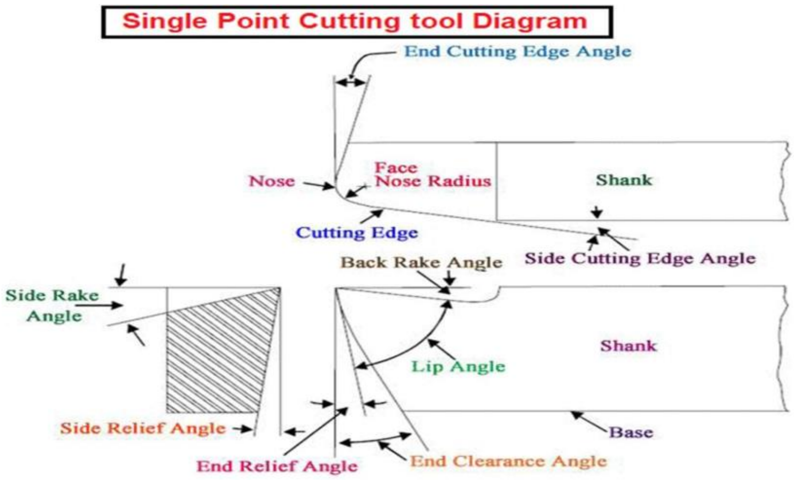


Figure 1.4 Single Point Cutting Tool Diagram

1.3.1 Terminology or Nomenclature of Single Point Cutting tool

1. Shank:

The main body of the tool is known as the shank. It is the backward part of thetool which is held by tool post.

2. Face:

The top surface tool on which chips passes after cutting is known as a face. It is the horizontal surface adjacent of cutting edges.

3. Flank:

Sometime flank is also known as cutting face. It is the vertical surface adjacent to the cutting edge. According to cutting edge, there are two flankside flank and end flank.

4. Nose or Cutting Point:

The point where both cutting edge meets known as cutting point or nose. It is infront of the tool.

5. Base:

The bottom surface of the tool is known as the base. It is just the opposite surface ofthe face.

6. Heel:

It is an intersecting line of face and base.

7. End Cutting Edge Angle:

- The end cutting angle is defined as the angle between the end cutting edge or flank and the plane that is perpendicular to the side of the shank.
- This angle falls between the range of 5 to 15 degrees.

8. Side Cutting Edge Angle:

The angle between the side cutting edge or flank to the plane parallel to the side ofthe shank known as side cutting edge angle.

9. Back Rake Angle:

- The rack angle is designed to facilitate the smooth flow of chips from the workpiece. This angle promotes the easy removal of chips from the cutting zone. The back rack angle is the angle between the face and the plane that is perpendicular to the end cutting edge.

- When machining softer materials, it is recommended to use a larger positive rake angle. This allows for easier cutting and helps to reduce cutting forces.

9. Side Rack Angle:

- The side rack angle is the angle between the face and the plane that is perpendicular to the side cutting edge. It is designed to facilitate the smooth flow of chips when the material is being cut by the side cutting edge.
- The extent to which a chip is bent during the machining process is determined by the side rack angle. When the side rack angle increases, the degree of chip bending decreases, resulting in smoother surface finish.

11. End Relief Angle:

- The clearance angle is an important angle that helps to prevent tool wear and rubbing between the flank and the workpiece. It is also commonly referred to as the relief angle.
- The end cutting angle is created by the end flank in relation to the plane that is perpendicular to the base.
- This angle typically falls within the range of 6 to 10 degrees.

12. Side Relief Angle:

- The side relief angle is the angle between the side flank and the plane that is perpendicular to the base. It is designed to prevent rubbing between the side flank and the workpiece during the cutting process. This angle allows the tool to feed sideways into the work material without experiencing any rubbing.
- If the side relief angle is too small, the tool will rub against the workpiece, resulting in overheating, blunting of the tool, and poor surface finish.

13. Nose Radius:

The intersecting area of both cutting edges is known as the nose of the tool.

1.3.2 Factors influencing rake angle of the single point cutting tool:

1. **Type of material being cut:** a harder material like cast iron may be machined with a smaller rake angle than that required by asoft metal like mild steel or aluminum.

2. **Type of tool material being used**: tool material like cemented carbide permits turning at a very high speed. It has been observed that in machining at a very high cutting speed rake angle has a little influence of cutting pressure.

3. **Depth of cut**: in rough turning, a high depth of cut is given towithstand severe cutting

pressure. So, the rake angle should be decreased to increase the lip angle that provides strength to the cutting edge.

The rigidity of the tool holder and condition of the machine: an improperly supported tool on an old and worn-out machine can’ttake up severe cutting pressure. so, machining under such conditions the tool used should have a larger rake angle than that atthe normal condition to reduce the cutting pressure.

1.3.3 Tool Signature

The tool signature or tool designation is used to denote a standardized system of specifying the principal tool angles of a single-point cutting tool. Some common systems used for tool designation or tool nomenclature are the following-

1. **American or (ASA) System.**

   The coordinate system of tool nomenclature defines the primary angles such as side rake, back rake, and nose angle, without considering their orientation in relation to the cutting edge. Therefore, it does not provide any information on the tool's behavior during the cutting process. The nomenclature system employs three reference planes, namely x-x, y-y, and z-z, which are similar to those used in traditional machine drawing. The z-z plane contains the tool's base, and the other two planes are mutually perpendicular to the z-z plane.

2. **British system:**

   The system being referred to in this statement is the British Standard (BS) 1886-1952 system. This system specifies the maximum allowable rake angle for a tool. The different parameters of the tool are indicated in a specific order, which is as follows: Back rake, Side rake, End relief angle, Side relief angle, End cutting angle, Side cutting edge angle, and Nose radius.

3. **Continental systems:**

   The tool nomenclature category comprises several systems, including the German or DIN System (DIN-6581), Russian Systems (OCT-BKC 6897 and 6898), and Czechoslovakian System (CSN-1226). These systems are used to specify the various parameters of a tool in relation to the reference planes of the tool. By using these systems, manufacturers can ensure that their tools are produced to a consistent standard and that they are suitable for their intended application.

4. **International system:**

It is an internationally adopted system, developed recently. It incorporates the salient features of tool nomenclature of different systems in it.

1.3.4 Single Point Cutting Tool Examples:

Single Point Cutting tool consists of only one main cutting edge that can perform material removal action at a time in a single pass.

1.Turning tool

2.Shaping tool

3.Planning tool

4.Slotting tool

5.Boring tool

6.Fly Cutter

1.3.5 Material Used for Single Point Cutting tools:

Tool bits generally made of seven materials

1.High-speed steel

2.Cast alloys

3.Carbides

4.Ceramics

5.Cermets

6.Cubic Boron Nitride

7.Polycrystalline Diamond

Advantages of Single Point Cutting Tool:

- Single Point Cutting tool is simple in construction hence easy to Design and Manufacture.
- As compare to multipoint cutting tool single point cutter are cheaper.
- Resharpening of cutter is easy
-

Disadvantages of Single-point Cutting Tools:

- These tools have low material removal rates (MRR) hence productivity is low.

- The tool wear rate is high.
- Tool life is short.
- High Cutting temperature

1.4 Lathe Machine and Types:

A lathe machine rotates a workpiece about an axis while holding it on a chuck and tool on a tool post to perform various operations, including turning, facing, chamfering, thread cutting, knurling, drilling, and more. This results in an object with symmetry about that axis.

A lathe machine's primary purpose is to shape and size metal by removing material from a workpiece. The workpiece rotates around an axis while various tools, held in place by a tool post, perform operations such as turning, facing, chamfering, thread cutting, knurling, and drilling. Lathes are best suited for creating cylindrical and planar surfaces perpendicular to the axis of rotation, and can also produce tapers, bellows, and other shapes. Additionally, they can create solids of revolution, plane surfaces, and screw threads with the appropriate attachments.

1.4.1 Parts of Lathe Machine

The following are the main parts of lathe machine:

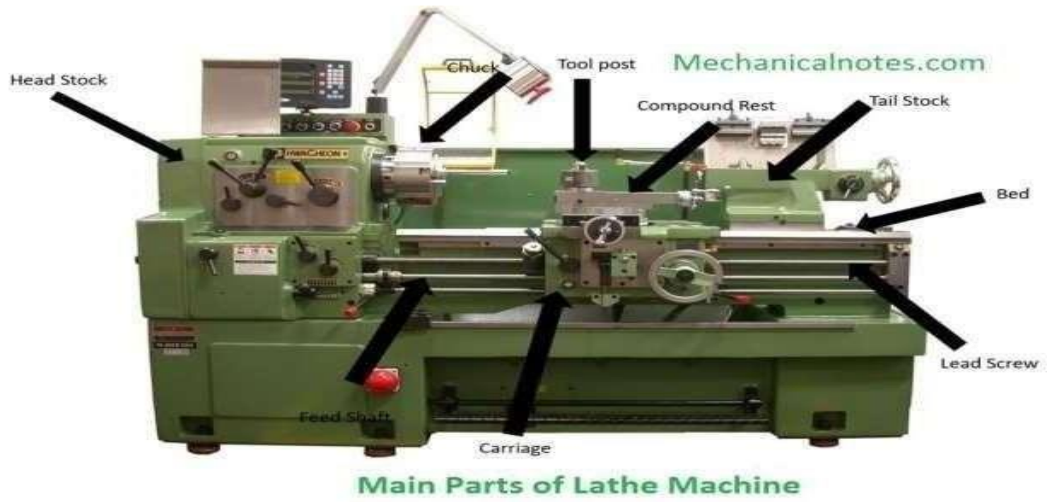


Figure 1. 5 Lathe Machine and Its Parts

1.Headstock

2.Carriage

3.Feed mechanism

4.Tailstock

5.Screw or thread cutting mechanism

6.Feed rod

7.Lead screw

1. Headstock

- H1: Geared headstock housing,
- H2: Intermediate gears lever,
- H3: High Low gear lever,
- H4: Camlock spindle,
- H5: Tumbler gears – forward/reverse and engage/disengage,
- H6: Quick change gearbox with 4 selectors (3 levers),
- H7: Lead screw
- H8: Feed screw,
- H9: Forward reverse switch,
- H10: Change gear cover

Figure 1.6 Head stock of Lathe Machin

It is located on the left-hand side of the lathe bed. It has a hollow spindle andthe different types of mechanism for driving and changing the speed of the spindle.

In this case, the speed increases when the belt is shifted from larger to smallerdiameter pulleys. The spindle is made up of nickel, chrome steel and carbon steel. The front end of the spindle hole is taper for holding the centers perfectly.

The speed changing is based on the following conditions,

1. The type of material to be cut

- Hard and tough materials like cast iron – slow speed
- Soft materials like aluminum, brass – high speed

2.Type of cutting tool material

- For high – speed hard tools made of tungsten carbide is used.
- For slow – speed medium hardness tool is used.

3.The type of finish-finishing cut-small depth-high speed

- Rough cut – high depth – low speed.

4.The diameter of the workpiece

- For large diameter workpiece – low speed
- For smaller diameter workpiece – high speed

5.Type of operation

- For turning, boring, drilling – high speed
- For thread cutting, tapping, reaming – low speed.

2. Tailstock

The tailstock is located on the right-hand side of the lathe bed. The tailstock supports the other end of the workpiece when it is machining between two centers.

Figure 1.7 Tail stock of lathe

- T1: A feed screw
- T2: Reduction gearbox (optional)
- T3: Body
- T4: Adjustable base
- T5: Spindle
- T6: Locking Lever

It holds the tool rigidly and perfectly for performing operations such as drilling, reaming, tapping, and boring. It can move along the guideways and can clamp in any position on the bed.

The tailstock is consisting of the dead center, spindle, adjusting screw, hand wheel, etc. The spindle can move forward and backward of the body called barrel by means of a handwheel. The keyway is provided on the inside surfaceof the barrel to hold the dead Centre.

3. Carriage

The carriage is one of the most important parts of the lathe tool and it will serve as a supporting, moving, and controlling part of the cutting tool.

- **Saddle**

It is 'H' shaped. The saddle fits over the bed and slides along the guideways by carrying the cross slide and tool post. It can lock in any position in its movement.

- **Cross Slide**

The cross-slide is a component that attaches to both the saddle and the compound rest of a lathe. This part is operated by turning the handwheel to produce movement. To achieve transverse movement, the nut located on the feed screw must be engaged with the binder screw of the cross slide. If a taper turning attachment is being used, the binder screw is left open to disengage the cross slide from the cross-feed screw. In this case, the cross slide is connected to the guide block. When the pinion is keyed to the cross-feed screw and is meshed with the apron gearing, the cross slide can move automatically.

- **Compound rest**

It is a circular base, graduated in degrees and it is used to obtain angular cutsand tapers of the variable cross-section. It consists of a compound slide handwheel, compound slide feed screw, compound slide nut. The compound slide handwheel is mainly used in taper turning operations to give the feed.

- **Tool post**

The tool post is placed above the compound rest and it holds the tool firmly. There are different types of tool post,

1. Single screw tool post
2.Four-way tool post
3.Eight-way tool post

4. Feed mechanism

The amount of the tools relative to the workpiece is called 'Feed'.

A lathe tool has 3 types of feed

1. **Longitudinal feed**: Here the tool moves parallel to the lathe axis. It is affected by means of the carriage movement.
2. **Cross-feed:** Here the tool moves at right angles to the lathe axis.
3. **Angular feed**: By adjusting the compound slide andswiveling it to the required angle to the lathe axis.

Cross and longitudinal feeds are both hand and power operated, but angular is only hand operated.

5. Screw or Thread Cutting Mechanism

The lathe is important to the machine tool, which is used to cut the required type of threads on a given work. The rotation of the screw is used to move the tool along the workpiece to produce the screw threads. The half-nut mechanism is used in the lathe.

6. Feed Rod

It is a long shaft having a keyway extends from the feed box across and in front of the bed. The power is transmitted from the lathe spindle to the apron gears through the feed rod. The feed rod is mainly using to move the carriage or cross slide for the operations such as turning, boring, facing and all other considering the threadcutting operation.

7. Leadscrew

It is a long-threaded shaft used for only thread cutting operation. The lead screw is in an arranged position in all operations from the gearbox. It may alsobe used to give the motion for turning, boring, etc., in the lathes which are equipped with a feed rod.

1.4.2 Types of Lathe Machines

Following are the seven different types of lathe machine:

1.Speed Lathe Machine

2.Engine Lathe Machine

3.Bench Lathe Machine

4.Toolroom Lathe Machine

5.Capstan and Turret Lathe Machine

6.Special purpose lathe machines

7.Automatic Lathe Machine

8.CNC lathe machine

1.5 Workpiece material and their specific applications.

Nickel Aluminum Bronze C95500 is a popular copper alloy with a composition of copper, aluminum, nickel, iron, and manganese. The alloy is also known by its trade name, "AMS 4880."

This alloy has excellent corrosion resistance, high strength, and good wear resistance. It is often used in marine applications, such as propellers, seawater valves, and marine hardware. It is also used in other applications, such as gears, bushings, and bearings.

The typical composition of C95500 is as follows:

Copper: 78-82%

Aluminum: 8-10%

Nickel: 3-5%

Iron: 3-5%

Manganese: 1-2%

This alloy can be easily machined and welded using standard techniques. However, due to the high copper content, it is important to use proper ventilation when welding toavoid copper fume exposure. Overall, Nickel Aluminum Bronze C95500 is a versatilealloy that offers excellent properties for a variety of applications.

Figure 1.8 Ni-Al-Br C95500 alloy

Table 1.5.1 Ni-Al-Br C95500 Composition

Element	Content (%)
Copper	78-82
Aluminum	8-10
Nickel	3-5
Iron	3-5
Manganese	1-2

1.6 Temperature Gun Measurement

Temperature guns, also known as infrared thermometers, are electronic devices that are used to measure the surface temperature of an object without the need for physical contact. They are equipped with infrared sensors that detect and measure the amount of heat energy that is radiating from an object.

These devices have many applications, such as in the medical field to measure body temperature, in the food industry to ensure proper cooking and storage temperatures, in the automotive industry to detect overheating engines, and in the HVAC industry to diagnose heating and cooling systems.

When using a temperature gun, it is important to point it directly at the object of interest and be as close as possible to ensure accurate readings. Some temperature guns come with additional features, such as adjustable emissivity settings to account for different surfaces and ambient temperature compensation to adjust for changes in the environment.

Overall, temperature guns offer a quick and convenient way to measure surface temperature without the need for physical contact, making them a valuable tool in various industries and applications.

Figure 1.9(a) showing temperature Under machining

Figure 1.9(b) Cautions when usage of temperature gun

1.7 DYNAMOMETER

In the context of machining operation turning, a dynamometer can be used to measure the cutting forces that occur during the process. This is important because understanding these forces can help optimize the machining parameters such as cutting speed, feed rate, depth of cut, leading to improved surface finish, tool life, and machining efficiency.

A cutting force dynamometer typically consists of a sensor that measures the forces acting on the cutting tool during the machining process. This sensor can be mounted directly on the tool or on the tool holder or spindle. The forces measured include the axial force (Fx), radial force (Fy), and tangential force (Fz),which are the forces acting in the x, y, and z directions respectively.

By analyzing the cutting force data, machinists can optimize the machining process to achieve the desired results. For example, if the cutting forces are too high, the tool may be experiencing excessive wear or the machine may be overloaded, leading to poor surface finish and increased tool replacement costs. Adjusting the machining parameters based on the cutting force data can help improve the machining performance and reduce costs.

Figure 1.10 Dynamometer

1.8 INTRODUCTION TO MINITAB

Minitab is a statistics software developed by Barbara F. Ryan, Thomas A. Ryan, Jr., and Brian L. Joiner in 1972 at Pennsylvania State University. Originally, Minitab was a light version of NIST's statistical analysis program, OMNITAB, and is now widely used for statistical research and learning. Statistical analysis software provides accurate, reliable and fast results, replacing the need for manual computation of statistics and graphing. Minitab is user-friendly, with only a few fundamentals to learn. The software is distributed by Minitab Inc, a private company headquartered in State College, Pennsylvania, with subsidiaries in Coventry, England (Minitab Ltd.), Paris, France (Minitab SARL), and Sydney, Australia (Minitab Pty.).

Minitab is a statistical analysis software package that was originally developed in 1972 at Pennsylvania State University by researchers Barbara F. Ryan, Thomas A. Ryan Jr., and Brian L. Joiner as a light version of NIST's statistical analysis program OMNITAB. Today, Minitab is frequently used alongside six sigma, CMMI, and other statistics-based process improvement methods. The latest version of the software, Minitab 16, is available in seven languages: English, French, German, Japanese, Korean, Simplified Chinese, and Spanish. Statistical analysis computer applications have the advantage of being more accurate, reliable, and faster than computing statistics and drawing graphs manually. Minitab Inc. produces two additional products that complement Minitab 16: Quality Trainer, an eLearning package that integrates with Minitab 16 to teach statistical tools and concepts in the context of quality improvement, and Quality Companion 3, an integrated tool for managing Six Sigma and Lean Manufacturing projects that combines Minitab data with management and governance tools and documents.

Minitab has two main types of files, projects and worksheets. Worksheets arefiles that are made up of data; think of a spreadsheet containing variables of data. Projects are made up of commands, graphs, and worksheets. Every time you save a Minitab project, you will be saving graphs, worksheets, and commands. However, each one of the elements can be saved individually for use in other documents or Minitab projects. Likewise, you can print projects and their elements.

1.8.1 Minitab project and worksheets.

Minitab software has two main types of files - projects and worksheets. A worksheet in Minitab is similar to a spreadsheet that contains data variables. On the other hand, a project in Minitab comprises of commands, graphs, and worksheets. Whenever you save a Minitab project, you save all these elements including graphs, worksheets, and commands. However, each element can be saved separately for future use in other documents or Minitab projects. Additionally, you can print projects and their elements for your reference.

The Menu bar: You can open menus and choose commands. Here you can find the built-in routines.

The Toolbar: Shortcuts to some Minitab commands.

1.8.2 Two windows in MINITAB

1. Session Window: The area that displays the statistical results of your data analysis and can also be used to enter commands.

2. Worksheet Window: A grid of rows and columns used to enter and manipulate the data. Note: This area looks like a spreadsheet but will not automatically update the columns when entries are changed.

Other windows include:

5. Graph Window: When you generate graphs, each graph is opened in its own window.
6. Report Window: Version 13 has a report manager that helps you organizeyour results in a report.
7. Other Windows: History and Project Manager are other windows. SeeMinitab help for more information on these if needed

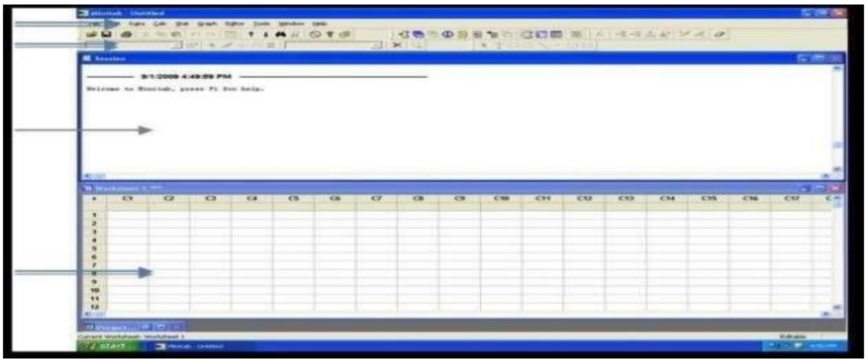


Figure 1.11 Minitab Interface

1.8.3 Taguchi in Minitab

Taguchi methods are a set of statistical techniques used for design of experiments (DOE)that can help improve the quality of manufactured products and processes. Minitab is a statistical software package that provides tools for conducting DOE using Taguchi methods.

Minitab provides a specific Taguchi DOE platform, which allows you to create and analyze designs of experiments using Taguchi methods. This platform provides a user- friendly interface for setting up Taguchi designs, including defining factors, levels, and interactions. It also provides tools for analyzing the results of Taguchi experiments, including graphical representations of the data and statistical analysis.

To access the Taguchi DOE platform in Minitab, you can go to the "DOE" menu and select "Taguchi Design." From there, you can choose the type of Taguchi design you want to create, such as an L8 designer an L16 design. You can then specify the factors and levelsfor the design, and Minitab will generate the necessary experimental runs.

Once you have conducted the Taguchi experiment, you can use Minitab to analyze the results and determine the optimal settings for the factors that will lead to the best quality outcome. This can help you optimize your manufacturing process and improve the qualityof your products.

Overall, the Taguchi DOE platform in Minitab is a powerful tool for conducting DOE using Taguchi methods and can help you improve the quality of your products and processes.

1.9 INTRODUCTION TO TOPSIS

TOPSIS, which stands for Technique for Order of Preference by Similarity to Ideal Solution, is a popular multi-criteria decision analysis technique. It enables comparison of a set of alternatives based on a predetermined criterion and is widely used across various industries for making analytical decisions based on collected data.

Suppose we want to evaluate the financial strength of multiple companies and determine which one is the strongest. These companies form our set of alternatives, and we need to utilize reliable metrics to make a decision. To achieve this, we can employ indicators derived from financial statements, such as ROA (return on assets), ROE (return on equity), DR (debt ratio), or CG (capital gearing). These indicators will serve as our criteria set for comparing and combining the companies.

The mysterious logic of TOPSIS is based on the concept that the chosen alternative should have the shortest geometric distance from the best solution and the longest geometric distance from the worst solution. Pretty simple huh?

The methodology enables the identification of trade-offs between criteria, where a weak performance in one criterion can be compensated by a strong performance in another. This approach provides a holistic modeling approach, as alternative solutions are not excluded based on predefined thresholds.

1.9.1 TOPSIS algorithm

Generally, the whole TOPSIS process can be encapsulated in 7 steps:

1. Create a matrix consisting of M alternatives and N criteria. This matrix is usually called an “evaluation matrix.”

   $$(a_{ij})_{M \times N}$$

   As an example: M will be the number of our companies, while N, the number of metrics (ROA, ROE, DR, CG).

2. Normalize evaluation matrix:

   $$\alpha_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{M}(a_{ij})^2}}$$

   Each metric j for each company i is normalized to be in between 0 and 1. The higher its value the better the metric.

   1. Calculate the weighted normalized decision matrix. It is important to note that each criterion should have its own weight so that all of them will sum up to 1. The weights can be derived randomly (not recommended) or based on expert knowledge (industry standard).

$$\chi_{ij} = \alpha_{ij} * \omega_j$$
$$\omega_j = \frac{w_j}{\sum_{j=1}^{N} w_j}$$
$$\sum_{j=1}^{N} \omega_j = 1$$

After we assign a weight to each financial metric, we need to normalize those so that these sum up to 1. Then we need to multiply each normalized metric from step 2 by correspondingnormalized weight.

2.Determine the best and the worst alternative for each criterion:

$$\chi_j^b = \max_{i=1}^{M} \chi_{ij}$$
$$\chi_j^w = \min_{i=1}^{M} \chi_{ij}$$

We want to find the maximum and minimum value of each financial metric among all companies.

3.Calculate the Euclidean distance between the target alternative and the best/worstalternative:

$$d_i^b = \sqrt{\sum_{j=1}^{N} (\chi_{ij} - \chi_j^b)^2}$$
$$d_i^w = \sqrt{\sum_{j=1}^{N} (\chi_{ij} - \chi_j^w)^2}$$

This is a calculation of the geometric distance between the value of each financial metric fora given company **i** and the best/worst value of such a metric among all companies.

4.For each alternative calculate the similarity to the worst alternative. The results areour **TOPSIS** scores.

$$s_i = \frac{d_i^w}{d_i^w + d_i^b}$$

We compute a score for each company that is based on distances obtained in a step before.

5. Rank alternatives according to the **TOPSIS** score by descending order.

The company with metrics closest to the best will obtain the highest score and therefore willbe at the top of our ranking.

And… that's all. We obtained a ranked set of alternatives based on specified criteria.

1.10 Cutting Fluids

Cutting fluids, also known as cutting oils or coolant, are liquids that are used in machiningand metalworking processes to lubricate and cool the cutting tool and workpiece. They are essential for preventing excessive heat and friction, which can cause damage to the tool and workpiece, as well as reducing the overall efficiency of the machining process.

There are several types of cutting fluids available, including oils, emulsions, and synthetics. The type of cutting fluid used depends on the specific application and the material being machined. For example, water-based fluids are often used for cutting aluminium, while oil-based fluids are better for cutting steel.

Cutting fluids can also contain additives, such as rust inhibitors and detergents, to improvetheir performance and protect the machinery. However, some cutting fluids may contain hazardous chemicals and need to be handled and disposed of properly to avoid environmental and health hazards.

Cutting fluids are liquids used in machining and metalworking to lubricate and cool the cutting tool and workpiece, prevent heat and friction, and improve efficiency. There are different types of cutting fluids, including oils, emulsions, and synthetics, with various additives to enhance their performance. However, some cutting fluids may contain hazardous chemicals, requiring proper handling and disposal.

USAGE OF CUTTING FLUIDS IN THIS PROJECT

1. **FINE KUT 56 CUTTING FLUID**

FineKut 56 is a type of cutting fluid used for machining operations such as turning, milling, drilling, and tapping. It is specifically formulated for use on ferrous and non- ferrous metals, including aluminum, brass, and copper alloys.

FineKut 56 is a water-soluble cutting fluid, meaning it can be easily mixed with water to create a stable emulsion. This emulsion provides lubrication and cooling during the machining process, which helps tore duce tool wear and extend tool life. The fluid is designed to have a low foaming tendency, which can help to maintain the cleanliness of the workpiece and machining equipment.

In addition to its lubricating and cooling properties, Fine Kut 56 also contains corrosion inhibitors to help protect the machined parts and equipment from rust and corrosion. It is also low in odor, which can help to improve the working environment for operators.

Fine Kut 56 is typically used in a concentration range of 5% to 10%, depending on the application and material being machined. The fluid can be applied by flood, spray, or mist depending on the machining operation and equipment. It is important to note that the proper disposal of used cutting fluids is necessary to avoid environmental contamination,and local regulations should be followed.

Overall, Fine Kut 56 is a versatile cutting fluid that can provide effective lubrication and cooling for a variety of machining operations on both ferrous and non-ferrous metals.

CHEMICAL PROPERTIES OF FINE KUT 56

Fine Kut 56 cutting fluid is a water-soluble oil (also known as an emulsion) and containsa range of chemicals designed to enhance its performance during machining operations. The specific chemical properties of Fine Kut 56 cutting fluid include:

Lubricants: The cutting fluid contains a range of lubricating agents to reduce friction between the tool and the workpiece during machining. These lubricants help to improve thesurface finish of the machined part and extend the life of the cutting tool.

Corrosion inhibitors: Fine Kut 56 cutting fluid contains corrosion inhibitors that help to protect the workpiece and machining equipment from rust and corrosion. These inhibitors work by forming a protective layer on the surface of the metal, which helps to prevent the oxidation process.

Surfactants: Surfactants are compounds that help to reduce the surface tension of the cutting fluid, allowing it to spread more evenly over the surface of the workpiece. This improves the cooling and lubricating properties of the fluid and helps to improve the overall efficiency of the machining process.

Biocides: Cutting fluids can provide an ideal environment for the growth of bacteria, fungi, and other microorganisms, which can cause unpleasant odors, health hazards, and damage to the equipment. FineKut 56 cutting fluid contains biocides to prevent the growthof these microorganisms.

pH adjusters: Cutting fluids must maintain a specific pH range to ensure optimal performance. Fine Kut56 cutting fluid contains pH adjusters to maintain the appropriate pH range for the specific machining operation and metal being machined.

Detergents: Fine Kut 56 cutting fluid contains detergents that help to remove debris and chips from the cutting zone, keeping the workpiece and equipment clean.

Overall, the chemical properties of Fine Kut 56 cutting fluid are designed to improve the lubricating, cooling, and protective properties of the fluid, while also maintaining the appropriate pH and preventing the growth of microorganisms.

PROPERTIES OF HYDRAULIC OIL

2. HYDRAULIC OIL

Hydraulic oil is not typically used as a cutting fluid due to its lack of specific properties required for machining operations. However, there are some hydraulic oils that are formulated specifically for use as a cutting fluid, and these may have different properties than typical hydraulic oils. Some of the properties of hydraulic oil cutting fluids may include:

Lubrication: Hydraulic oil cutting fluids can provide lubrication between the tool and workpiece during machining operations. This lubrication can help to reduce friction and wear on the cutting tool, resulting in a longer tool life and better surface finish.

Cooling: Hydraulic oil cutting fluids can also help to cool the workpiece and cutting tool during machining operations. This cooling helps to prevent overheating of the workpieceand tool, which can lead to tool wear and poor surface finish.

Corrosion resistance: Hydraulic oil cutting fluids may contain corrosion inhibitors that help to protect the workpiece and machining equipment from rust and corrosion during the machining process.
Anti-wear properties: Hydraulic oil cutting fluids may also contain anti-wear additives that help to protect the cutting tool from wear during machining operations.

Low foaming: Hydraulic oil cutting fluids may be formulated to have low foaming properties, which can help to maintain the cleanliness of the workpiece and machining equipment.

Environmental considerations: Some hydraulic oil cutting fluids may be formulated with biodegradable or environmentally friendly additives to minimize their impact on the environment.

Overall, while hydraulic oil cutting fluids may provide some of the properties required for effective machining, they may not be as effective as dedicated cutting fluids that are formulated specifically for machining operations. Additionally, it is important to use the correct type and grade of hydraulic oil cutting fluid for the specific machining operation and metal being machined to ensure optimal performance.

3. XTRAA COOLANT OIL

Coolant oil is sometimes used as a cutting fluid in machining operations, where it is applied to the cutting tool and the workpiece to help reduce friction and dissipate heat. This can help to improve cutting efficiency, reduce tool wear, and improve surface finish.

FEATURES

- Formulated using latest OAT technology.
- Excellent corrosion inhibition and rust protection
- Fully resistant to biofouling and foaming.

CHAPTER 2

LITERATURE STUDY

A literature review is a thorough overview of earlier studies on a subject. The literature review examines academic books, journals, and other materials that are relevant to a particular field of study. This chapter will help you learn more about your chosen field of study. The literature review part serves as a guide, providing details and recommendations based on journal and other media sources.

Krishnamurthy et al. [1] the effects of different vegetable-based cutting fluids (i.e., coconut oil, sunflower oil, and palm oil) on the machinability of nickel aluminium bronze C95500. The results show that all the vegetable-based cutting fluids improved the surface roughness and reduced the cutting forces compared to dry machining. Among the three oils, coconut oil produced the best results. The study concludes that vegetable-based cutting fluids are an environmentally friendly and effective alternative to traditional cutting fluids for machining nickel aluminum bronze C95500.

Arunachalam et al. [2]The effects of different cutting fluids (i.e., vegetable oil, synthetic oil, and water-soluble oil) on the machinability of nickel aluminium bronze C95500. The results show that the vegetable oil-based cutting fluid produced the best surface finish and the lowest cutting forces, while the synthetic oil-based fluid produced the lowest tool wear. The study concludes that vegetable oil-based cutting fluids are a promising alternative to traditional cutting fluids for machining nickel aluminium bronze C95500.

Hegde et al. [3] the effects of different cutting fluids (i.e., vegetable oil, soluble oil, and synthetic oil) and cutting parameters (i.e., cutting speed, feed rate, and depth of cut) on the machining of nickel aluminium bronze C95500 using CNC turning. The results show that vegetable oil-based cutting fluid produced the best surface finish and the lowest cutting forces, while the soluble oil-based fluid produced the lowest tool wear. The study concludes that the optimal cutting parameters and cutting fluid depend on the specific machining operation.

Neetu Kanaujia et. al. [4] studied the outcome of different parameters (i.e., cutting velocity

(Vc), feed rate (Vf), depth of cut (Dc) and coolant pressure (Pc)) on the responses like material removal rate (MRR), surface roughness (Ra) and tool tip temperature (Tavg). Inserts made of uncoated carbide are used to machine 7075 aluminium. Their main goal is to identify a parametric configuration where MRR, Ra, and Tavg are all at their minimal values. Here, L16 orthogonal array was employed, and TOPSIS approach along with Taguchi philosophy was applied to optimise the outcomes. The optimal process variables, which are cutting velocity = 605 RPM, feed rate = 0.12 mm/rev, depth of cut = 0.61 mm, and coolant pressure = 60 bar, were discovered, according to their findings (A2B2C3D3). In this parametric configuration, MRR will represent the highest energy usage and Ra the lowest.

Maheswara Rao et. al. [5] optimized the impact cutting parameters (speed, feed, and depth of cut) of turning AA7075 using CNC (Computer Numerical Control), to produce low Surface Roughness using tungsten carbide insert. The Taguchi's L9 (3 levels*3 parameters) Orthogonal array approach was used in the experiment design. To determine the importance of the cutting parameters on the surface roughness, analysis of variance (ANOVA) was carried out. The findings indicated that the most crucial factors affecting surface roughness are feed and cutting speed. According to Taguchi analysis, the least surface roughness is determined at 1000 rpm (Level 1) cutting speed, 0.2 mm/rev feed, and 0.5 mm (Level 1) depth of cut, respectively. Following that, a forecasted range of ideal surface roughness values was created.

Periasamy et. al. [6] experimentally investigated the effects of cutting speed, feed rate, and depth of cut during CNC turning operations on composites made of aluminium and metal. The trials were carried out using a L9 orthogonal array architecture. According to Taguchi analysis, the set of cutting speed of 315 m/min, feed 0.1 mm/rev, and depth of cut of 1.0 mm is the most effective combination of machining parameters for the multi-performance characteristics of the AMCs. To validate the methodology, optimal and experimental data were compared. They found that the surface roughness decreased from 5.57 to 5.417 mm.

Mohana Rao et. al. [7] utilizing physical vapour deposition (PVD) carbide inserts and uncoated carbide inserts to machine aluminium alloy AA6063 improved the cutting conditions and the surface nature of the workpiece material. Using the Taguchi approach, the exams were conducted using the L9 orthogonal array. The analysis of variance

(ANOVA) method was also used to complete the investigation, and the multiple regression (MR) method was used to examine the combined effects of the factors. The test results were compared, and the optimal testing with TiC coating PVD coated and uncoated carbide inserts were obtained separately.

According to the results of the analysis of variance, it was found that the influence of feed (84%) is greater on surface roughness than that of speed (2%), depth of cut (13%) and cutting force (79%) while the influence of speed (68%) is greater on temperature than that of feed (6%) and depth of cut (21%). During the machining of the aluminium alloy AA6063, it was observed that using PVD coated carbide inserts produced 11% better surface roughness, 10% less power, and 12% lower temperature than using uncoated carbide inserts.

Jayaramana et. al. [8] optimized the machining parameters on turning of AA 6063 T6 aluminium alloy with multiple responses based on orthogonal array with grey relational analysis. Experiments are conducted on AA 6063 T6 aluminium alloy. Using an uncoated carbide insert and a dry cutting environment, turning tests are conducted. In this study, turning parameters including cutting speed, feed rate, and cut depth are optimised considering a variety of responses such surface roughness , roundness, and material removal rate. (MRR). The grey analysis yields a grey relational grade (GRG). The values of the grey relational grade were used to identify the optimal parameter levels, and ANOVA was used to establish which factors contributed significantly. Confirmation testing is done to verify the test result. Experimental results have shown that these results may effectively improve the reactions in the turning process.

Upinder Kumar et. al. [9] Conducted experiments to optimize surface roughness in CNC Turning by Taguchi method. For the turning tests, medium carbon steel (AISI 1045), 28 mm in diameter and 17 mm in length is employed. Signal-to-noise ratio (S/N), Analysis of variance (ANOVA), and an L27 orthogonal array are all employed. Utilizing the STALLION-100 HS CNC lathe, tests are conducted using three levels of machining parameters. They concluded that feed rate, followed by depth of cut, had the greatest impact on surface roughness. The least important element determining surface roughness is cutting speed.

Rao, et. al. [10] investigated the influence of speed, feed, and depth of cut on Surface Roughness and Cutting forces during machining of AISI 1050 steels (hardness of 484HV) on CNC lathe with ceramic ($Al2O3+TiC$ matrix) tool. The Taguchi technique was used to perform the trials (L27 design with 3 levels and 3 factors). The findings showed that feed rate has the greatest impact on both cutting forces and surface roughness. Cutting force is significantly influenced by depth of cut, although surface roughness is very little affected. Cutting forces are significantly influenced by the interactions between feed, depth of cut, and all three cutting parameters, although none of these interactions significantly affect the surface roughness that is created.

Yang and Tarng [11] investigated the cutting characteristics of S54C steel bars using tungsten carbide cutting tools, the Taguchi method was studied as a potent tool for design optimisation for quality. It was used to find the best cutting parameters for turning operations based on orthogonal array, signal-to-noise (S/N) ratio, and the analysis of variance (ANOVA). The key cutting parameters that have the most effects on the cutting performance in turning operations were also discovered via this investigation, in addition to the best cutting parameters for cutting operations. Experimental findings are presented to support the efficacy of this strategy.

Kaladhar et. al. [12] conducted the experimental study to determine the effects of speed, feed, depth of cut, and nose radius on multiple performance characteristics, namely, surface roughness (Ra) and material removal rate (MRR) during turning of AISI 202 austenitic stainless steel using a CVD coated cemented carbide tool. To plan experiments, Taguchi's L8 orthogonal array (OA) is chosen. They discovered that feed and nose radius are the two most important factors influencing surface roughness. They also found that cutting speed is the second-most important characteristic for MRR after DOC.

Suleiman Abdulkareem et. al. [13] investigated the influence of the three most important machining parameters of depth of cut, feed rate and spindle speed on surface roughness during turning of AISI 1045. Analysis of variance (ANOVA) and the Box Behnken experimental design approach were used to examine the impact of machining settings on surface roughness height Ra. According to the results of the trials, the feed rate is the factor that has the greatest impact on Ra, followed by cutting speed, with spindle speed having the least impact. Additionally, they discovered that high spindle and cutting speeds had a favourable impact on Raas against feed rate.

Shreemoy Kumar et. al. [14] turned the AISI 304 austenitic stainless steel in dry condition in trials utilising multi-objective Grey relational analysis, and the machinability features 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 and surface roughness, and then speed and depth of cut.

Wang et. al.[15] the effects of different cutting fluids (i.e., water-soluble coolant, vegetable oil-based fluid, and air) on tool wear and surface roughness during milling of Inconel 718. The results show that the vegetable oil-based cutting fluid produces the lowest tool wear and surface roughness. The study concludes that vegetable oil-based cutting fluids are a promising alternative to traditional water-soluble coolants for milling Inconel 718.

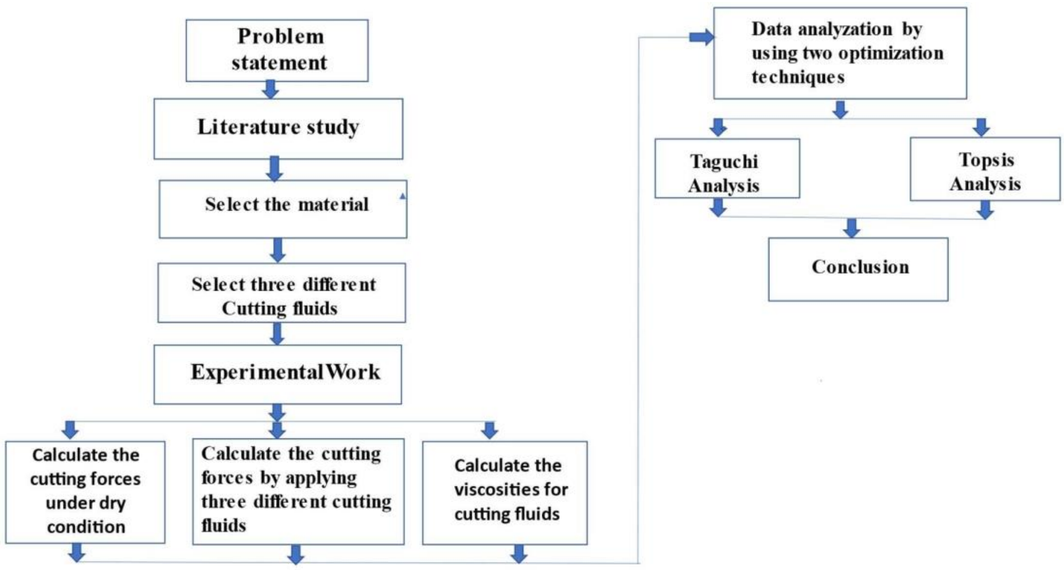
SCOPE OF THE WORK

The scope of our project is to investigate the effect of cutting fluids on turning operations of nickel aluminum bronze C95500 alloy. We conduct experiments using three different cutting fluids and measure cutting forces under various cutting conditions. We analyze the experimental data using statistical analysis techniques and apply Taguchi and TOPSIS analysis to identify the optimal cutting fluid for minimizing cutting forces. The project's scope also includes a literature review, experimental design, data analysis, interpretation, and conclusion.

The project's scope involves a combination of experimental, statistical, and analytical skills to investigate the effect of cutting fluids on turning operations of nickel aluminum bronze C95500 alloy. The findings of the study can provide valuable insights into the selection of cutting fluids for machining operations and can be useful in improving the machining performance of nickel aluminum bronze C95500 alloy.

After reviewing the literature, it is apparent that the majority of research focuses on investigating the influence of cutting parameters and cutting fluids on machining nickel aluminium bronze C95500. However, this study takes a different approach and examines the cutting forces that arise during the turning operation. To determine the optimal machining conditions, Topsis optimization technique was utilized, resulting in the best outcome among all the experiments conducted. Furthermore, Taguchi was employed to identify the most significant factor affecting the machining process.

METHODOLOGY FLOW CHART



CHAPTER-3

DESIGN OF EXPERIMENTS

3.1 Design of Experiments (DOE) Overview

In industrial settings, designed experiments are used to investigate how process or product variables affect product quality in a systematic manner. Improvement efforts are then focused on enhancing the manufacturability, reliability, quality, and performance of the product by targeting these variables. Given the limited resources, it is crucial to maximize the amount of information gained from each experiment.

A well-designed experiment can yield significantly more information while using fewer resources than an unplanned experiment. Rather than conducting a "one factor at a time" experiment, a well-designed experiment identifies the essential effects and incorporates them into the design. Interactions between input variables occur when the effect of one variable is influenced by the level of another. The four phases of a typical designed experiment are planning, screening (process characterization), optimization, and verification.

3.1.1 Planning

Thorough planning can help prevent potential issues that may arise during the execution of an experimental plan. Factors such as personnel availability, equipment availability, funding, and mechanical considerations can impact the successful completion of an experiment. The necessary preparation steps for an experiment will vary depending on the specific problem being addressed. However, there are general steps that should be followed, including:

- Define the problem. Developing a good problem statement helps in studying the right variables.
- Define the objective. A well-defined objective will ensure that the experiment answers the right questions and yields practical, usable information. At this step, define the goals of the experiment.
- Develop an experimental plan that will provide meaningful information. Review relevant background information, such as theoretical principles and knowledge gained through observation or previous experimentation.

Ensuring that both the process and measurement systems are in control is essential. It is ideal for both the process and measurements to be statistically in control, which can be evaluated using a functioning statistical process control (SPC) system. Minitab offers several tools to assess process control and analyze measurement systems.

3.1.2 Screening

In many processes' development and manufacturing applications, potentially influential variables are numerous. Screening reduces the numberof variables by identifying the key variables that affect product quality. This reduction allows focusing process improvement efforts on the crucial variables. Screening suggests the "best" optimal settings for these factors.

The following methods are often used for screening:

- Two-level full and fractional factorial designs are used extensively in industry
- Plackett-Burman designs have low resolution, but they are helpful in some screening experimentation and robustness testing.
- General full factorial designs (designs with more than two levels) may alsobe helpful for small screening experiments.

3.1.3 Optimization

After identifying the vital variables by screening, there is a need to determine the "best" or optimal values for these experimental factors. Optimalfactor values depend on the process objective.

The optimization methods available in Minitab include general full factorialdesigns (designs with more than two levels), response surface designs, mixture designs, and Taguchi designs.

- Factorial Designs Overview describes methods for designing andanalyzing general full factorial designs.
- Response Surface Designs Overview describes methods for designing and analyzing central composite and Box-Behnken designs.
- Mixture Designs Overview describes designing and analyzing simplex centroid, simplex lattice, and extreme vertices designs. Mixture designs are aparticular class of response surface designs where the proportions of the components (factors), rather than their magnitude, are essential.
- Response Optimization describes methods for optimizing multiple responses.

Minitab provides numerical optimization, an interactive graph, and an overlaid contour plot to help to determine the "best" settings to simultaneously optimize multiple responses.

- Taguchi Designs Overview describes methods for analysing Taguchi designs. Taguchi designs may also be called orthogonal array designs, robustdesigns, or inner-outer array designs. These designs are used for creating products that are robust to conditions in their expected operating environment.

3.1.4 Verification

Verification involves performing a follow-up experiment at the predicted "best" processing conditions to confirm the optimization results.

3.2 Advantages & Disadvantages of DOE

DOE became a more widely used modelling technique superseding its predecessor one-factor-at- time (OFAT) technique. One of the main advantages of DOE is that it shows the relationship between parameters and responses. In other words, DOE shows the interaction between variables which in turn allows us to focus on controlling essential parameters to obtainthe best responses. DOE also can provide us with the most optimal setof parametric values to find the best possible output characteristics. Besides that,the mathematical model generated can be used as a prediction model to predictthe possible output response based on the input values. Another main reason DOE is used because it saves time and cost in terms of experimentation. DOEfunctions so that the number of experiments or the number of runs is determined before the actual experimentation is done. This way, time and costcan be saved as we do not have to repeat unnecessary experiment runs. Most usually, experiments will have an error occurring. Some of them might be predictable, while some errors are just out of control. DOE allows us to handlethese errors while continuing with the analysis. DOE is excellent when it comes to predicting linear behavior. However, when it comes to nonlinear behavior, DOE does not always give the best results.

3.3 Factorial Designs

3.3(a) Factorial Designs Overview

Factorial designs allow for the simultaneous study of the effects that several factors may have on a process. When experimenting, varying the factors simultaneously rather than one at a time is efficient in terms of time andcost and allows for studying interactions between the factors. Interactions arethe driving force in many processes. Without the use of factorial experiments,essential interactions may remain undetected.

3.3(b) Screening designs

In many processes development and manufacturing applications, the number of potential input variables (factors) is significant. Screening (process characterization) reduces the number of input variables by identifying the keyinput variables or process conditions that affect product quality. This reductionallows focusing process improvement efforts on the few crucial variables. Screening may also suggest the "best" or optimal settings for these factors. Optimization experiments can then be done to determine the best settings. In industry, two-level full and fractional factorial designs and Plackett-Burman designs are often used to "screen" for the significant factors that influence process output measures or product quality. General full factorial designs (designs with more than two levels) may be used with small screening experiments.

3.3.1 Full factorial designs

In a complete factorial experiment, responses are measured at all combinations of the experimental factor levels. The combinations of factor levels represent the conditions at which responses will be measured. Each experimental condition is called a "run," and the response measurement an observation. The entire set of runs is the "design.

1(a) Two-level full factorial designs

In a two-level complete factorial design, each experimental factor hasonly two levels. The experimental runs include all combinations of these factorlevels. Although two- level factorial designs cannot fully explore a broad region in the factor space, they provide helpful information for relatively fewruns per factor. Because two-level factorials can indicate significant trends, which are used to provide direction for further experimentation.

1(b) General full factorial designs

In a general complete factorial design, the experimental factors can have any number of levels. For example, Factor A may have two levels, FactorB may have three levels, and Factor C may have five levels. The experimentalruns include all combinations of these factor levels. General full factorial designs may be used with small screening experiments or in optimization experiments.

3.3.2 Fractional factorial designs

In a full factorial experiment, responses are measured at all combinations of the factor levels, which may result in a prohibitive number ofruns. For example, a two-level full factorial design with 6 factors requires 64 runs; a design with 9 factors requires 512 runs.

To minimize time and cost, can use designs that exclude some of the factor level combinations. Factorial designs in which one or more level combinationsare excluded are called fractional factorial designs. Minitab generates two- level fractional factorial designs for up to 15 factors.

Fractional factorial designs are helpful in factor screening because they reducethe number of runs to a manageable size. The runs that are performed are a selected subset or fraction of the complete factorial design.

3.3.3 Plackett-Burman designs

Plackett-Burman designs are a class of resolution III, two-level fractional factorial designs often used to study the main effects. In a resolutionIII design, the main effects are aliased with two-way interactions. Minitab generates designs for up to 47 factors. Each design is based on the number ofruns, from 12 to 48, and is always a multiple of 4. The number of factors mustbe less than the number of runs.

3.4 Choosing a Factorial Design

The design, or layout, provides the specifications for each experimental run. It includes the blocking scheme, randomization, replication,and factor level combinations. This information defines the experimental conditions for each test run. While experimenting, need to measure the response(observation) at the predetermined settings of the experimental conditions. Each experimental condition that is employed to obtain a response measurement is a run. Minitab provides two-level full and fractional factorial designs, Plackett-Burman designs, and full factorials for more than two levels.

3.5 Design of Experiments

3.5.1 Creating Taguchi Design

Use Minitab's general full factorial design option when any factor has more than two levels. Using this can create designs with up to 15 factors. Each factormust have at least two levels, but not more than 100 levels.

To create a general full factorial design

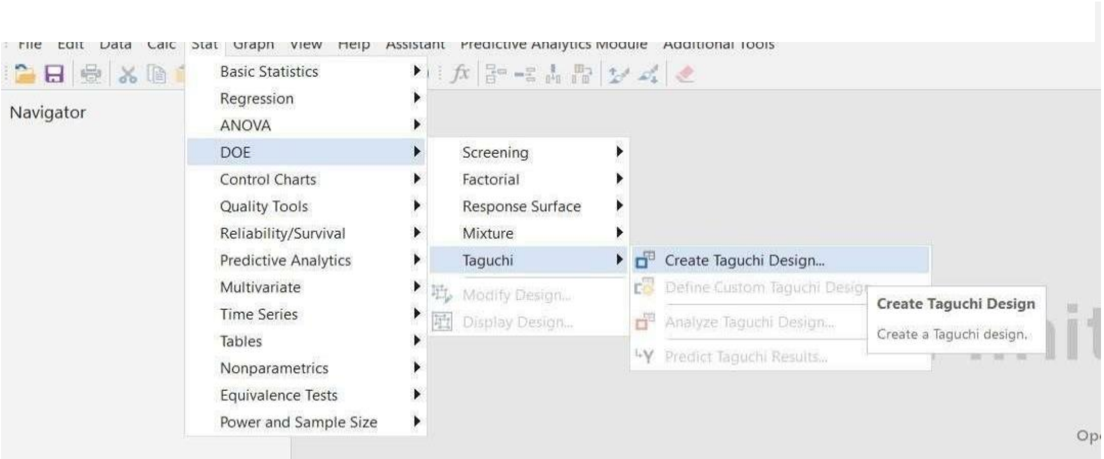


Figure 3.1 Creating a Taguchi design in Minitab

1. Choose Stat > DOE > Taguchi > Create Taguchi Design…

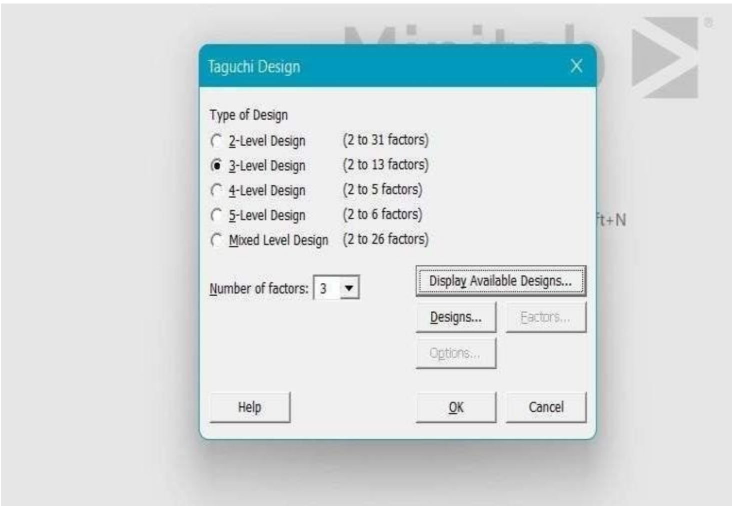


Figure 3.2 Selection of Factors & Levels

2. From the Number of factors, choose a number from 3.

3.Select the 3-level Design (2 to 13 Factors).

4. Now Click on Display Available Options.

5.Selection of Available Taguchi Designs in Minitab

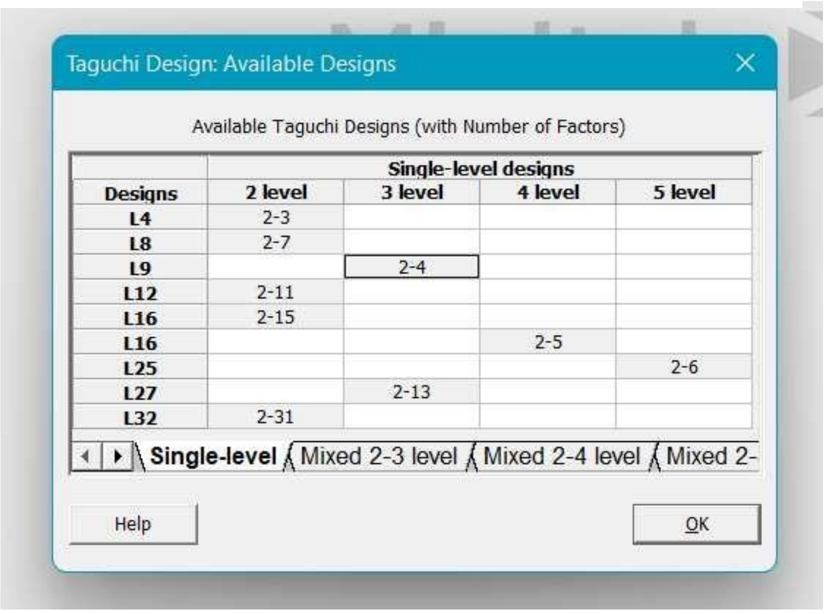


Figure 3.3 Selection of available Taguchi designs in mini tab

6.A window will appear showing all the available Taguchi Designs(with number of Factors)

7. Now Select 2-4 Design with 3 level L9 Orthogonal Arrayand Click OK.Figure 3. 4: Selection of Taguchi Design in Minitab.

8. Now Click on Display Available Options.

9.Selection of Available Taguchi Designs in Minitab

10.A window will appear showing all the available TaguchiDesigns (with number of Factors)

11. Now Select 2-4 Design with 3 level L9 Orthogonal Array and Click OK. Figure 3. 4: Selection of Taguchi Design in Minitab

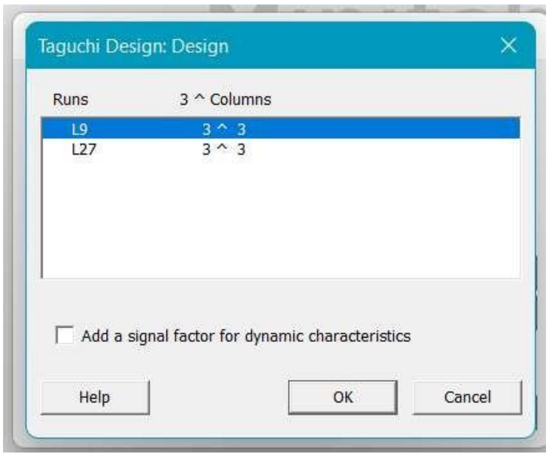


Figure 3.4 Selection of factors in mini tab

12. Now Click Designs and select L9 3 ^ 3, and click on OK

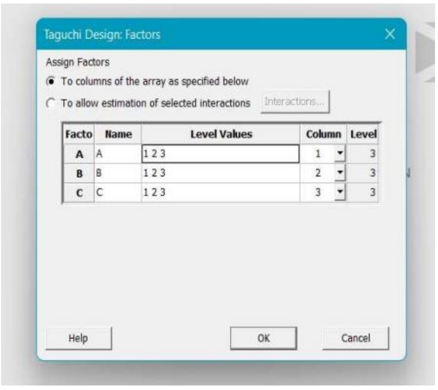


Figure 3.5 Taguchi Design: Factors in Minitab Values.

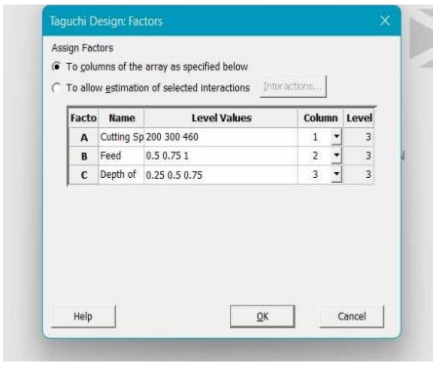


Figure 3.6 Input of the Factors and their Values.

13. Now Click Factors and a new window will appear showing the factors and their level values.

14. Double click on the Cells to edit and change the factors i.e., Factors A, B, C to Cutting Speed, Feed, Depth pf Cut.

15. Now double click on the Level Values cells to change the values andchange cutting speed values to 200 300 400, Feed to 0.5 0.75 1, Depth ofcut to 0.25 0.5 0.75. Now click OK.

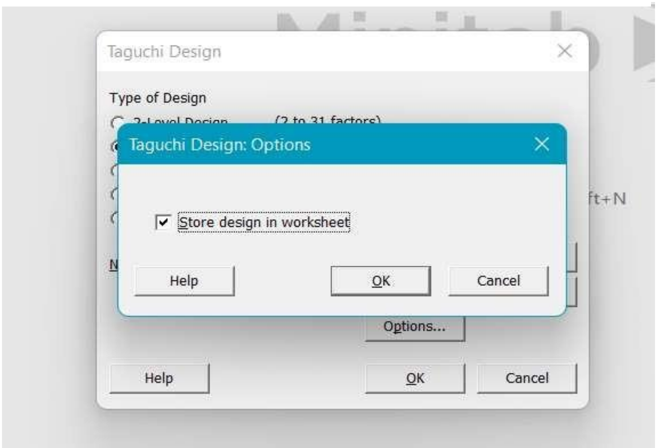


Figure 3.7 Storing the Design in Worksheet

16. New window will and select the check box and click OK.

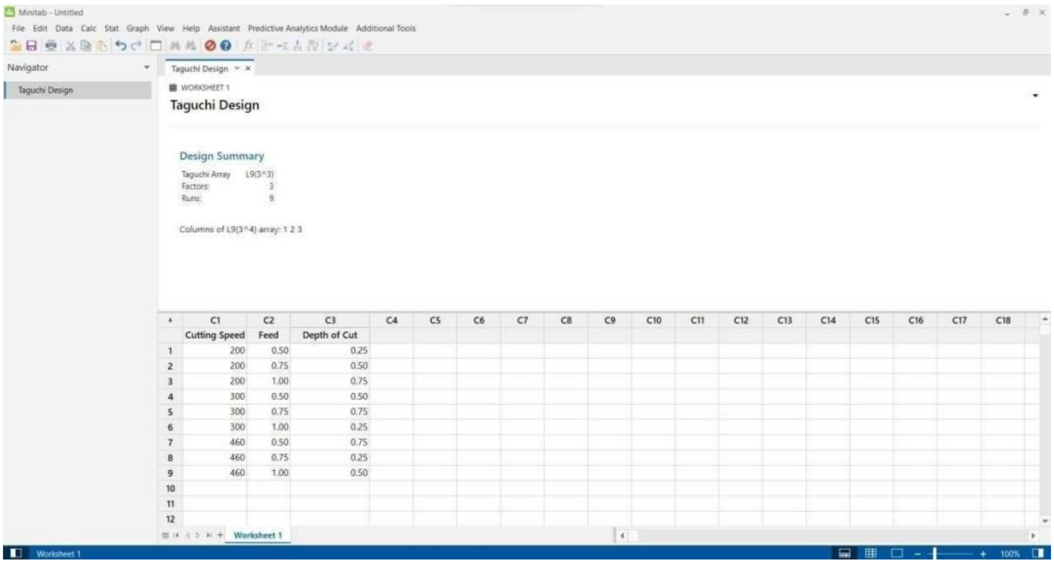


Figure 3. 8 Interface of the Minitab After Inputting the Values

CHAPTER 4

EXPERIMENTATION

The project was done in 3 stages.

- Design of experiments was done using the full factorial method.
- Forces calculated by Dynamometer and temperature readings machining the workpiece on lathe machine
- Analysis of results was done using MINITAB 17.1.30.
- Using the Topsis optimization technique for best results.

4.1 Selection of process variables

- A total of three process variables and three levels are selected for theexperimental procedure.

The deciding process variables are

- Speed
- Feed
- Depth of cut
- Speed of the spindle, i.e., the speed at which the spindle rotates the tool.
- Feed is the rate at which the material is removed from the work piece.
- Depth of cut is the depth up to which the tool is emerged in one cycle.

4.2 Selection of levels:

Since it is a three-level design by observing the parameters taken invarious projects, the levels of the factors are designed as follows

Table 4. 1 Selection of process variables

FACTORS	LEVEL 1	LEVEL 2	LEVEL 3
SPEED(RPM)	200	300	460
FEED(MM/REV)	0.5	0.75	1
D.O.C(MM)	0.2	0.4	0.6

4.3 Deign of Experiments:

Design of experiments was done using the Taguchi Design method.

Design of experiments (DOE) or experimental design is the design of any information-gathering exercises where variation is present, whether under thecomplete control of the experimenter or not.

4.4 Selection of material

Nickel aluminum bronze C95500 is a copper-based alloy that contains nickel, aluminum, iron, and manganese. It is known for its excellent mechanical properties, corrosion resistance, and wear resistance. Some of the important chemical properties of this alloy are:

- Copper Content: The copper content in C95500 alloy is typically around 78-82%.
- Nickel Content: The nickel content in this alloy ranges from 3.0% to 5.0%. Nickel provides excellent resistance to corrosion and improves the strength of the alloy.
- Aluminum Content: The aluminum content in C95500 alloy ranges from 8.0%to 10.0%. Aluminum enhances the strength and hardness of the alloy andimproves its corrosion resistance.
- Iron Content: The iron content in this alloy is usually between 3.0-5.0%. Iron isadded to the alloy to improve its wear resistance.
- Manganese Content: The manganese content in C95500 alloy is typically around 1.0-2.0%. Manganese improves the mechanical properties of the alloyand enhances its resistance to wear and fatigue.
- Other Elements: The alloy may also contain small amounts of other elementssuch as tin, lead, and zinc. These elements are added to the alloy to enhance specific properties.

Overall, nickel aluminum bronze C95500 is a high-strength, corrosion- resistant, and wear-resistant alloy that is widely used in marine, aerospace.

Table 4.2 Ni-Al-Br C95500 Composition

Element	Content (%)
Copper	78-82
Aluminum	8-10
Nickel	3-5
Iron	3-5
Manganese	1-2

4.5 Experimentation

1. The work piece is clamped to the machine by using standard 3 jaw chuck.;

Figure 4.1 Clamping of the work piece

Figure 4.2 Workpiece under turning operation

2. The tool used for turning is HSS. Initially this tool is fixed in the tool turret using tool holding fixture.

Figure 4.3 Apply cutting fluids during machining process

3. Connect the dynamometer to the system for digitalizing the graphs for various cutting forces.

4. After set all the arrangements we started the experimentation procedure.

5. Start the turning operation with specific speed, feed, and depth of cut.

6. We take three different factors for speed, feed, depth of cut and 9 levels for each oil by changing the factors of speed, feed, and depth of cut.

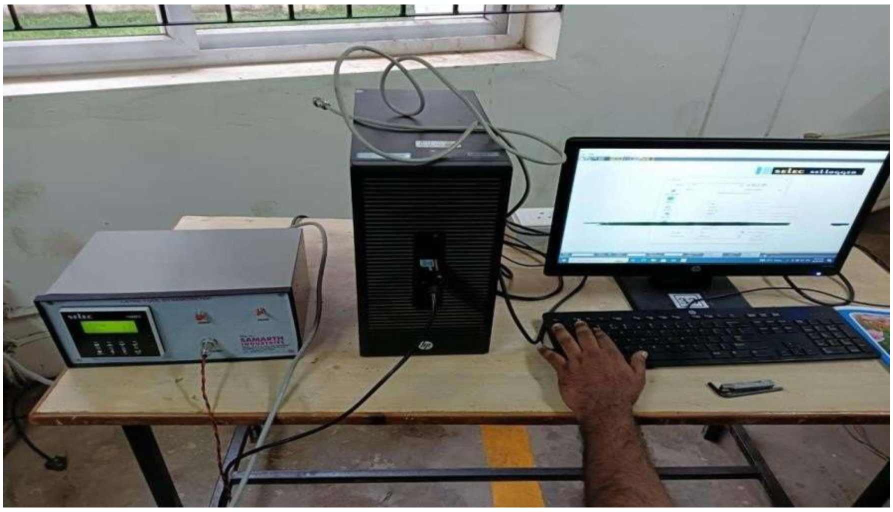


Figure 4.4 Taking readings from dynamometer

7. We conduct the same procedure for three oils and dry air lubrication.

8. We take the values of temperature, cutting forces and obtain the graphs at variousspeed, feed, and depth of cut.

9. We calculate the viscosity of the three different cutting oils at different temperature raises during machining of alloy.

10. Calculate the surface roughness of the machining part of specimen and note thevalues before and after machining of alloy specimen.

Figure 4. 5 Connecting the computer operating system to lathe machine.

Figure 4.6 sprayer for applying cutting fluids

4.6 Viscosity Role in Cutting Fluids

Cutting fluids are used in machining processes to lubricate the tool and workpiece interface, cool thecutting zone, and remove chips from the cutting zone. Viscosity is an important property of cutting fluids that plays a crucial role in their performance.

Viscosity is a measure of a fluid's resistance to flow. In cutting fluids, viscosity influences the fluid's ability to lubricate and cool the cutting zone. A fluid with high viscosity will resist flow and tend to cling to the surface, providing better lubrication and cooling. However, a fluid with too high viscositymay cause excessive drag, which can reduce the tool's cutting performance.

On the other hand, a fluid with low viscosity will flow more easily and may not provide enough lubrication and cooling, which can cause the tool to overheat and wear out quickly. Therefore, it isimportant to balance the viscosity of the cutting fluid to optimize its performance.

Different machining processes require different viscosity levels in cutting fluids. For example, high- speed machining typically requires a low-viscosity fluid to minimize drag, while drilling and tappingrequire a higher viscosity fluid to provide better lubrication.

In summary, the viscosity of cutting fluids is crucial to their ability to lubricate, cool, and remove chipsfrom the cutting zone. Balancing viscosity with other properties of the fluid can help optimize its performance for different machining processes.

7.3 Viscosity table for three different fluids

Temperature	Viscosity in (strokes)		
	oil 1(fine kut 56)	oil 2(xtraa coolant)	oil 3 (hydraulic oil)
27.5	3.1923	1.3199	3.6351
30	2.9216	1.2457	3.253
35	2.7001	1.1591	2.774
40	2.3801	1.0724	2.023
Average	2.7985	1.1993	2.9213

Figure 4.7 Redwood Viscometer 2

- It is used to find viscosity of three different cutting fluids.

4.7 MATERIAL REMOVAL RATE

Material removal rate (MRR) in turning operation refers to the volume of material removed from a workpiece per unit time during the turning process. It is usually measured in cubic millimeters per minute (mm^3/min) or cubic inches per minute(in^3/min).

The material removal rate is influenced by various factors such as the cutting speed, feed rate, depth of cut, and the material properties of both the workpieceand the cutting tool. Increasing any of these parameters usually leads to a higherMRR.

To calculate the material removal rate in turning, the following formula can beused:

MRR = π * (D/2) ^2 * V * f

Where:

D is the diameter of the workpieceV is the cutting speed

f is the feed rate

It's important to note that the actual material removal rate achieved in a turningoperation may differ from the calculated value due to factors such as tool wear, machine stability, and cutting conditions.

Table 4.4 Material Removal Rate for Nine experiments

Cutting Speed(m/min)	Feed(mm/rev)	Depth of Cut(mm)	MRR (mm3/min)
0.01884	0.5	0.2	6.65523
0.01884	0.75	0.4	9.982845
0.01884	1	0.6	13.31046
0.02826	0.5	0.4	9.9828
0.02826	0.75	0.6	14.9742
0.02826	1	0.2	19.9656
0.04332	0.5	0.6	15.3027
0.04332	0.75	0.2	22.9541
0.04332	1	0.4	30.6055

4.8 SURFACE ROUGHNESS

Surface roughness is often a good predictor of the performance of a mechanical component, since irregularities in the surface may form nucleation sites for cracks or corrosion. It is a measure of the texture of a surface. It is quantified by the vertical deviations of a real surface from its ideal form. If these deviations are large, the surface is rough. If small, the surface is smooth. The Surface Roughness is represented as Ra.

- Roughness Average, Ra, is the arithmetic average of the absolute values of the profileheights over the evaluation length.
- Maximum Height of the Profile, Rt the vertical distance between the highest and lowestpoints of the profile within the evaluation length.
- Average Maximum Height of the Profile, Rz is the average of the successive values of Rt calculated over the evaluation length.

Surface roughness tester

Surface roughness testers, also known as roughness gauges, are portable and have a stylus with a small, smooth contact point for tracing the surface of a work piece to measure minuteirregularities. It has probes that detects the surface roughness values and the surface measurements are displayed on the LCD screen such as Ra, Rt, and Rz. surface roughness tester

Figure 4.8 Surface Roughness Tester

Table 4.5 Surface roughness values for the material

S.NO	RA	RZ	RT
1	6.592	26.908	33.284
2	0.857	5.422	8.748
3	5.298	31.192	60.424

CHAPTER 5

RESULTS & DISCUSSIONS

5.1 TAGUCHI ANALYSIS

The main stage in the Taguchi approach to achieve high quality without raising cost is the optimization of process parameters. The best process variables are chosen not just to increase quality but also to be less sensitiveto changes in the environment and other noise-related factors. Basically, conventional process parameter design is difficult to utilize and is complex. When there are many process parameters, there must be many experiments performed. The Taguchi technique utilizes a unique design of orthogonal arrays to explore the full process parameter space with a minimal number ofexperiments in order to complete this objective. The difference between theexperimental value and the intended value is then determined using a loss function.

To measure the performance characteristic deviating from the desired value, Taguchi advises using the loss function. The loss function's result is subsequently converted into a signal-to-noise (S/N) ratio. The lower-the- better, higher-the-better, and nominal-the-better categories of performance characteristic are typically used in the examination of the S/N ratio. Based on the S/N analysis, the S/N ratio is calculated for each level of the processparameter. The higher S/N ratio equates to a better performance characteristic, regardless of the category of the performance characteristic. As a result, the level of a process parameter that has the largest S/N ratio isthe ideal level. This is accurate when only one performance attribute is being optimized.

But optimizing for numerous performance traits differs from optimizing for a single performance trait. A performance characteristic's higher S/N ratio can match an other performance characteristic's lower S/N ratio. In order to optimize a variety of performance aspects, the S/N ratio must be evaluated overall. To solve this problem, the grey relational analysis is adopted in thestudy.

In this project we take 3 parameters speed, feed, and depth of cut.

Table 5.1 values of speed, feed, depth of cut

Speed (rpm)	Feed (mm/rev)	Depth of Cut(in mm)
200	0.5	0.2
200	0.75	0.4
200	1	0.6
300	0.5	0.4
300	0.75	0.6
300	1	0.2
460	0.5	0.6
460	0.75	0.2
460	1	0.4

1. The values obtained from Dry Turning Operation by Dynamometer.

Table 5.2 Values of Dry turning operation

Speed (rpm)	Feed(mm/rev)	Depth of Cut(mm)	Cutting Force (Newtons)	Feed Force (Newtons)	Thrust Force (Newtons)
200	0.5	0.2	2	0	5
200	0.75	0.4	15	1	14
200	1	0.6	17	6	12
300	0.5	0.4	5	2	6
300	0.75	0.6	17	7	11
300	1	0.2	3	1	5
460	0.5	0.6	11	6	9
460	0.75	0.2	7	1	7
460	1	0.4	10	2	8

2. The values obtained by using Fine kut 56 cutting fluid used in Turning Operationby using Dynamometer.

Table 5.3 Values obtained by using Finekut 56 in turning operation

Speed (rpm)	Feed(mm /rev)	Depth of cut(mm)	Cutting Force (Newtons)	Feed Force (Newtons)	Thrust Force (Newtons)
200	0.5	0.2	6	2	7
200	0.75	0.4	10	4	9
200	1	0.6	17	6	10
300	0.5	0.4	8	4	5
300	0.75	0.6	16	5	8
300	1	0.2	6	1	5
460	0.5	0.6	11	5	7
460	0.75	0.2	5	1	5
460	1	0.4	11	2	9

3. The values obtained by using Hydraulic cutting fluid used in Turning Operationby using Dynamometer.

Table 5.4 Values obtained by using hydraulic oil in turning operation

Speed (rpm)	Feed(mm /rev)	Depth of Cut(mm)	Cutting Force (Newtons)	Feed Force (Newtons)	Thrust Force (Newtons)
200	0.5	0.2	4	1	7
200	0.75	0.4	8	1	5
200	1	0.6	16	6	8
300	0.5	0.4	11	5	8
300	0.75	0.6	19	6	11
300	1	0.2	7	1	2
460	0.5	0.6	13	6	8
460	0.75	0.2	6	1	6
460	1	0.4	14	3	11

4. The values obtained by using Xtraa Coolant cutting fluid used in TurningOperation by using Dynamometer.

Table 5.5 Values obtained by xtraa coolant oil in turning operation

Speed (rpm)	Feed(mm /rev)	Depth of Cut(mm)	Cutting Force (Newtons)	Feed Force (Newtons)	Thrust Force (Newtons)
200	0.5	0.2	6	2	11
200	0.75	0.4	10	3	9
200	1	0.6	17	5	11
300	0.5	0.4	8	4	5
300	0.75	0.6	16	5	7
300	1	0.2	6	1	3
460	0.5	0.6	11	5	5
460	0.75	0.2	6	1	5
460	1	0.4	13	4	8

5.3 ANALYZING TAGUCHI DESIGN IN MINITAB.

Step 1: Open the project file with the factors that are filled during the design ofexperiment process.

Step 2: Now fill the Performance indexes of both the Dry and Wet Turning Processthat are obtained from the TOPSIS method.

Step 3: Now open the Stat ribbon > DOE > Taguchi > Analyze Taguchi Design.

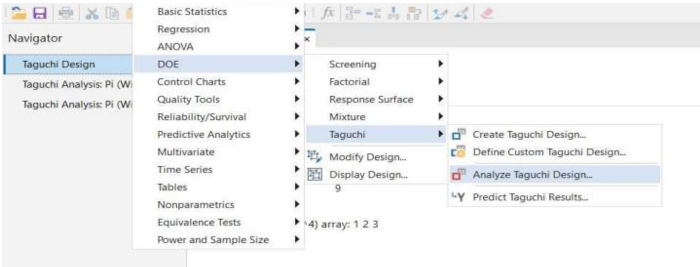


Figure 5.1 Analysis Process of Taguchi Design

Step 4: Now select one of the Performance Index and click on select.

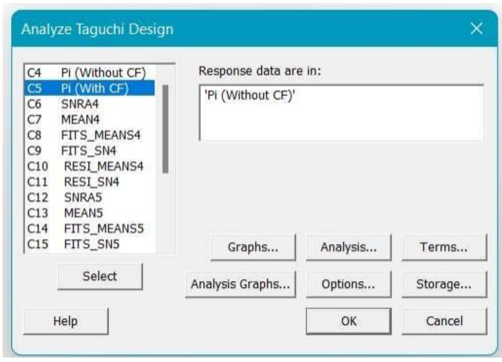


Figure 5.2 Selection of The Performance Characteristic

Step 5: Now select on the Options and select the Signal to Noise Ratio to Larger is Better and click OK.

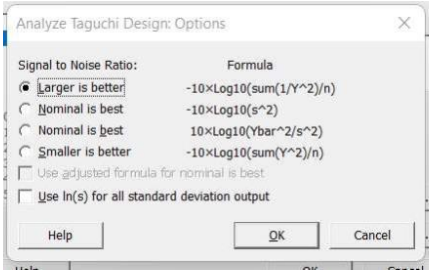


Figure 5.3 Selecting the Suitable S/N Ratio

Step 6: Now select on the Storage and select the Signal to Noise Ratios, Means, Fits,Residuals and click on OK.

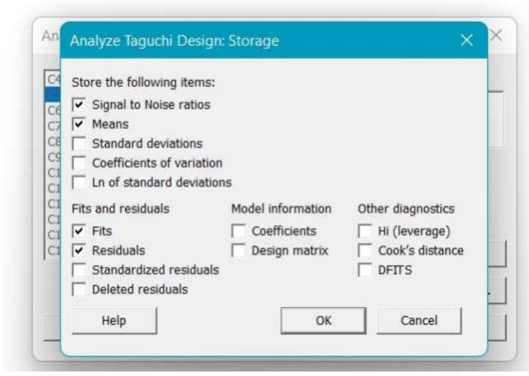


Figure 5.4 Selection of the Parameters to be Stored in the worksheet

Step 7: Now select on the Analysis of Graphs and select the Histogram, Normal Plot, Residual vs Fits and click on OK.

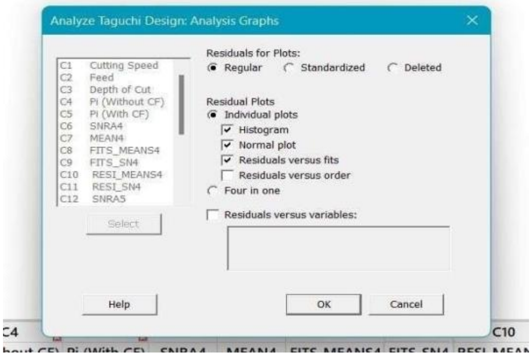


Figure 5. 4 Selection of the graphs to be obtained

TABLES AND GRAPHS

Taguchi Analysis: cutting force, feed force, thrust force versus speed, feed, depth of cut.

1. Dry Condition

Table 5.6 signal to noise ratio in dry condition

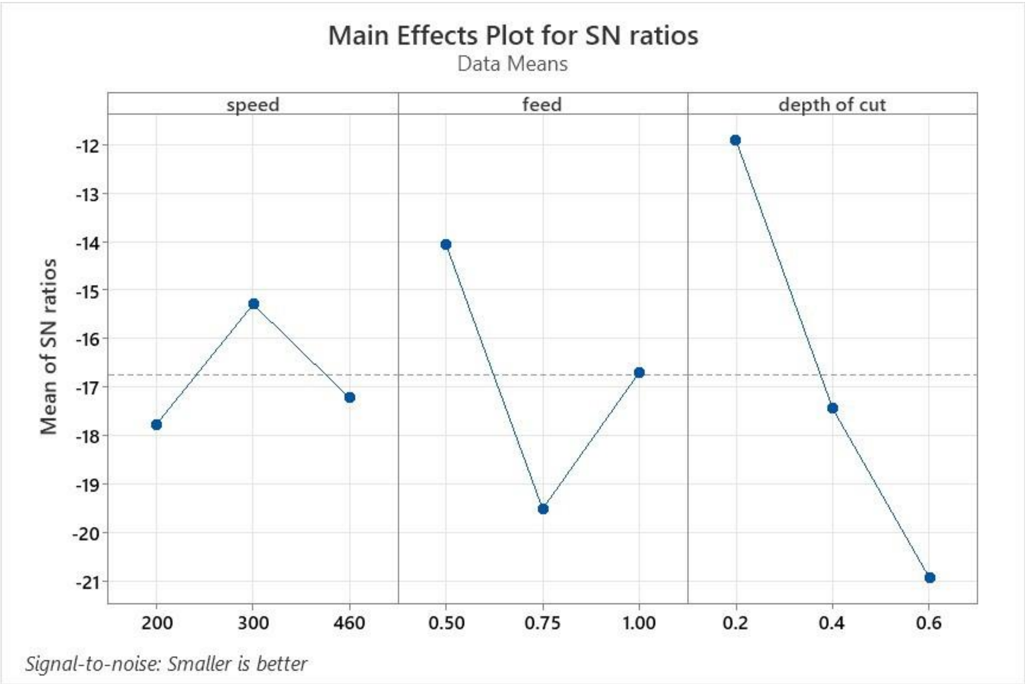
Speed (rpm)	Feed (mm/ rev)	Depth of Cut(mm)	CuttingForce (N)	Feed Force(N)	ThrustForce (N)	SNRA1	MEAN1
200	0.5	0.2	2	0	5	-9.85277	2.333333
200	0.75	0.4	15	1	14	-21.4819	10
200	1	0.6	17	6	12	-21.9405	11.66667
300	0.5	0.4	5	2	6	-13.3579	4.333333
300	0.75	0.6	17	7	11	-21.8469	11.66667
300	1	0.2	3	1	5	-10.6695	3
460	0.5	0.6	11	6	9	-18.9946	8.666667
460	0.75	0.2	7	1	7	-15.1851	5
460	1	0.4	10	2	8	-17.4819	6.666667

Table 5.7 Response Table for Signal to Noise Ratios

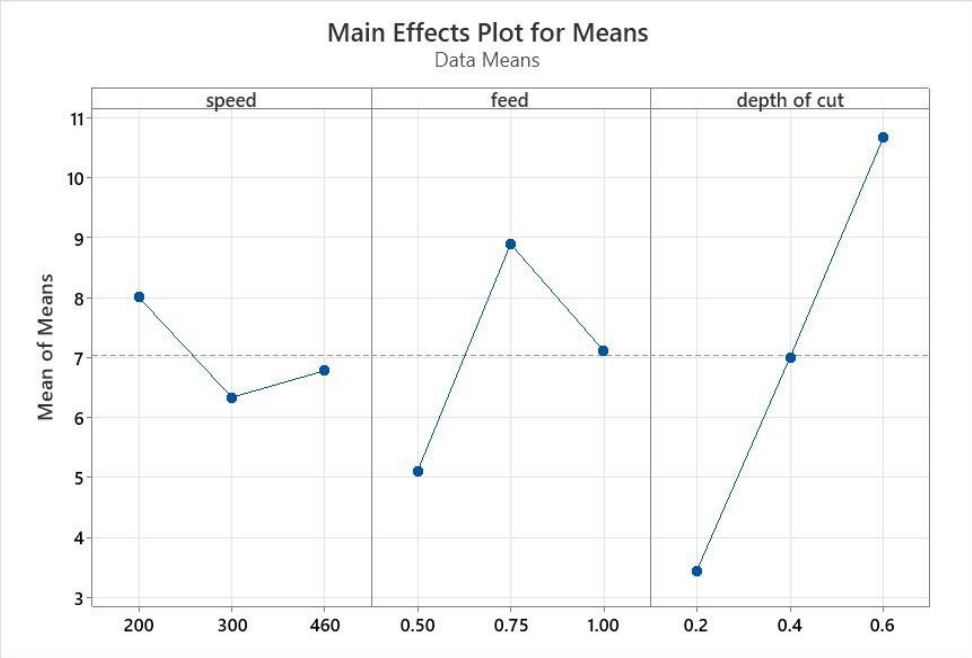
Level	Speed (rpm)	Feed (mm/rev)	Depth of Cut (mm)
1	-17.76	-14.07	-11.9
2	-15.29	-19.5	-17.44
3	-17.22	-16.7	-20.93
Delta	2.47	5.44	9.02
Rank	3	2	1

Table 5.8 Response Table for Means

Level	Speed (rpm)	Feed(mm/rev)	Depth of Cut (mm)
1	8	5.111	3.444
2	6.333	8.889	7
3	6.778	7.111	10.667
Delta	1.667	3.778	7.222
Rank	3	2	1



Graph 1 Main Effects plot for SN ratios Dry turning



Graph 2 Main Effect plot for means Dry condition

2. Usage of Fine Kut 56 cutting fluid in Machining

Table 5.9 Signal to noise ratio in usage of fine kut 56

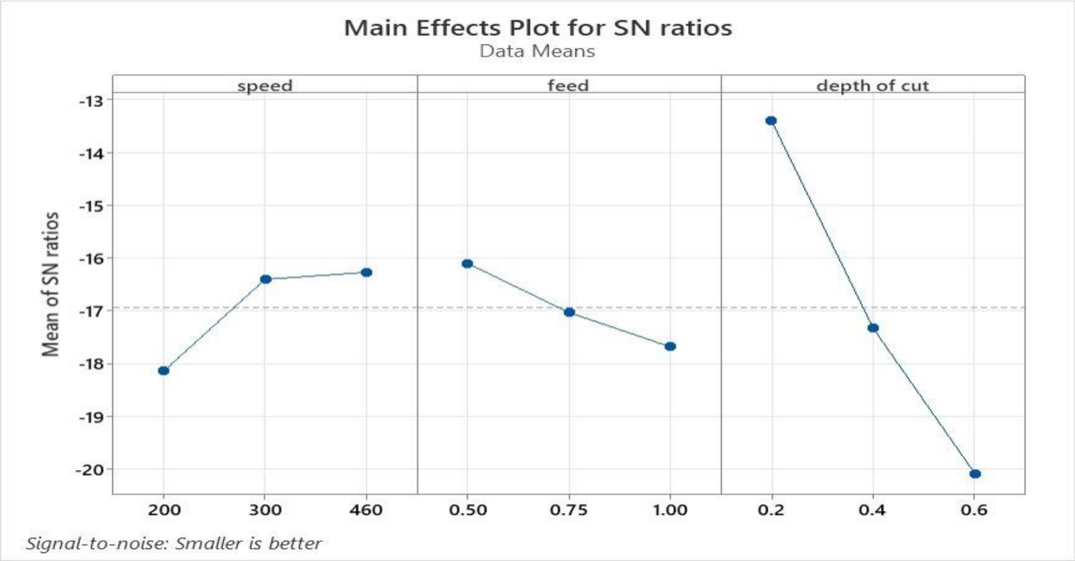
Speed (rpm)	Feed (mm /rev)	Depth of Cut (mm)	Cutting Force (N)	Feed Force (N)	ThrustForce (N)	SNRA2	MEAN2
200	0.5	0.2	6	2	7	-14.723	5
200	0.75	0.4	10	4	9	-18.173	7.66667
200	1	0.6	17	6	10	-21.513	11
300	0.5	0.4	8	4	5	-15.441	5.66667
300	0.75	0.6	16	5	8	-20.607	9.66667
300	1	0.2	6	1	5	-13.153	4
460	0.5	0.6	11	5	7	-18.129	7.66667
460	0.75	0.2	5	1	5	-12.304	3.66667
460	1	0.4	11	2	9	-18.367	7.33333

Table 5.10 Response Table for Signal to Noise Ratios

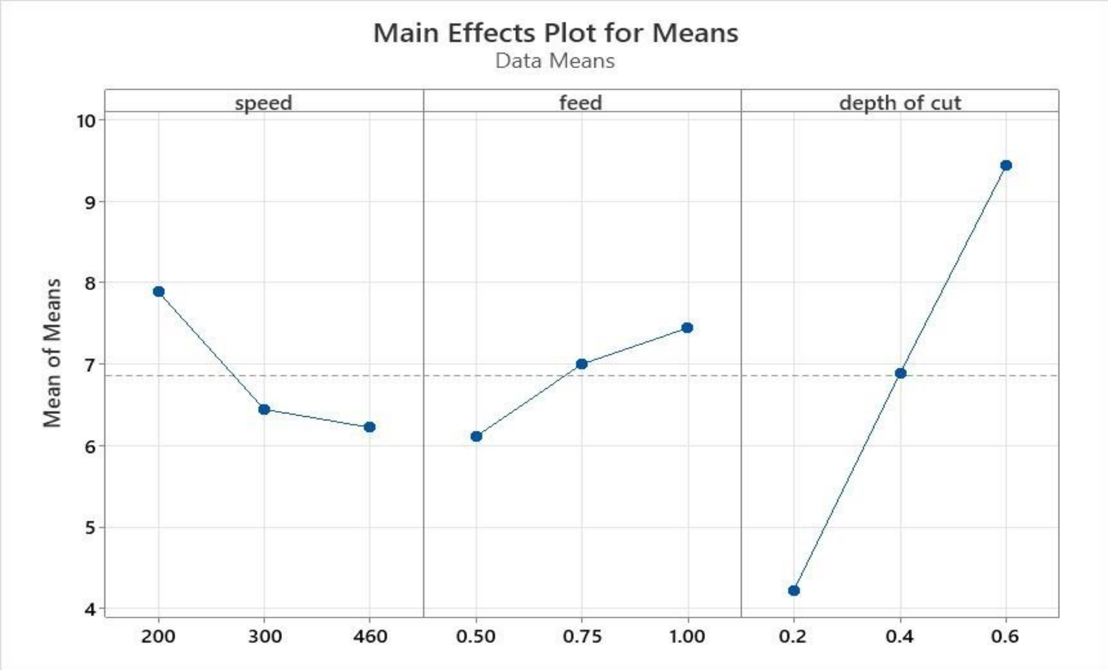
Level	Speed (rpm)	Feed(mm/rev)	Depth of Cut (mm)
1	-18.14	-16.1	-13.39
2	-16.4	-17.03	-17.33
3	-16.27	-17.68	-20.08
Delta	1.87	1.58	6.69
Rank	2	3	1

5.11 Response Table for Means

Level	Speed (rpm)	Feed (mm /rev)	Depth of Cut (mm)
1	7.889	6.111	4.222
2	6.444	7	6.889
3	6.222	7.444	9.444
Delta	1.667	1.333	5.222
Rank	2	3	1



Graph 3 Main Effects plot for SN ratios Finekut 56



Graph 4 Main Effects plot for means Finekut 56

3. Usage of Hydraulic Oil Cutting fluid in Machining

Table 5.12 Signal to noise in usage of hydraulic oil

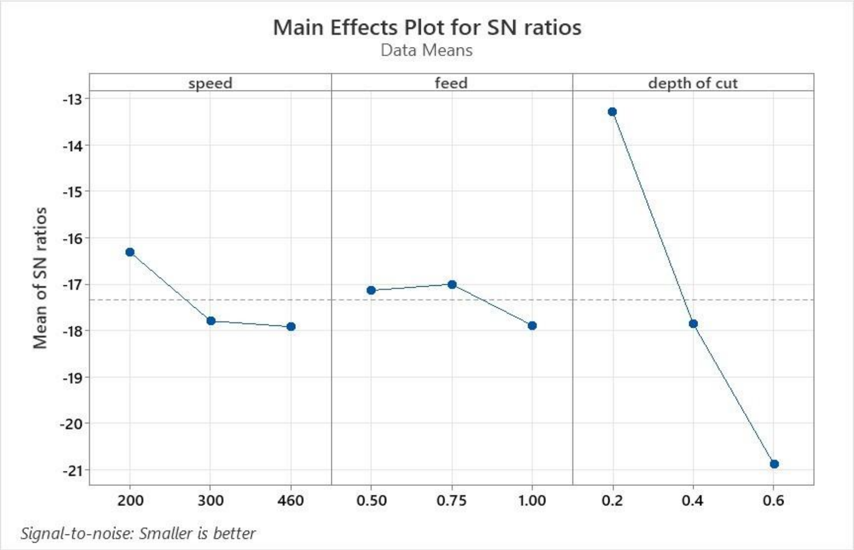
Speed (rpm)	Feed (mm /rev)	Depth ofCut (mm)	Cutting force (N)	Feed Force (N)	ThrustForce (N)	SNRA3	MEAN3
200	0.5	0.2	4	1	7	-13.424	4
200	0.75	0.4	8	1	5	-14.771	4.66667
200	1	0.6	16	6	8	-20.743	10
300	0.5	0.4	11	5	8	-18.451	8
300	0.75	0.6	19	6	11	-22.372	12
300	1	0.2	7	1	2	-12.553	3.33333
460	0.5	0.6	13	6	8	-19.526	9
460	0.75	0.2	6	1	6	-13.862	4.33333
460	1	0.4	14	3	11	-20.361	9.33333

5.13 Response Table for Signal to Noise Ratios

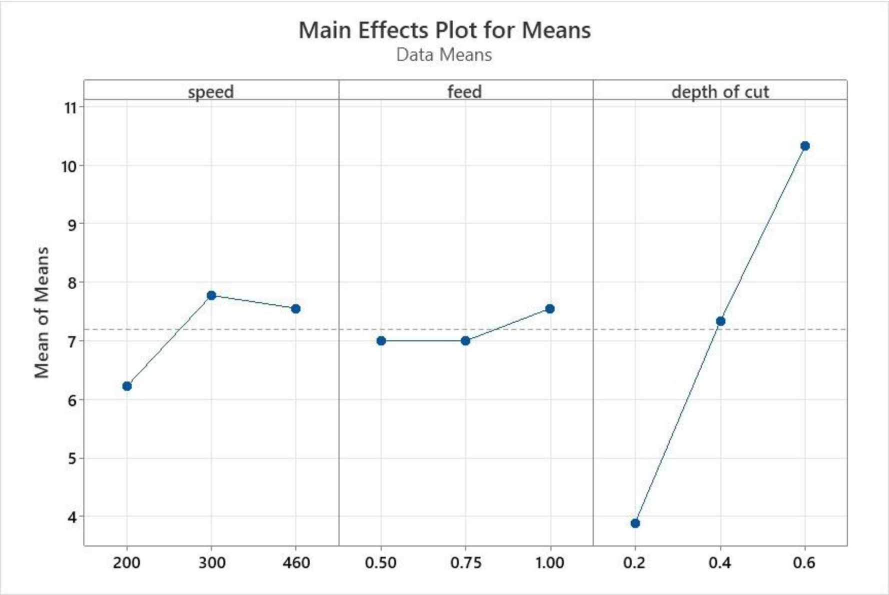
Level	Speed (rpm)	Feed (mm/rev)	Depth of Cut (mm)
1	-16.31	-17.13	-13.28
2	-17.79	-17	-17.86
3	-17.92	-17.89	-20.88
Delta	1.6	0.88	7.6
Rank	2	3	1

Table 5 .14 response for signal to noise ratio

Level	Speed (rpm)	Feed (mm/rev)	Depth of Cut (mm)
1	6.222	7	3.889
2	7.778	7	7.333
3	7.556	7.556	10.333
Delta	1.556	0.556	6.444



Graph 5 Main Effects plot for SN ratios Hydraulic oil



Graph 6 Main Effects plot for means Hydraulic oil

4. Usage of Xtraa Coolant Oil Cutting fluid in Machining

Table 5.15 Signal to noise ratio in usage of xtraa coolant oil

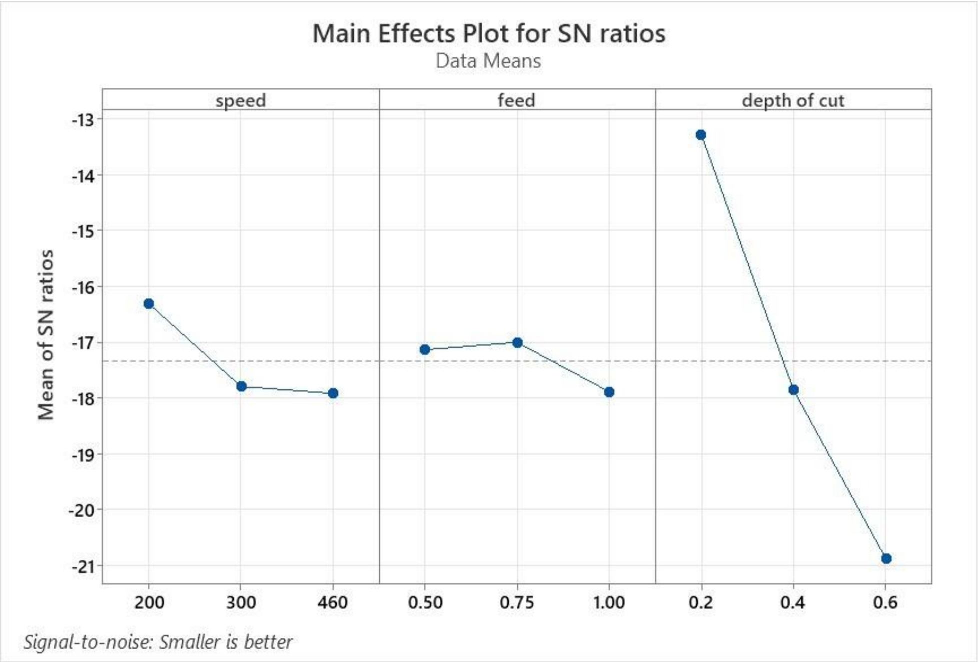
Speed (rpm)	Feed (mm /rev)	Depth of Cut (mm)	Cutting Force (N)	Feed Force (N)	Thrust Force (N)	SNRA4	MEAN4
200	0.5	0.2	6	2	11	-17.297	6.33333
200	0.75	0.4	10	3	9	-18.016	7.33333
200	1	0.6	17	5	11	-21.614	11
300	0.5	0.4	8	4	5	-15.441	5.66667
300	0.75	0.6	16	5	7	-20.414	9.33333
300	1	0.2	6	1	3	-11.856	3.33333
460	0.5	0.6	11	5	5	-17.559	7
460	0.75	0.2	6	1	5	-13.153	4
460	1	0.4	13	4	8	-19.191	8.33333

Table 5.16 Response Table for Signal to Noise Ratios

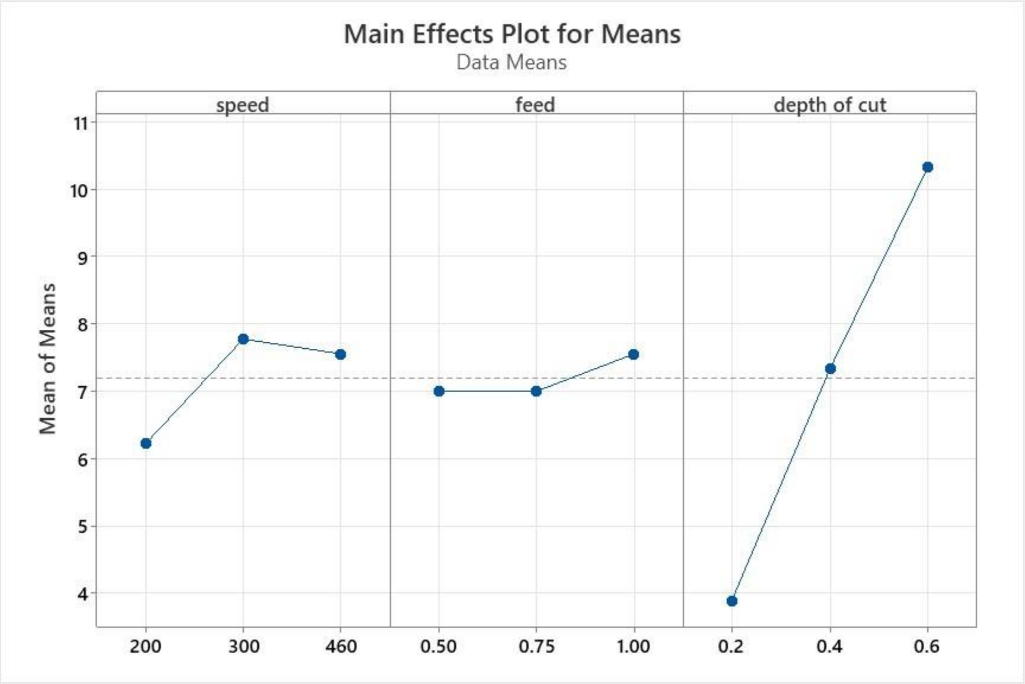
Level	Speed (rpm)	Feed (mm/rev)	Depth of Cut (mm)
1	-18.98	-16.77	-14.1
2	-15.9	-17.19	-17.55
3	-16.63	-17.55	-19.86
Delta	3.07	0.79	5.76
Rank	2	3	1

Table 5.17 Response Table for Means

Level	Speed (rpm)	Feed(mm/rev)	Depth of Cut (mm)
1	8.222	6.333	4.556
2	6.111	6.889	7.111
3	6.444	7.556	9.111
Delta	2.111	1.222	4.556
Rank	2	3	1



Graph 7 Main Effects plot for SN ratios coolant oil



Graph 8 Main Effects Plot for means coolant oil

5.2 Topsis analysis

1.Dry condition

1. Create a matrix consisting of M alternatives and N criteria. This matrix is usually called an "evaluation matrix" $(a_{ij})_{M \times N}$

Table 5.18 The values obtained from dry turning operation

	Non Benf	Benf	Benf
weightage	0.3	0.35	0.35
	Cutting force	Thrust force	Feed force
Expt 1	2	5	0
Expt 2	15	14	1
Expt 3	17	12	6
Expt 4	5	6	2
Expt 5	17	11	7
Expt 6	3	5	1
Expt 7	11	9	6
Expt 8	7	7	1
Expt 9	10	8	2

2.Normalize evaluation matrix:

$$\alpha_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{M}(a_{ij})^2}}$$

Table 5.19 Normalized Matrix of cutting force, Thrust force, Feed force

	Cutting force	Thrust force	Feed force
Expt 1	0.060003	0.18367959	0
Expt 2	0.450022502	0.514302851	0.087038828
Expt 3	0.510025502	0.440831015	0.522232968
Expt 4	0.150007501	0.220415508	0.174077656
Expt 5	0.510025502	0.404095097	0.609271796
Expt 6	0.0900045	0.18367959	0.087038828
Expt 7	0.330016501	0.330623261	0.522232968
Expt 8	0.210010501	0.257151425	0.087038828
Expt 9	0.300015001	0.293887343	0.174077656

3.Calculate the weighted normalized decision matrix. It is important to note that each criterion should have its own weight so that all of them will sum up to 1. The weightscan be derived randomly (not recommended) or based on expert knowledge (industry standard).

$$\chi_{ij} = \alpha_{ij} * \omega_j$$

Table 5.20 Weighted Matrix

	Cutting force	Thrust force	Feed force	SI +	SI-	PI	RANK
Expt 1	0.0180009	0.064287856	0	0.030464	0.267957	0.897917	2
Expt 2	0.135006751	0.180005998	0.03046359	0.164563	0.185457	0.529847	6
Expt 3	0.153007651	0.154290855	0.182781539	0.222549	0.030464	0.120403	9
Expt 4	0.04500225	0.077145428	0.06092718	0.04269	0.202033	0.825559	3
Expt 5	0.153007651	0.141433284	0.213245129	0.239974	0.012858	0.050854	7
Expt 6	0.02700135	0.064287856	0.03046359	0.009	0.239556	0.963789	1
Expt 7	0.09900495	0.115718141	0.182781539	0.180021	0.073022	0.288575	8
Expt 8	0.06300315	0.090002999	0.03046359	0.051831	0.213642	0.804759	4
Expt 9	0.0900045	0.10286057	0.06092718	0.08718	0.172671	0.664499	5

4.Determine the best and the worst alternative for each criterion:

$$\chi_j^b = \max_{i=1}^{M} \chi_{ij}$$

$$\chi_j^w = \min_{i=1}^{M} \chi_{ij}$$

Table 5.21 The Best and Worst Alternative for Each Criterion

V +	0.0180009	0.06428786
V_	0.15300765	0.15429086

According to the TOPSIS analysis, the best result among the nine experiments was achieved during experiment 6, where a dry condition was used.

1.Finekut 56

1. Create a matrix consisting of M alternatives and N criteria. This matrix is usually called an "evaluation matrix" $(a_{ij})_{M \times N}$

Table 5.22 The values obtained from Finekut 56

weightage	Non Benf	Benf	Benf
	0.3	0.35	0.35
	Cutting force	Thrust force	Feed force
Expt 1	6	7	2
Expt 2	10	9	4
Expt 3	17	10	6
Expt 4	8	5	4
Expt 5	16	8	5
Expt 6	6	5	1
Expt 7	11	7	5
Expt 8	5	5	1
Expt 9	11	9	2

2.Normalize evaluation matrix:

$$\alpha_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{M}(a_{ij})^2}}$$

Table 5.23: Normalized Matrix of cutting force, Thrust force, Feed force

	Cutting force	Thrust force	Feed force
Expt 1	0.185340619	0.313363037	0.015625
Expt 2	0.308901032	0.402895333	0.353553391
Expt 3	0.525131754	0.447661481	0.530330086
Expt 4	0.247120825	0.223830741	0.353553391
Expt 5	0.494241651	0.358129185	0.441941738
Expt 6	0.185340619	0.223830741	0.088388348
Expt 7	0.339791135	0.313363037	0.441941738
Expt 8	0.154450516	0.223830741	0.088388348
Expt 9	0.339791135	0.402895333	0.176776695

3.Calculate the weighted normalized decision matrix. It is important to note that each criterion should have its own weight so that all of them will sum up to 1. The weightscan be derived randomly (not recommended) or based on expert knowledge (industry standard).

$$\chi_{ij} = \alpha_{ij} * \omega_j$$

Table 5.24 Weighted Matrix

	Cutting force	Thrust force	Feed force	SI +	SI-	PI	RANK
Expt 1	0.055602186	0.109677063	0.00546875	0.03268	0.21226	0.86659	3
Expt 2	0.092670309	0.141013367	0.123743687	0.14165	0.091	0.39116	6
Expt 3	0.157539526	0.156681518	0.18561553	0.22574	3E-08	1.3E-07	9
Expt 4	0.074136248	0.078340759	0.123743687	0.1215	0.13008	0.51706	5
Expt 5	0.148272495	0.125345215	0.154679608	0.18672	0.045	0.19419	8
Expt 6	0.055602186	0.078340759	0.030935922	0.0271	0.20113	0.88126	2
Expt 7	0.10193734	0.109677063	0.154679608	0.16229	0.07911	0.32771	7
Expt 8	0.046335155	0.078340759	0.030935922	0.02547	0.20598	0.88997	1
Expt 9	0.10193734	0.141013367	0.061871843	0.101	0.13656	0.57485	4

4.Determine the best and the worst alternative for each criterion:

$$\chi_j^b = \max_{i=1}^{M} \chi_{ij}$$

$$\chi_j^w = \min_{i=1}^{M} \chi_{ij}$$

Table 5.25 The Best and Worst Alternative for Each Criterion

V +	0.04633515	0.07834076	0.0054688
V_	0.15753953	0.15668152	0.1856155

Based on the TOPSIS analysis, it was found that the usage of Finekut 56 as a cutting fluid resulted in the best outcome during experiment 8, out of the total nine experiments conducted.

2.Hydraulic oil

1. Create a matrix consisting of M alternatives and N criteria. This matrix is usually called

an “evaluation matrix” $(a_{ij})_{M \times N}$

Table 5.26 The values obtained from usage of hydraulic oil as cutting fluid

	Non Benf	Benf	Benf
weightage	0.3	0.35	0.35
	Cutting force	thrust force	feed force
Expt 1	4	7	1
Expt 2	8	5	1
Expt 3	16	8	6
Expt 4	11	8	5
Expt 5	19	11	6
Expt 6	7	2	1
Expt 7	13	8	6
Expt 8	6	6	1
Expt 9	14	11	3

2.Normalize evaluation matrix:

$$\alpha_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{M} (a_{ij})^2}}$$

Table 5.27 Normalized Matrix of cutting force, Thrust force, Feed force

	Cutting force	Thrust force	Feed force
Expt 1	0.112331191	0.29902518	0.006849315
Expt 2	0.224662383	0.213589414	0.082760589
Expt 3	0.449324765	0.341743063	0.496563533
Expt 4	0.308910776	0.341743063	0.413802944
Expt 5	0.533573158	0.469896712	0.496563533
Expt 6	0.196579585	0.085435766	0.082760589
Expt 7	0.365076372	0.341743063	0.496563533
Expt 8	0.168496787	0.256307297	0.082760589
Expt 9	0.393159169	0.469896712	0.248281767

3.Calculate the weighted normalized decision matrix. It is important to note that each criterion should have its own weight so that all of them will sum up to 1. The weightscan be derived randomly (not recommended) or based on expert knowledge (industry standard).

$$\chi_{ij} = \alpha_{ij} * \omega_j$$

Table 5.28 Weighted Matrix

	Cutting force	Trust force	Feed force	SI +	SI-	PI	RANK
Expt 1	0.033699357	0.104658813	0.00239726	0.07476	0.22119	0.7474	3
Expt 2	0.067398715	0.074756295	0.028966206	0.06208	0.19394	0.75753	2
Expt 3	0.13479743	0.119610072	0.173797237	0.21828	0.05148	0.19085	8
Expt 4	0.092673233	0.119610072	0.144831031	0.17836	0.08599	0.32528	6
Expt 5	0.160071948	0.164463849	0.173797237	0.2519	3.7E-08	1.5E-07	9
Expt 6	0.058973875	0.029902518	0.028966206	0.03667	0.22204	0.85826	1
Expt 7	0.109522911	0.119610072	0.173797237	0.20778	0.06758	0.24542	7
Expt 8	0.050549036	0.089707554	0.028966206	0.06758	0.19637	0.74398	4
Expt 9	0.117947751	0.164463849	0.086898618	0.17985	0.09657	0.34936	5

4. Determine the best and the worst alternative for each criterion:

$$\chi_j^b = \max_{i=1}^{M} \chi_{ij}$$

$$\chi_j^w = \min_{i=1}^{M} \chi_{ij}$$

Table 5.29 The Best and Worst Alternative for Each Criterion

V +	0.03369936	0.02990252	0.0023973
V_	0.16007195	0.16446385	0.1737972

Based on the TOPSIS analysis, it was found that the usage of Hydraulic oil as a cutting fluid resulted in the best outcome during experiment 6, out of the total nine experiments conducted.

3.Xtraa coolant oil

1. Create a matrix consisting of M alternatives and N criteria. This matrix is usually called an "evaluation matrix" $(a_{ij})_{M \times N}$

Table 5.30 The values obtained from usage of Xtraa coolant oil as cutting fluid

	Non Benf	Benf	Benf
weightage	0.3	0.35	0.35
	Cutting force	Thrust force	Feed force
Expt 1	6	11	2
Expt 2	10	9	3
Expt 3	17	11	5
Expt 4	8	5	4
Expt 5	16	7	5
Expt 6	6	3	1
Expt 7	11	5	5
Expt 8	6	5	1
Expt 9	13	8	4

2.Normalize evaluation matrix:

$$\alpha_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{M}(a_{ij})^2}}$$

Table 5.31 Normalized Matrix of cutting force, Thrust force, Feed force

	Cutting force	Thrust force	Feed force
Expt 1	0.180333927	0.482381911	0.016393443
Expt 2	0.300556545	0.394676109	0.271607238
Expt 3	0.510946126	0.482381911	0.45267873
Expt 4	0.240445236	0.219264505	0.362142984
Expt 5	0.480890472	0.306970307	0.45267873
Expt 6	0.180333927	0.131558703	0.090535746
Expt 7	0.330612199	0.219264505	0.45267873
Expt 8	0.180333927	0.219264505	0.090535746
Expt 9	0.390723508	0.350823208	0.362142984

3.Calculate the weighted normalized decision matrix. It is important to note that each criterion should have its own weight so that all of them will sum up to 1. The weightscan be derived randomly (not recommended) or based on expert knowledge (industry standard).

$$\chi_{ij} = \alpha_{ij} * \omega_j$$

Table 5.32 Weighted Matrix

	Cutting force	Thrust force	Feed force	SI +	SI-	PI	RANK
Expt 1	0.054100178	0.168833669	0.005737705	0.12279	0.18208	0.59725	3
Expt 2	0.090166963	0.138136638	0.095062533	0.13327	0.09456	0.41506	5
Expt 3	0.153283838	0.168833669	0.158437556	0.21962	4.4E-08	2E-07	9
Expt 4	0.072133571	0.076742577	0.126750044	0.12614	0.12677	0.50124	4
Expt 5	0.144267142	0.107439607	0.158437556	0.18766	0.06205	0.2485	8
Expt 6	0.054100178	0.046045546	0.031687511	0.02595	0.20243	0.88638	1
Expt 7	0.09918366	0.076742577	0.158437556	0.16215	0.10681	0.39712	6
Expt 8	0.054100178	0.076742577	0.031687511	0.0402	0.18543	0.82185	2
Expt 9	0.117217053	0.122788123	0.126750044	0.15658	0.06652	0.29817	7

4.Determine the best and the worst alternative for each criterion:

$$\chi_j^b = \max_{i=1}^{M} \chi_{ij}$$

$$\chi_j^w = \min_{i=1}^{M} \chi_{ij}$$

Table 5.33 The Best and Worst Alternative for Each Criterion

V +	0.05410018	0.04604555	0.0057377
V_	0.15328384	0.16883367	0.1584376

Based on the TOPSIS analysis, it was found that the usage of Xtraa coolant oil as a cutting fluid resulted in the best outcome during experiment 6, out of the total nine experiments conducted

CHAPTER 6

CONCLUSION

In this paper, cutting fluids can help improve the efficiency and quality of the machining process by reducing heat and friction, preventing tool wear, and improving surface finish. The main intention of the project is to use high alloy material Ni-Al-Br (C95500) effectively in various industries. However, the machining of this high alloy material generates more heat and leads to uneven distribution of cutting forces and increase the cost of manufacturing. Hence, with in this study three different cutting fluids are considered and evaluated the performance using lathe tool dynamometer set up.Two optimization methods (Taguchi and Topsis) are used for prediction of the most influencing parameter for achieving lower cutting force, temperatures and good surface finish.

The best experiment from the study is obtained by Topsis analysis for three types of cutting fluids (Finekut 56, hydraulic oil, xtraa coolant oil). From the optimization in Taguchi, we conclude that depth of cut plays a major role in turning operation.

After performing Topsis optimization technique, it was noticed that under dry condition and using hydraulic oil, and extra coolant oil during machining, the experiment number 6 (speed 300 rpm, feed 1mm/rev, depth of cut 0.2 mm) exhibited best results. However, the best result was obtained after using Finekut 56 as a lubricating oil, with a cutting speed of 460 rpm, a feed rate of 0.75mm/rev, and a depth of cut of 0.2mm for experiment number 8. This was in comparison with dry condition state hydraulic and Xtraa coolant oils. In overall comparison, we noticed Fine cut 56 oil exhibited better results for reduction of cutting forces and exhibiting good surface finish. Therefore, we suggest to use finekut 56 as a cutting fluid for machining of Ni-Al-Br alloy in industrial applications.

FUTURE SCOPE

Studying the effect of other machining operations: Turning is just one type of machining operation. We could explore the effect of cutting fluids on other machining operations, such as drilling, milling, or grinding. By studying the effect of cutting fluids on a variety of machining operations, we can gain a more comprehensive understanding of their performance and incorporating nano particles in conventional cutting fluids to get best results in machining.

Studying the effect of cutting fluids on other materials: Nickel aluminum bronze C95500 alloy is just one material that can be machined. We could study the effect of cutting fluids on other high alloy materials used in industrial applications.By studying the effect of cutting fluids on a variety of materials, you can gain a more comprehensive understanding of their performance.

Investigating the effect of using multiple cutting fluids: Instead of using just one cutting fluid, we could explore the effect of using multiple cutting fluids in combination. By using multiple cutting fluids, we may be able to achieve better results than with just one cutting fluid.

Investigation of other cutting fluids: In our project, we are using three different cutting fluids. However, there are many other cutting fluids available in the market that can be used for turning operations of nickel aluminum bronze C95500 alloy. You can investigate the effect of other cutting fluids on cutting forces and compare their performance with the cutting fluids used in our project.

Application of other multi-criteria decision-making methods: In our project, we are using TOPSIS method for evaluating the relative performance of cutting fluids. However, there are many other multi-criteria decision-making methods available such as Analytic Hierarchy Process (AHP), Grey Relational Analysis (GRA), and Decision-Making Trial and Evaluation Laboratory (DEMATEL). We can compare the performance of these methods with TOPSIS and select the most appropriate method for our application.

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