PERFORMANCE EVALUATION OF GREEN FLUID USING MQL TECHNIQUE IN HARD TURNING OF HARD MATERIAL

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 **"Performance Evaluation of Green Fluids using MQL technique in Hard turning of hard material** "being submitted by **M. Sai Sampath (319126520024), S. Uma Shankar (319126520049), K. Likitha Sravani (319126520018), N. Mohan (319126520026), V. David (319126520059)** tothe Department of Mechanical Engineering, ANITS is a record of the bonafide work carried out by them under the esteemed guidance of **Mr.R.D.V.Prasad.** 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

There is a growing demand for renewable and biodegradable cutting fluids in response to environmental concerns and stricter regulations on contamination and pollution. The aim of this effort is to achieve "green machining" by considering the type of cutting fluid used and the methods for applying it during the machining process. The heat generated by friction at the tool chip interface and between the tool clearance face and the workpiece is a key factor in determining surface quality. A thorough understanding of cutting fluid application methods can significantly reduce heat generation and improve surface roughness, which are both important quality indicators. The use of bio-based cutting fluids has greatly reduced the ecological problems associated with mineral-based cutting fluids. The article provides an overview of the minimum quantity lubrication (MQL) method, which greatly reduces the amount of cutting fluids used while maintaining or even improving cutting performance compared to other cooling methods.

In an effort to improve the machining process for stainless steel 303, cotton seed oil was used as a minimum quantity lubrication (MQL) agent. The study involved testing the effect of different process parameters, including speed, feed, depth of cut, and flow rate, on the output machining characteristics. The Taguchi Design of Experiments (DOE) methodology was used to carry out 9 experiments with varying parameters. The resulting forces (F(x), F(y), F(z)) and cutting tool tip temperatures were evaluated, and the output parameters were optimized using individual optimality and Grey Relation Analysis (GRA). Through this analysis, the best combination of process parameters was identified.

TABLE OF CONTENTS

Description **Page No.**

REFERENCES

APPENDIX

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 INTODUCTION TO MACHINING

Machining is a process used in manufacturing industries to shape raw materials into desired shapes and sizes by removing unwanted material using cutting tools. It is a precise and accurate process that can be performed on different materials such as metal, plastic, wood, and ceramics. Machining is essential in producing a wide range of products that require high precision, including parts for machines, tools, and various industrial components.

Machining is a versatile manufacturing process that offers several benefits. One of its key advantages is the ability to create complex geometries and intricate designs with a high level of precision. Additionally, machining can produce both low and high-volume parts, making it suitable for a range of manufacturing applications. The development of sophisticated computer-controlled machining systems has also led to highly automated and efficient production processes. These advancements have further increased the versatility and usefulness of machining in modern manufacturing.

An overview of different types of machining techniques, including turning, drilling, milling, grinding, and honing. Turning is performed by rotating the material on a lathe and using a cutting tool to remove the unwanted material. Drilling creates holes in the material using a drill bit. Milling removes material from the surface of the material using a rotating cutter. Grinding involves using a grinding wheel to remove small amounts of material to achieve a smooth surface. Honing is the process of removing small amounts of material to achieve a precise surface finish.

Machining is a process that requires a high level of skill, precision, and experience. It is crucial to have a deep understanding of the materials, cutting tools, and machining techniques to ensure high-quality output. Machining is important in producing complex and intricate parts and components for various industries, such as aerospace, automotive, medical, and electronics.

1.2 VARIOUS TYPES OF MACHINING

Machining is a manufacturing process that involves removing material from a workpiece to create a desired shape or size using various cutting tools and techniques. The following are some of the most common types of machining:

1. **Turning:** The workpiece is rotated while a cutting tool is held against it to remove material and create a cylindrical shape.
2. **Milling:** A cutting tool with multiple teeth rotates around the workpiece to remove material and create complex shapes.
3. **Drilling:** A rotating cutting tool is used to create holes in the workpiece.
4. **Grinding:** Abrasive particles are used to remove material and create a smooth surface finish.
5. **Broaching:** A special cutting tool with teeth of increasing size is used to create complex shapes or features.
6. **Electrical Discharge Machining (EDM**): A tool with an electrode and the workpiece are submerged in a dielectric fluid, and electrical sparks are used to remove material and create the desired shape.
7. **Laser cutting:** A focused laser beam is used to cut through the workpiece and create a desired shape.

Each type of machining has its own advantages and limitations, and the choice of method depends on the specific requirements of the project.

1.2.1 TURNING MACHINING

The manufacturing process of turning machining involves removing material from a workpiece by rotating it against a cutting tool. This process is commonly utilized to create cylindrical parts like rods, shafts, and tubes. The workpiece is clamped in a chuck and rotated at high speed during the process while the cutting tool is brought into contact with its surface. The cutting tool is then fed into the workpiece to remove material and form the desired shape. The cutting tool can be stationary or moved along the workpiece to create complex shapes. Turning machines can be manually or automatically operated using computer numerical control (CNC). CNC turning machines are widely employed in modern manufacturing due to their ability to achieve high precision and repeatability. Turning machining is suitable for a wide range of materials, including metals, plastics, and composites. It is a versatile process that can be used to create both simple and intricate parts with high accuracy and consistency.

1.3 INTRODUCTION TO LATHE

A lathe is a machine tool that has been used for centuries in turning machining. It rotates a workpiece on its axis while a cutting tool is used to shape it by removing material. The machine has four basic components: a bed, headstock, tailstock, and carriage. The bed forms the base of the lathe and provides support for the other components. The headstock contains the spindle that rotates the workpiece, while the tailstock supports the other end of the workpiece and can be adjusted to change its length. The carriage holds the cutting tool and can be moved along the bed and crosswise to the workpiece to create the desired shape.

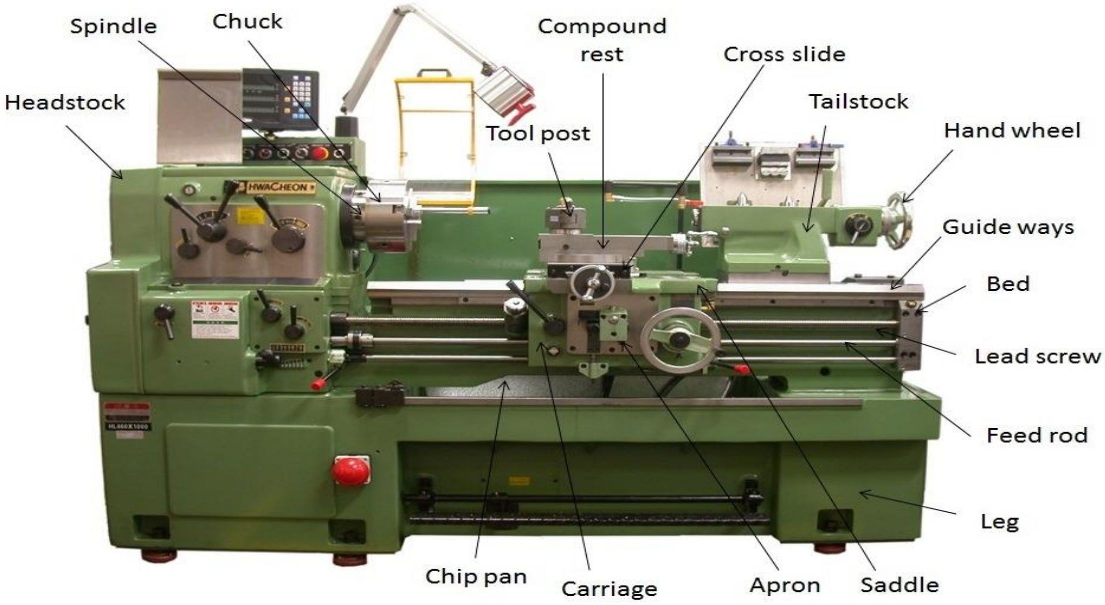


Fig 1.1 Lathe Machine

Lathes are available in various sizes and configurations, ranging from small benchtop models to large industrial machines. They can be operated manually or automatically using CNC technology. Manual operation involves using hand wheels and levers to move the cutting tool and adjust the machine settings. CNC operation, on the other hand, involvesusing a computer program to control the movement of the cutting tool and the rotation of the workpiece. Lathes are used in manufacturing industries to create cylindrical parts such as shafts, rods, and tubes. They are versatile and can be used on different materials such as metals, plastics, and composites. Lathes are essential tools in industries such as aerospace, automotive, and medical device manufacturing.

1.3.1 VARIOUS TYPES OF LATHE OPERATIONS

There are various operations that can be performed using a lathe machine. Below are some of the most frequently used lathe operations:

1.**Facing:** This involves removing material from the end of a workpiece to create a flat surface that is perpendicular to the axis of rotation.

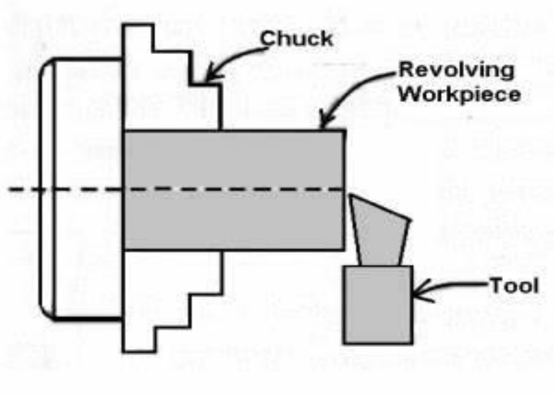


Fig 1.2 FACING

2.**Drilling:** It involves using a cutting tool to create a hole in the workpiece. The cutting tool is fed into the workpiece at a high speed to create a cylindrical hole.

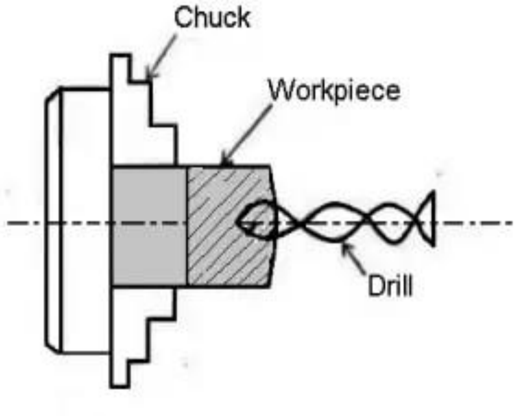


Fig 1.3 DRILLING

3.**Boring:** This is similar to drilling, but it is used to create a larger diameter hole. The cutting tool is moved in a circular motion to enlarge an existing hole.

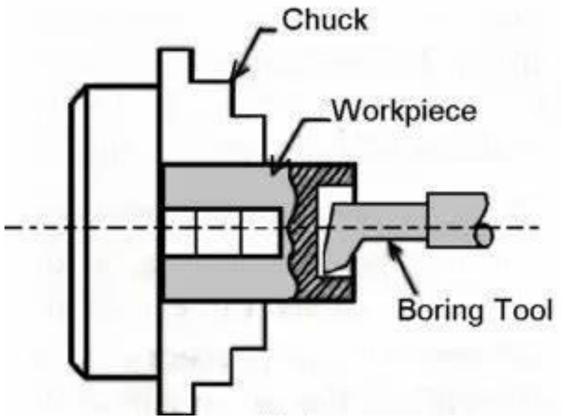


Fig 1.4 BORING

4.**Knurling:** This is a process used to create a textured surface on the workpiece. The cutting tool is pressed against the workpiece while it is rotated to create a pattern of small ridges.

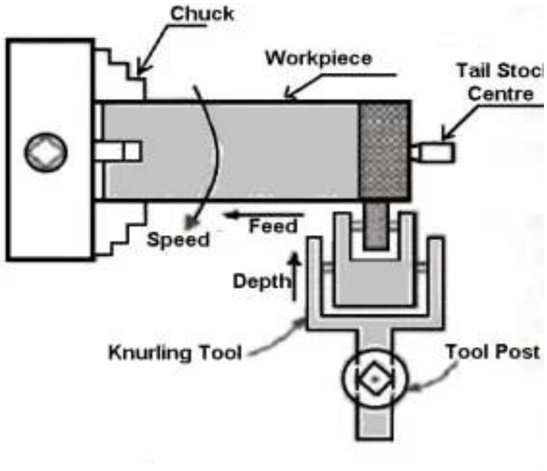


Fig 1.5 KNURLING

5.**Thread cutting:** This is the process of creating a threaded surface on the workpiece. The cutting tool is moved along the workpiece at a specific angle to create the desired thread profile.

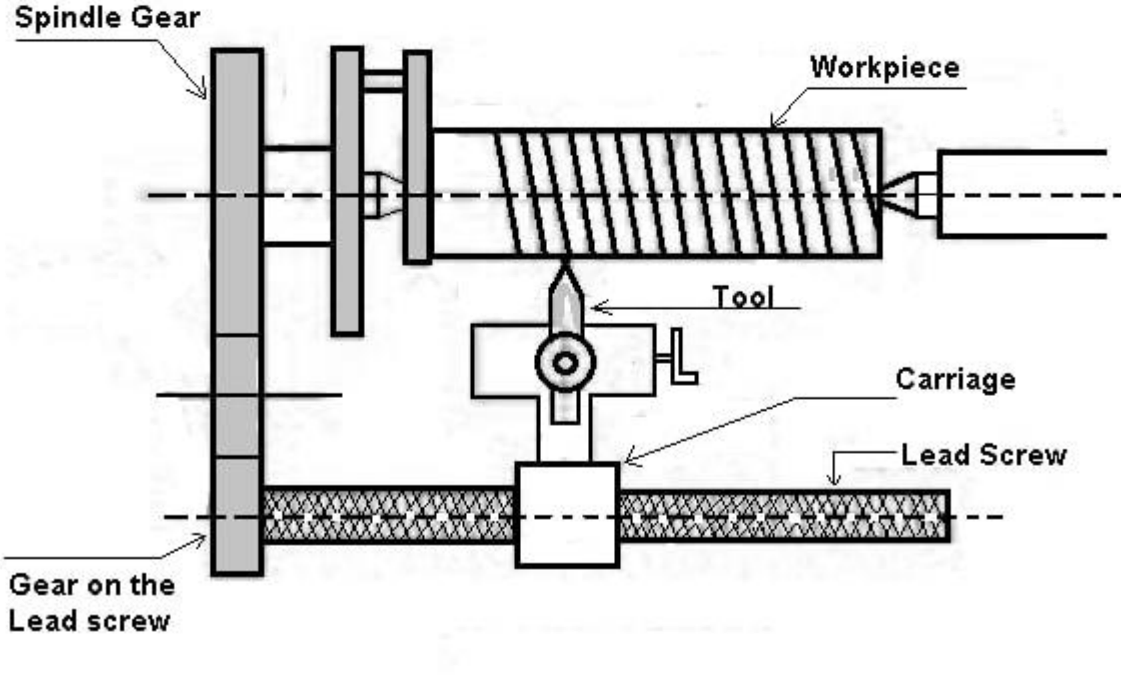


Fig 1.6 THREADING

6.**Turning:** This is the process of removing material from the workpiece to create a cylindrical shape. The cutting tool is moved parallel to the axis of rotation to create the desired diameter.

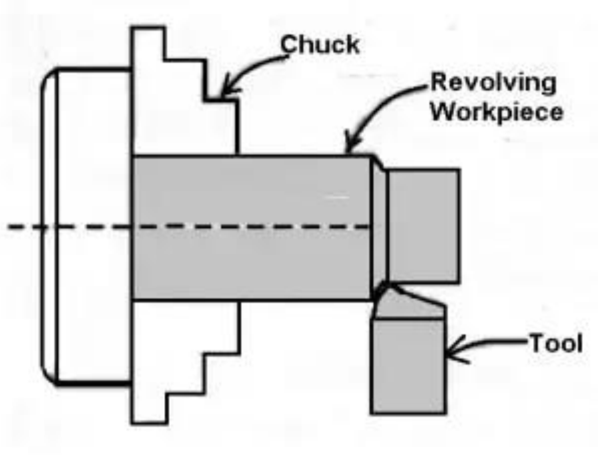


Fig 1.7 TURNING

7.**Parting:** This is the process of cutting off a section of the workpiece to create a separate part. The cutting tool is fed into the workpiece perpendicular to the axis of rotation to create a groove that separates the part from the rest of the workpiece.

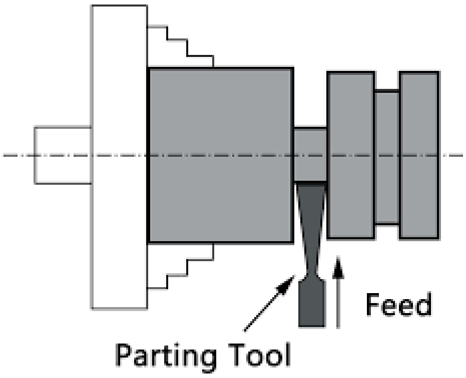


Fig 1.8PARTING

1.3.2 TYPES OF LATHES

There exists a wide variety of lathes, each engineered for specific applications. The following are some of the most commonly used types:

Engine Lathe: This is the most prevalent type of lathe, utilized for general-purpose tasks such as turning, facing, drilling, and threading.

Turret Lathe: A turret lathe has a tool turret capable of holding multiple tools, enabling rapid and effortless tool changes.

CNC Lathe: A computer numerically controlled (CNC) lathe is guided by a computer program to steer the cutting tool, resulting in greater precision and efficiency.

Automatic Lathe: An automatic lathe is programmed to automatically repeat a sequence of machining operations.

Swiss Lathe: A Swiss lathe, also called a Swiss screw machine, is intended for small, intricate parts.

Vertical Lathe: A vertical lathe, also known as a vertical turning center, has a vertical spindle and is used for large, heavy workpieces.

Speed Lathe: A speed lathe is designed for small, high-speed work.

Brake Lathe: A brake lathe is a specialized type of lathe used for resurfacing brake rotors.

These are only some of the many varieties of lathes, each with its own unique attributes and potential applications.

1.3.3 PARTS OF LATHE MACHINE

A lathe machine is composed of multiple intricate parts that work together to perform specific functions. Here are some of the essential components of a lathe machine:

Bed: The bed is the foundational frame of the lathe that holds all other parts in place.

Headstock: Located at one end of the bed, the headstock holds the spindle that rotates the workpiece.

Tailstock: Positioned at the opposite end of the bed, the tailstock supports the other end of the workpiece.

Carriage: The carriage moves along the bed and carries the cutting tool.

Cross-slide: Mounted on the carriage, the cross-slide moves perpendicularly to the spindle axis to perform operations such as facing.

Compound rest: Positioned on the cross-slide, the compound rest can be angled to enable angled cuts.

Chuck: Mounted on the spindle, the chuck secures the workpiece in place.

Tool post: The tool post holds the cutting tool and allows for the adjustment of the depth and angle of the cut.

Lead screw: A long screw that runs along the bed and moves the carriage and cutting tool.

Feed rod: Used to control the movement of the cutting tool along the workpiece.

These are only some of the crucial components of a lathe machine, each of which has a crucial role in the overall performance of the machine.

1.4 USE OF LUBRICATION

1.4.1 TYPES OF LUBRICATION IN LATHE

There are various lubrication types suitable for a lathe machine, each with its own advantages and limitations. Below are some of the most commonly used lubrication types:

Oil lubrication: This type of lubrication is the most prevalent in lathes and entails the use of oil to lubricate the machine's moving components. Oil can be applied by hand or via a centralized lubrication system and is typically more effective than grease for high-speed operations.

Grease lubrication: Grease is a dense, sticky lubricant used primarily in applications where oil may not be appropriate, such as dirty or dusty environments. Grease is administered to the machine's lubricated components, offering extended protection against wear and corrosion.

Dry lubrication: Dry lubrication involves the use of a dry film or coating to reduce friction between moving parts. This type of lubrication is often employed in applications where oil or grease is unsuitable, such as high-temperature environments or circumstances where the lubricant could contaminate the workpiece.

Air lubrication: Air lubrication involves the use of compressed air to create a thin lubricant layer between moving parts. This type of lubrication is frequently used in high-speed applications, such as in CNC lathes, to reduce friction and enhance efficiency.

The type of lubrication utilized in a lathe machine depends on various factors, such as the work being done, the operating environment, and the machine manufacturer's requirements. It is critical to use the proper lubrication and adhere to the manufacturer's maintenance and lubrication instructions.

1.5 MINIMUM QUANTITY LUBRICATION

Minimum quantity lubrication (MQL) is a method of lubrication that uses a very small amount of lubricant to reduce friction and heat during machining operations. This technique is also known as micro-lubrication or near-dry machining.

In MQL, a small amount of lubricant is delivered directly to the cutting edge of the tool using a high-pressure air stream or other delivery system. The lubricant is atomized into a fine mist, which provides a thin film of lubrication between the tool and the workpiece. Because only a small amount of lubricant is used, MQL can significantly reduce the amount of coolant and lubricant needed for a given machining operation, resulting in lower costs and environmental impact.

Some of the benefits of MQL include:

Reduced tool wear and longer tool life

Improved surface finish and accuracy

Reduced energy consumption and production costs

Lower environmental impact due to reduced coolant and lubricant usage

Improved workplace safety by reducing exposure to coolant mist and other hazards.

MQL is often used in high-speed machining applications, such as turning and milling, where traditional coolant and lubrication methods may not be effective or efficient. However, it is important to note that MQL may not be suitable for all applications and materials, and may require specialized equipment and training for proper implementation.

Fig 1.9MQL SET UP

COTTON SEED OIL AS CUTTING FLUID

Cottonseed oil is a natural oil that can be used as a cutting fluid in machining operations. It has several properties that make it a good choice for this application:

Lubrication: Cottonseed oil has natural lubricating properties that can help reduce friction and wear between the cutting tool and the workpiece.

Cooling: The high thermal conductivity of cottonseed oil can help to dissipate heat generated during cutting, reducing the risk of overheating and damage to the tool and workpiece.

Rust prevention: Cottonseed oil contains natural antioxidants that can help to prevent rust and corrosion on metal surfaces.

Environmental friendliness: Cottonseed oil is a renewable, biodegradable, and non-toxic fluid that is environmentally friendly and can help reduce the use of petroleum-based cutting fluids.

However, there are some limitations to using cottonseed oil as a cutting fluid. It has a lower flash point than many petroleum-based fluids, which means it may be more flammable and require additional safety precautions during use. Additionally, it may not be suitable for all machining applications or materials, and may require specialized equipment and procedures for effective use.

Overall, cottonseed oil can be a viable alternative to traditional cutting fluids for certain applications, and its natural lubricating and cooling properties can help improve machining performance and reduce environmental impact.

1.6 CUTTING TOOLS

Cutting tools are essential in the field of machining as they are used for removing material from a workpiece through various techniques such as cutting, drilling, milling, and turning. These tools are manufactured from a range of materials including high-speed steel (HSS), carbide, ceramic, and diamond, and are available in different shapes and sizes to cater to specific machining operations.

Some of the commonly used types of cutting tools include end mills, drill bits, turning tools, milling cutters, reamers, taps and dies, broaches, and saw blades. End mills are ideal for milling slots, pockets, and other features in a workpiece, while drill bits are used for drilling holes. Turning tools are employed for shaping or turning a workpiece on a lathe machine, and milling cutters are suitable for milling flat surfaces, grooves, and other features in a workpiece. Reamers are designed for enlarging and finishing existing holes in a workpiece, while taps and dies are used for threading and cutting screw threads. Broaches are employed for cutting complex shapes in a workpiece, and saw blades are used for cutting metal, wood, and other materials.

Choosing the appropriate cutting tool is crucial and depends on several factors, including the material being machined, the desired surface finish, the machining operation being performed, and the machine used. It is essential to follow the manufacturer's maintenance and replacement guidelines to ensure effective and safe machining operations.

Cutting tools are indispensable in various machining operations, such as cutting, drilling, milling, and turning. They come in a variety of shapes and sizes and are made from different materials, such as carbon steel, high-speed steel, satellite, and carbide. Linear cutting tools, such as tool bits and broaches, are used for shaping and planning machines, while rotary cutting tools, such as drill bits, countersinks, counterbores, taps and dies, reamers, and cold saw blades, are used for cutting.

Some cutting tools may have inserts or replaceable tips made from materials such as cemented carbide, polycrystalline diamond, and cubic boron nitride. Carbide cutting tools are often used for operations that require maximum cutting speeds. Therefore, choosing the right cutting tool for a particular machining operation is crucial to achieving the desired results.

1.6.1 CUTTING TOOLS FOR TURNING MACHINES

The efficiency of the cutting process is affected by the tool material and geometry, a fact widely recognized in the field. With the introduction of turning operations, there have been significant advancements in tool design and material techniques. This section will provide a brief introduction to.

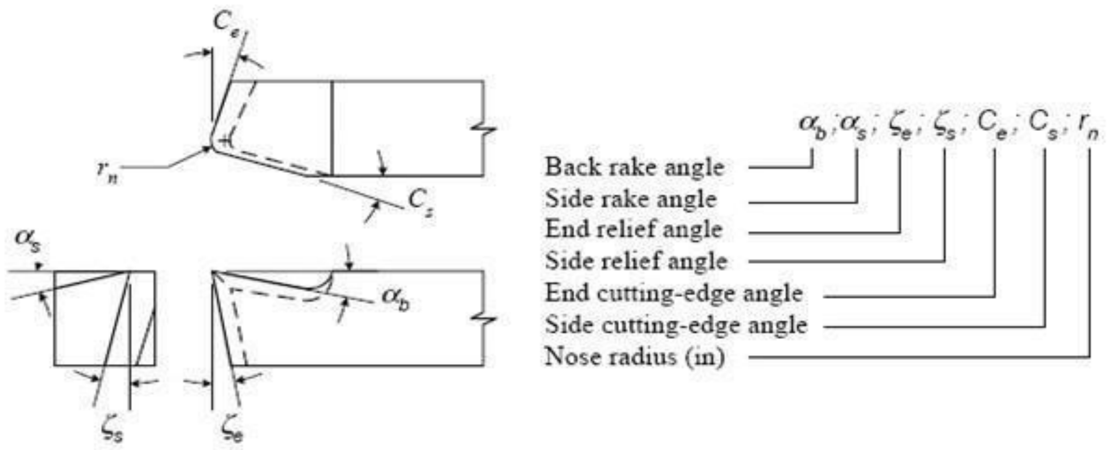


Fig 1.10: Cutting Tool Nomenclature

1.6.2 INSERT TOOL & IDENTIFICATION

Insert tools are a type of cutting tool that feature replaceable cutting edges or inserts, which are mounted onto the tool body. These inserts can be made from a variety of materials, such as carbide, ceramic, cermet, cubic boron nitride (CBN), and polycrystalline diamond (PCD).

There are several advantages to using insert tools in machining operations, including cost savings, faster tool changes, and reduced maintenance. They also offer greater flexibility in tool selection, as different inserts can be used on the same tool body to achieve different cutting results.

Inserts are typically identified using a combination of letters and numbers that describe the insert type, size, geometry, thickness, and material. For instance, "CCMT 09 T3 08-UM" indicates a diamond-shaped, 80-degree rhombic insert that is 9mm in size, has a triangular shape with a 0.8mm corner radius, a thickness of 3.18mm, and is made from uncoated cemented carbide.

When selecting inserts, it is important to consider factors such as the material being machined, cutting speed, depth of cut, and desired surface finish. It may be necessary to consult with the manufacturer or a machining expert to ensure the best results.

1.6.3 PVD AND CVD TECHNIQUES

PVD and CVD are two different techniques used to deposit thin films onto surfaces for various applications.

PVD (Physical Vapor Deposition) is a process in which a material is vaporized in a vacuum and then deposited onto a surface to create a thin film. This process is typically done in a high vacuum environment, and the deposition occurs through condensation or reaction on the surface of the substrate. PVD can be used to deposit a variety of materials, such as metals, ceramics, and semiconductors. PVD coatings can improve the hardness, wear resistance, and corrosion resistance of cutting tools, and are commonly used in the manufacturing of cutting tools.

CVD (Chemical Vapor Deposition) is a process in which a thin film is deposited on a substrate by chemical reaction between gases at high temperatures. In this process, a gas is introduced into a reaction chamber and heated to a high temperature, causing the gas to break down and deposit onto the surface of a substrate. CVD can be used to deposit a wide range of materials, including metals, ceramics, and diamond coatings. CVD coatings can provide high wear resistance, high temperature stability, and low friction for cutting tools, making them ideal for machining hard materials.

Both PVD and CVD techniques have advantages and disadvantages, and the choice between them depends on the specific application requirements. PVD coatings are typically thinner and have a smoother surface finish, while CVD coatings can be thicker and have higher wear resistance. PVD coatings are also generally easier to produce and are more cost-effective, while CVD coatings require higher temperatures and can be more expensive.

1.7 MINI TAB SOFTWARE

Minitab is a statistical software package that offers an easy-to-use interface for data analysis and visualization, and is utilized in various industries including healthcare, finance, and manufacturing. This software is capable of performing multiple statistical analyses like ANOVA, regression analysis, and hypothesis testing, and offers visualization tools such as histograms, box plots, and scatter plots.

Apart from its analytical and visualization tools, Minitab offers users features to manipulate and analyze data including data cleaning and transformation, data importing and exporting, and customizable reporting. Its user-friendly interface makes it a popular choice even for those not familiar with statistical software.

Minitab is commonly used in Six Sigma projects and quality improvement initiatives, as it provides a powerful solution for analyzing process data and identifying areas for improvement. In academia, Minitab is also widely used to teach statistical concepts and analysis. In summary, Minitab is a versatile and user-friendly statistical software package that serves a crucial role in data analysis and visualization across various industries.

Procedure for Minitab

- First, you need to put your data values in one of the columns of the Minitab worksheet.

- Put a variable name in the gray box.
- Click on “Stat”, then click on “Basic Statistics”, and then
- Click on “Display Descriptive Statistics”.
- Choose the variable for which you want the basic statistics.
- Click on “Select”.
- Click on the “Statistics” box, then check the box next to each statistic you want to see.
- Click on “OK” in that window, then click on “OK” in the next window.
- The values of all the statistics you selected should appear in the Session window.

In short, it helps organizations and institutions to visualize and analyze the trend to solve certain problems by bringing valuable insights from the data, in a quick and effective way. The main purpose of using Minitab software is that in this software we can done individual optimization and SM Research.

1.8 CUTTING FLUIDS

Cutting fluids play a critical role in machining and metalworking processes by cooling and lubricating cutting tools and workpieces. These fluids are necessary for the efficient operation of cutting tools and can enhance the quality of finished products.

The primary objective of cutting fluids is to reduce the heat generated during machining, which can damage the cutting tools and workpieces and reduce their lifespan. By absorbing and dissipating heat away from the cutting zone, cutting fluids effectively decrease heat and prevent workpiece warping and cracking.

In addition to cooling, cutting fluids provide lubrication for cutting tools and workpieces, reducing friction and wear. Lubrication helps to extend the lifespan of cutting tools and improve the surface finish of the workpiece, while also preventing the accumulation of chips and swarf that can obstruct the cutting tool and harm the finished product.

Cutting fluids are available in different types, including oil-based, water-based, and synthetic fluids. Oil-based fluids are commonly used for heavy-duty applications, while water-based fluids are used for lighter-duty applications. Synthetic fluids, on the other hand, are a blend of oil and water-based fluids and are frequently used in high-performance applications.

Choosing the right cutting fluid depends on several factors, including the type of material being machined, the type of cutting tool being used, and the machining process being used. It is essential to select the right cutting fluid for the job to ensure the best results and to prolong the life of the cutting tools and workpieces.

1.8.1 TYPE OF CUTTING FLUID

Various types of cutting fluids are available for use in metalworking and machining operations, each with its own set of advantages and disadvantages. These include mineral oil-based fluids, water-based fluids, synthetic fluids, vegetable oil-based fluids, and semi-synthetic fluids.

Mineral oil-based fluids, derived from petroleum, are cost-effective and provide good lubrication and cooling properties. However, they can be flammable and have poor biodegradability.

Water-based fluids are environmentally friendly, cost-effective, and provide good lubrication. However, they can cause rusting and require additives to improve performance.

Synthetic fluids, made from synthetic chemicals, are expensive but offer good cooling and lubrication properties, and have a longer lifespan than mineral oil-based fluids.

Vegetable oil-based fluids are biodegradable and provide good lubrication and surface finish, but can be expensive and have a shorter lifespan than synthetic fluids.

Semi-synthetic fluids, a combination of mineral oil and water-based fluids, provide good performance and a longer lifespan than mineral oil-based fluids, but are more expensive than water-based fluids.

The selection of cutting fluid should take into account the specific application and machining process, as well as environmental and safety considerations.

1.8.2 CUTTING FLUID AND CUTTING FLUID IN MACHINING

Cutting fluids are essential coolants and lubricants used in metalworking and machining processes to improve tool life, reduce friction, and improve surface finish. These fluids also help to prevent heat buildup, which can cause deformation of the workpiece and cutting tool, and flush away chips and debris.

There are several types of cutting fluids available, including mineral oil-based, water-based, synthetic, semi-synthetic, and vegetable oil-based fluids, each with their own advantages and disadvantages. The choice of cutting fluid depends on the specific application, machining process, and environmental and safety considerations.

Cutting fluids can be applied through various methods, such as flood, mist, and spray, depending on the machining process, fluid type, and environmental and safety factors.

In addition to providing cooling and lubrication, the appropriate cutting fluid and application method can improve the quality of the final product by affecting the surface finish and dimensional accuracy of the machined part. Thus, the use of cutting fluids is critical to optimizing the machining process and producing high-quality final products.

1.9 MATERIALS AND ITS APPLICATIONS

There are various materials used in manufacturing, each with its own unique properties and applications. Here are some of the common materials used in manufacturing and their applications:

Metals: Metals are preferred in manufacturing due to their strength, durability, and electrical conductivity. Steel, aluminum, copper, and brass are some commonly used metals in manufacturing. Metals find applications in a wide range of fields from construction to electronics.

Plastics: Plastics are lightweight, durable, and affordable, making them a popular choice in manufacturing. Common types of plastics used in manufacturing include polyethylene, polystyrene, and polypropylene. Plastics are used in various fields, including packaging and automotive parts.

Ceramics: Ceramics are known for their hardness, high-temperature resistance, and electrical insulation properties. They are commonly used in manufacturing for applications such as cutting tools, ball bearings, and electrical components.

Composites: Composites are materials made from two or more different materials, typically a matrix material and a reinforcement material. The combination of materials can result in a material with superior properties compared to individual materials. Carbon fiber composites and fiberglass composites are some common types of composites used in manufacturing. Composites are used in applications such as aerospace and automotive parts.

Wood: Wood is a natural material that is commonly used in construction and furniture manufacturing due to its strength and durability. It is also used in the production of paper and packaging materials.

Glass: Glass is a versatile material that is commonly used in manufacturing for applications such as windows, mirrors, and optical components. Glass can also be used in the production of electronics, such as touch screens and display panels.

Rubber: Rubber is a flexible material that is commonly used in manufacturing for applications such as tires, seals, and gaskets. It is also used in the production of consumer goods such as footwear and toys.

The selection of material used in manufacturing depends on the specific application, the desired properties of the final product, and the cost and availability of the material.

1.9.1 BASIC FEATURES OF MATERIALS

The physical and chemical characteristics of materials are essential in determining their behavior and performance in various applications. Here are some of the key features of materials:

Density: Density refers to the mass of a material per unit volume, and it is an important consideration since it influences the weight and size of the final product.

Strength: A material's strength is its capacity to resist external forces without breaking or deforming. It is crucial for applications where the material is subjected to stress or strain.

Hardness: Hardness is a material's ability to resist penetration or scratching. It is important in applications where the material will experience wear and tear.

Elasticity: Elasticity refers to a material's ability to return to its original shape after it has been stretched or compressed. It is important in applications that involve repeated loading and unloading.

Ductility: Ductility is a material's ability to undergo deformation without fracturing. Materials that are ductile can be stretched into thin sheets or drawn into wires.

Conductivity: Conductivity is a material's ability to conduct heat or electricity. Materials that are good conductors of heat or electricity are important for applications such as electronics.

Corrosion resistance: Corrosion resistance is a material's ability to resist deterioration caused by chemical reactions with its environment. Materials that are resistant to corrosion are crucial for applications exposed to harsh environmental conditions or chemicals.

Overall, the basic features of materials determine their suitability for specific applications and their performance in particular environments. The selection of materials for an application should consider the specific requirements and conditions to ensure optimal performance and longevity.

1.10 TURNING PROCESS PARAMETERS AND RESPONSE VARIABLES

1.10.1 PROCESS PARAMETERS

- The input process parameters affecting the response of Turning process are:
- Cutting Speed
- Depth of cut
- Feed rate
- Cutting Fluid
- Tool temperature

1.10.2 RESPONSE VARIABLES

Turning process performance can be measured by the Tool temperature, cutting forces and machining cost of the work piece that has been machined. These three machining characteristics have to be calculated for the selected input parameters. The response variables for Turning process are discussed below.

1.10.2.1 TOOL TEMPERATURE

Controlling tool temperature is crucial in machining processes as it affects the life of the cutting tool, machining accuracy, and surface quality of the workpiece. The temperature of the cutting tool can increase significantly due to the friction between the tool and the workpiece material, which can cause premature wear, deformation, or failure of the cutting tool.

Various factors can influence tool temperature during machining, such as cutting speed, feed rate, depth of cut, tool geometry, cutting tool material, and cutting fluid. Increasing cutting speed or decreasing feed rate can raise the tool temperature, while decreasing cutting speed or increasing feed rate can lower the tool temperature. A deeper cut generates more heat than a shallower cut, and the geometry and material of the cutting tool can also impact the tool temperature. Tools with smaller or positive rake angles tend to generate less heat than those with larger or negative rake angles. Cutting tools made of materials with higher thermal conductivity, such as diamond or cubic boron nitride, can dissipate heat more effectively and maintain lower temperatures than tools made of materials with lower thermal conductivity, such as carbide.

Cutting fluids also play a vital role in controlling tool temperature. They help reduce friction between the tool and the workpiece, thereby decreasing heat generation. Additionally, cutting fluids carry heat away from the cutting zone and cool the cutting tool, reducing its temperature.

In summary, monitoring and controlling tool temperature are essential for achieving optimal machining performance and prolonging the life of cutting tools.

1.10.2.2 CUTTING FORCES

Cutting forces refer to the forces that arise during machining processes, which impact the performance of the cutting tool and the quality of the machined surface. These forces are created by the interaction between the cutting tool and the workpiece material. There are three main cutting forces that are usually measured during a machining operation:

Cutting force (Fc): This force is perpendicular to the direction of the cutting edge and separates the chip from the workpiece material.

Feed force (Ff): This force is parallel to the direction of the cutting edge and moves the cutting tool along the workpiece surface.

Radial force (Fr): This force is perpendicular to the cutting edge and parallel to the workpiece surface, and controls the depth of cut and machining accuracy.

Several factors, such as cutting speed, feed rate, depth of cut, tool geometry, cutting tool material, and workpiece material, affect the magnitude of these cutting forces. High cutting speed or feed rate increases the cutting forces, while reducing them lowers the cutting forces. To achieve optimal machining performance and prolong the life of cutting tools, it is important to monitor and control cutting forces. High cutting forces can damage the cutting tool, while low cutting forces can result in poor surface finish and dimensional accuracy. By adjusting cutting parameters and selecting appropriate cutting tool materials and geometries, cutting forces can be minimized, and machining efficiency can be enhanced.

1.10.2.3 MACHINING COST

Machining cost refers to the total cost of producing a part or product using machining operations such as milling, turning, drilling, etc. It includes the cost of the raw material, tooling, labour, and overhead costs such as electricity, machine maintenance, and depreciation.

The machining cost can be calculated using several methods, depending on the type of machining operation and the available resources. Here are some common methods used for calculating machining costs:

- Cost Estimation Software: There are many software programs available that can estimate the machining cost based on input data such as part geometry, material type, cutting parameters, and labour rates.
- Spreadsheet Calculation: A spreadsheet can be used to estimate the machining cost by breaking down the cost into various components such as material cost, tooling cost, labour cost, and overhead costs.
- Activity-Based Costing: Activity-based costing (ABC) is a cost accounting method that assigns costs to specific activities or processes. In the case of machining, ABC can be used to calculate the cost of each machining operation and allocate it to the final product.

1.11. DESIGN OF EXPERIMENTS

1.11.1 DESIGN OF EXPERIMENT TECHNIQUES

There are commonly four techniques namely:

- Factorial Design
- Response Surface Methodology
- Mixture Design
- Taguchi Design

Among those, Taguchi Design is selected for finding the relative significance of various parameters.

1.11.2 TAGUCHI METHOD

The Taguchi method, developed by Genichi Taguchi in the 1950s, is a statistical approach to quality control that aims to optimize design and manufacturing processes to improve quality and reduce costs.

The method involves three main steps. First, the important factors that affect the quality of the product or process are identified, and experiments are designed to test the effects of these factors on the output. Second, data from the experiments is analyzed using statistical methods to identify the optimal settings for the factors that will result in the best quality output. Finally, once the optimal settings have been identified, they can be implemented in the design and manufacturing processes to improve quality and reduce costs.

The Taguchi method uses the signal-to-noise (S/N) ratio to measure the quality of the output. The S/N ratio evaluates the variability of the output relative to the desired target value, and it is used to assess the effectiveness of different factors in the design and manufacturing processes.

The Taguchi method has been widely used across various industries, including manufacturing, engineering, and design, due to its systematic and efficient approach to improving the quality of products and processes. It has been shown to be effective in reducing costs and improving customer satisfaction.

1.11.3 ANALYSIS OF EXPERIMENTAL DATA

Experimental data is interpreted and conclusions are drawn through the use of statistical methods. The aim of this analysis is to determine the significance of relationships between independent and dependent variables.

Common techniques used in analyzing experimental data are:

Descriptive statistics: This involves calculating measures of central tendency (such as the mean or median) and measures of variability (such as the standard deviation) for the data set.

Inferential statistics: This involves using statistical tests, such as t-tests, ANOVA, regression analysis, and chi-square tests, to determine the significance of the relationships between the independent and dependent variables.

Data visualization: This involves creating graphs and charts to visually represent the data and identify patterns and trends.

Quality control charts: This involves plotting the data over time to identify any changes or trends that may be indicative of a process shift or other issue.

The choice of analysis technique is dependent on various factors, such as the type of data collected, the research question, and the experimental design. The use of appropriate statistical methods ensures that the results are valid and reliable.

1.11.3.1 SIGNIFICANCE OF SIGNAL-TO-NOISE RATIO

Signal-to-noise ratio (SNR) is a measure of the quality of a signal relative to the level of background noise. It is commonly used in the field of engineering and applied sciences to evaluate the performance of a system or process.

The significance of SNR lies in its ability to quantify the level of useful information (signal) in a system or process relative to the level of unwanted information (noise). A high SNR indicates that the signal is strong relative to the noise, which means that the system is performing well and producing accurate and reliable results.

In contrast, a low SNR indicates that the signal is weak relative to the noise, which means that the system is not performing well and producing inaccurate or unreliable results. This can lead to errors in decision-making and can have serious consequences in certain applications, such as medical diagnosis, aerospace engineering, and financial forecasting.

Therefore, SNR is an important performance metric that can be used to optimize the design and operation of systems and processes, and to ensure that they are capable of producing accurate and reliable results.

CHAPTER 2

LITERATURE REVIEW

2.1 LITERATURE REVIEW

Sougata Roy et.al [1] A team of researchers conducted a study to investigate the effect of varying concentrations of TiO2 nanoparticles in vegetable oil to create a Nano fluid. Their goal was to improve the fluid's thermal and tribological properties. They analyzed the Nano fluid's viscosity and thermal conductivity and tested its effectiveness in turning AISI 1040 steel using the minimum quantity lubrication (MQL) technique. The researchers compared the Nano fluid's performance with that of conventional cutting fluids under dry and wet MQL machining conditions.

The researchers discovered that increasing the concentration of TiO2 nanoparticles in the vegetable oil led to a corresponding increase in the Nano fluid's thermal conductivity, viscosity, and density, while decreasing its specific heat. When tested in machining AISI 1040 steel using minimum quantity lubrication (MQL), the Nano fluid outperformed dry MQL and performed comparably to wet machining. However, the conventional cutting fluid demonstrated similar performance under both MQL and wet machining.

The study demonstrated the potential of TiO2-based Nano fluids as an alternative to conventional cutting fluids in machining processes. By adopting Nano fluids, manufacturers can reduce costs, minimize environmental impact, and improve machining process performance. The study also highlighted the importance of nanoparticle concentration in determining Nano fluid properties and emphasized the need for further research to optimize their performance for specific applications.

Soroush Masoudi et.al [2] The objective of this research was to examine the impact of Minimum Quantity Lubrication (MQL) machining on AISI 1045 steel and determine the influence of different parameters in the process. The results of the study indicated that MQL machining had a considerable effect in reducing surface roughness and cutting force compared to traditional wet and dry turning, regardless of the workpiece hardness and tools used. The primary reason for this improvement was the improved ability of the oil mist to penetrate the cutting area, leading to reduced friction and chip adhesion, as well as the lubricant's embrittlement effect that reduced the level of strain required for chip fracture. In addition, MQL machining also resulted in lower tool wear rates, which prolonged steady-state wear and decreased the likelihood of excessive tool wear. Conversely, wet and dry cutting generated higher roughness rates and forces due to increased tool wear. In summary, the study concluded that MQL machining can provide improved cutting efficiency and decreased tool wear, making it a viable alternative to conventional cutting methods**.**

Gobinda Chandra Behera et.al [3] This article investigates the advantages of using minimum quantity lubrication (MQL) in machining over dry machining. The study compares the effectiveness of coconut oil and rice bran oil as cutting fluids for MQL machining of AISI 304 stainless steel. Various factors such as cutting force, tool tip temperature, flank wear depth, tool wear mechanisms, chip morphology, and surface roughness of the machined workpiece are analyzed. The results indicate that MQL with rice bran oil is more effective than MQL with coconut oil, as it reduces cutting force and tool tip temperature, and decreases flank wear depth. Additionally, MQL with rice bran oil produces a superior surface finish with fewer tool wear mechanisms and smaller chips.

Anshuman Das et.al [4] A research study was conducted to evaluate the performance of oil-based emulsifier nano-cutting fluids in metal cutting by analyzing various factors such as cutting forces, cutting temperature, tool wear, and surface roughness. The study found that the cutting force increased proportionally with the depth of cut for all three types of cutting fluids. The highest flank wear was observed when the cutting speed was 140 m/min for all fluids. Based on the study's findings, the depth of cut was identified as the most significant cutting parameter affecting cutting force and feed force, while the speed was found to be the primary parameter affecting radial force for water-soluble coolant and compressed air. For nanofluids, the primary factors influencing cutting force, feed force, and radial force were identified as depth of cut, feed, and speed, respectively.

Amrit Pal1 et.al [5] An experimental study conducted by Hazoor Singh Sidhu analyzed the performance of drilling under different cutting fluid conditions, including dry, flood, and Minimum Quantity Lubrication (MQL). Results showed that MQL drilling provided the most favorable outcomes compared to dry and flood drilling. Dry drilling resulted in inadequate outcomes due to high COF and drilling forces, resulting in increased temperatures at the drill tip, higher roughness, and more drill wear. Flood drilling showed better drilling properties than dry drilling, but MQL drilling demonstrated even superior outcomes. The study found that using vegetable oils and distilled water in MQL drilling conditions improved drilling performance by reducing drilling forces, surface roughness, COF, and tool wear rate. This was due to the superior cooling and lubrication capabilities of vegetable oils and distilled water. Overall, the study suggests that MQL drilling conditions are a preferable alternative to conventional dry and flood drilling techniques for enhancing drilling performance and minimizing environmental impact.

N.R. Dhara et.al [6] This research aimed to evaluate the impact of using minimum quantity lubrication (MQL) during plain turning of AISI-1040 steel, specifically in reducing cutting temperature, chip reduction coefficient, and dimensional deviation. The study compared the effectiveness of MQL to conventional cutting fluid and dry machining at different speed-feed combinations, using an uncoated carbide insert. The results showed that MQL was more successful in reducing cutting temperature and chip reduction coefficient, leading to a lighter metallic chip color than the other methods. The depth of cut remained constant as it did not significantly affect the machining characteristics. Consequently, MQL has the potential to replace conventional cutting fluids, which are costly, hazardous, and harmful to the environment, thereby improving the machining process's sustainability and efficiency. Overall, this research provides valuable insights into the application of MQL to enhance the machining process.

Vivek Jakhara et.al [7] The quality of a material after turning is determined by measuring its surface roughness, which can be done using a portable surface roughness tester. Various techniques can be employed to enhance surface roughness, and one such technique is to use different cutting fluids during the turning process. To study the effect of cutting fluids on tool wear and surface roughness, an experiment was conducted using carbide cutting inserts on AISI 304 austenitic stainless steel, and the surface roughness was measured using a portable tester. The results showed that the choice of cutting fluid had a significant impact on both tool wear and surface roughness, with water-soluble cutting fluids being the most effective in reducing tool wear and improving surface roughness. Overall, the study suggests that the use of water-soluble cutting fluids can be particularly advantageous in enhancing the surface quality of AISI 304 austenitic stainless steel after turning

Harshit B. Kulkarni et.al [8] This article discusses the challenges arising from intermittent metal cutting, particularly milling, which causes significant fluctuations in cutting temperature and thermal shock, leading to cracks in the cutting tool. To address this issue, the study employs the Taguchi method to investigate the milling of AISI 1060 Aluminum, focusing on cutting speed, feed, and depth of cut as the machining parameters. The results suggest that nanofluid-based pulsed jet MQL machining can reduce cutting forces, lower cutting temperatures, and improve surface finish, making it a promising alternative to conventional flood coolant. The study also examines three coolant supply techniques (dry machining, MQL machining, and nanofluid MQL machining) to determine the most effective technique for enhancing the surface milling of Al7075-T6 slabs by optimizing spindle speed, feed, and depth of cut. The findings offer valuable insights into how to optimize machining parameters for surface milling of Al7075-T6 slabs**.**

Jinsang xu et.al [9] The objective of this study was to investigate the impact of minimum quality lubrication (MQL) on the drilling behavior of metallic composite stacks, specifically carbon/epoxy laminates and composite titanium compounds. MQL is commonly employed in machining various materials, but its effectiveness in drilling these composites has not been extensively studied. The study aimed to assess the feasibility of using MQL in drilling operations on multilayer Tungsten Carbide.

In order to evaluate the efficacy of MQL in drilling composite materials, the study employed a quantitative analysis of drilling outputs and surface morphologies of cut composite holes. The comparison included the extent of hole defects, geometrical accuracy of holes, and any resulting tool signatures. The performance of MQL was compared with that of other lubrication methods. The study's outcomes can provide valuable insights into the advantages and limitations of MQL in drilling composite materials.

Harshit B.Kulkarni et.al [10] Manufacturing heavily relies on machining, but the utilization of coolant as a cutting fluid has become a growing challenge due to the rise of environmental regulations and limited access to water resources. To tackle this challenge, experts have investigated the implementation of minimum quantity lubrication (MQL) methods, which can significantly decrease the volume of coolant needed during machining. During the surface milling of an aluminum slab, specifically the Al 7075-T6 variant, uncoated carbide tools were employed alongside a flood coolant approach that utilized 50-60 liters of coolant per hour. However, in an effort to decrease the amount of coolant used, the scientists opted to employ the MQL method, which entails applying a minimal amount of lubricant directly to the cutting tool at the tool-chip interface. As a result, this approach minimized the coolant flow to a range of 50-500 milliliters per hour.

The performance of the MQL method was enhanced by introducing nanoparticles to the coolant. The nanoparticles contribute to improving the fluid's thermal conductivity, thereby increasing its capacity to dissipate heat at the tool interface. Consequently, this enhancement can lead to improved tool life and better machining performance.

While milling Al7075-T6 slab using the MQL technique, researchers noticed that incorporating nanoparticles into the coolant led to better surface quality of machined parts and less wear of the cutting tool. Furthermore, the MQL method employing nanoparticle-enhanced coolant demonstrated potential in reducing environmental impact and conserving water resources. As a result, it could be a valuable approach for achieving sustainable machining processes.

Xitian tian et.al [11] In this paper, the authors investigate the use of two optimization techniques, namely Response Surface Methodology (RSM) and an improved Teaching Learning Based Optimization (TLBO) algorithm, to optimize cutting parameters for a milling operation under multiple objectives. The experiment is designed using a full factorial approach with four factors and three levels to measure cutting forces and surface roughness. Based on the experimental data, a prediction model is developed using cubic polynomial regression to estimate the cutting forces and surface roughness.

The proposed approach integrates the RSM model and the improved TLBO algorithm to achieve optimal cutting parameters. The RSM model is used to obtain initial estimates for the cutting parameters, while the TLBO algorithm fine-tunes the RSM model to search for the best solution. The results demonstrate that this hybrid approach is efficient and effective in optimizing cutting parameters, leading to improved performance in terms of cutting forces and surface roughness.

The study highlights the importance of utilizing multiple optimization techniques for complex manufacturing processes such as milling operations. The RSM-TLBO approach for cutting parameter optimization can be applied in other manufacturing processes to enhance performance and reduce costs.

Jagdeep Sharma et.al [12] The use of petroleum-based lubricants in machining processes has been linked to increased costs and environmental concerns. Dry machining has been suggested as an alternative, but it can lead to inadequate surface finishes and tool-tip damage. Near dry machining, which involves using small amounts of cutting fluid, is a compromise solution that offers benefits over traditional machining techniques.

Near dry machining has been found to reduce cutting temperatures by almost 50%, leading to improved surface finishes. Vegetable oils have also been shown to be advantageous over mineral oils in this process. Near dry machining can help to address the problems associated with the wastage and disposal of harmful metal working fluids and reduce the need for drying chips before recycling. This helps to create a cleaner and more sustainable production process.

Overall, near dry machining offers a viable solution to the issues associated with traditional machining techniques. By reducing the use of petroleum-based lubricants and improving surface finishes, near dry machining can contribute to a more sustainable and cost-effective production process. It is a step towards the development of eco-friendly technologies that can help us create a more sustainable future.

S.Amani et.al [13] To achieve optimal results in MQL machining, a series of experiments were conducted to determine the ideal parameters. These parameters included fluid flow rates, frequencies, positions, and nozzle directions, all of which were found to have a significant impact on the machining process. The fluid flow rate, fluid frequency, nozzle position, and distance were identified as crucial factors in achieving successful MQL machining outcomes.

The experiments also revealed that MQL has the potential to improve tool life and surface finish quality. As a result, higher cutting speeds can be utilized with MQL as compared to dry machining. These findings are important as they demonstrate that MQL can serve as a viable substitute for conventional machining methods. Furthermore, MQL has the added advantage of reducing the requirement for cutting fluid and its disposal, which can result in cost savings.

The experiments carried out in this study emphasize the significance of identifying and optimizing the different parameters involved in MQL machining. This optimization can assist manufacturers in enhancing the quality of their products and increasing efficiency, all while reducing costs. Therefore, the study highlights the importance of considering these factors in order to achieve better results in MQL machining.

Salem Abdullah bagaber et.al [14] This article emphasizes the strength of stainless steel and its exceptional ability to resist corrosion. The utilization of oil-based cutting fluids during machining processes is discouraged due to its adverse environmental impact. Instead, sustainable machining practices advocate for dry machining techniques with affordable cutting tools in a fluid-free environment. Additionally, energy consumption should be minimized.

In order to decrease power consumption without compromising traditional machining outcomes such as surface roughness and tool wear, the RSM multi-objective optimization approach was employed to fine-tune machining parameters. The relative importance of the parameters was ascertained by the compound desirability value, and the optimal parameter levels were established.

During the experiment, AISI 316 austenitic stainless steel was subjected to turning using an uncoated carbide tool in a cutting environment devoid of fluids. The findings revealed a noteworthy decrease in power consumption by 14.94%, as well as a reduction in both surface roughness and tool wear. The utilization of this method is an efficient means of mitigating the impact and expenses associated with machining processes.

A graphical representation can be used to confirm the accuracy of the results obtained. In summary, utilizing affordable cutting tools in a fluid-free environment for dry machining is an environmentally sustainable solution that minimizes the adverse effects of machining processes. Furthermore, fine-tuning machining parameters through multi-objective optimization techniques can notably reduce power consumption while simultaneously preserving traditional machining outcomes.

Soheyl khalilpourazari et.al [15] In the paper, a new algorithm called the Multi Objective

Dragonfly Algorithm (MODA) is proposed to optimize surface quality, grinding time, and process cost simultaneously in a grinding operation. The authors claim that MODA is a meta-heuristic method that can handle complicated operational constraints using an effective constraint handling approach. Compared to the Nondominated Sorting Genetic Algorithm (NSGA-II), the authors found that MODA performed better in identifying Pareto optimal solutions.

Despite the proposed algorithm's success, the authors acknowledge that there are numerous additional operational constraints that need to be considered in grinding operations to create more realistic mathematical models. They recommend developing stochastic and robust models that can take into account the uncertainty in the primary parameters. Furthermore, the authors propose that MODA can be utilized in other mechanical engineering optimization processes, such as milling and machining.

To summarize, the Multi Objective Dragonfly Algorithm (MODA) is an effective method for optimizing multiple objectives in grinding operations and can be adapted to other optimization challenges in mechanical engineering.

Do Duc Trung et.al [16] The aim of the research was to tackle the issue of multi-objective optimization in the external turning process of EN 10503 steel. The study utilized the Taguchi combination method and MOORA techniques to optimize four crucial process parameters, namely insert nose radius, cutting velocity, feed rate, and depth of cut. The objective was to minimize surface roughness and cutting forces in the X, Y, and Z directions while maximizing the material removal rate (MRR). An orthogonal Taguchi matrix was employed to design the experimental matrix, and the optimized cutting parameters were determined using the Taguchi method and MOORA technique. The proposed method's primary objective was to improve the quality and efficiency of the turning process by reducing the amplitude of cutting force, enhancing surface quality, and increasing the material removal rate. The research findings demonstrated the effectivenessof the proposed approach in optimizing the turning process. The optimized parameters resulted in a reduction in surface roughness and cutting forces in the X, Y, and Z directions, while the material removal rate increased. Based on these results, it can be concluded that the proposed method has the potential to improve the quality and efficiency of turning processes. To sum up, the study provided a solution for the challenge of multi-objective optimization in the external turning process of EN 10503 steel, using the Taguchi combination method and MOORA techniques. By optimizing the process parameters to achieve the desired objectives, the proposed method has the ability to improve the quality and efficiency of turning processes.

2.2 SCOPE OF THE WORK FROM THE LITERATURE

- From the above literature, it is observed that the various researchers considered various machining parameters to find the effect on Cutting forces, Machining Costs and Tool temperature in which most of the work is done on the different types of steels and other materials under the presence of various lubricants. The authors are identified some of gaps in the literature in the areas of performing experiments using Minimum Quantity of Lubrication (MQL) during the hard turning process.
- Hence, in this work, the authors have chosen SS 303 as base material with input parameters of speed, feed and depth of cut under the minimum quantity of lubrication as Cotton Seed Oil to predict the responses are Cutting forces, Machining Costs and Tool temperature. Further the authors validated the obtained results using GRA methods for finding the optimum combination of input parameters.

2.3 OBJECTIVES OF PRESENT WORK

- Experimental determination of the effects of the various process’s parameters such as speed, feed, and depth of cut on the performance measures like Cutting Forces, Machining Costs and Tool temperature in TURNING process under MQL.
- Single variable optimization of the process parameters of TURNING process using Taguchi DOE.

Validation of the results by using gray relation analysis (GRA) with individual optimization technique to predict the responses as Cutting Forces, Machining Costs and Tool temperature.

CHAPTER 3

PROBLEM STATEMENT

Based on literature Review, A soft material can easily undergo machining process but for a Hard material, the machining process is exceedingly difficult. While machining the hard material produce overheating of machine tool, surface finishing of material, tool wear and life Span of machine assets are also decreasing. In order to reduce or decrease these parameters, using a coolant or a lubricant to minimize the damage. But sometimes the lubricant or coolant used in the machining process are of high cost and health hazardous to workers and to the environment and some fluids are flammable. To avoid these problems using ecofriendly edible oils which doesn't harm the environment as well as the workers. For this selecting cotton seed oil as a lubricant because it has high thermal conductivity, low viscosity and economically cheap.

CHAPTER 4

EXPERIMENATATION

4.1 SELECTION OF WORK MATERIAL

STAINLESS STEEL 303 alloy the study focuses on this material which has good corrosion resistance and is commonly used in industrial applications and automobile parts. The research aims to identify the most effective parametric combination through experimental investigation and analysis of different combinations.

Table 4.1 Chemical composition of SS 303

Element	**C**	**Mn**	**P**	**S**	**Si**	**Cr**	**Ni**	**N2**	**Iron**
%	0.15	2.00	0.20	0.15	1.00	19.00	10.00	0.1	Bal

The work piece dimensions are length mm and diameter 30mm.

Table No: 4.2 Mechanical and Thermal properties of Material

Mechanical Properties	
Density(g/cc)	8.03
Poison’s ratio	0.30
Elastic Modulus (GPa)	193-200
Ultimate Tensile Strength (MPa)	500-750
Yield Point (MPa)	190-310
Elongation at break (%)	60
Hardness (HRC) BRINELL	140
Thermal Properties	
Melting Point(^{0}C)	1400-1450
Thermal Conductivity(W/m.K)	16.2
Specific Heat(J/Kg/K)	500

4.2 EQUIPMENT USED

This chapter reports briefly about the equipment's used for experimentation on turning of SS304 under MQL.

The following equipment were used namely

- LATHE (all geared head) as in Fig 4.4.1
- MQL setup as in Fig 4.4.2
- IR Camera Setup as in Fig 4.4.3
- Dynamometer as in Fig 4.5.4
- Cemented Carbide tool insert as in Fig 4.5.5

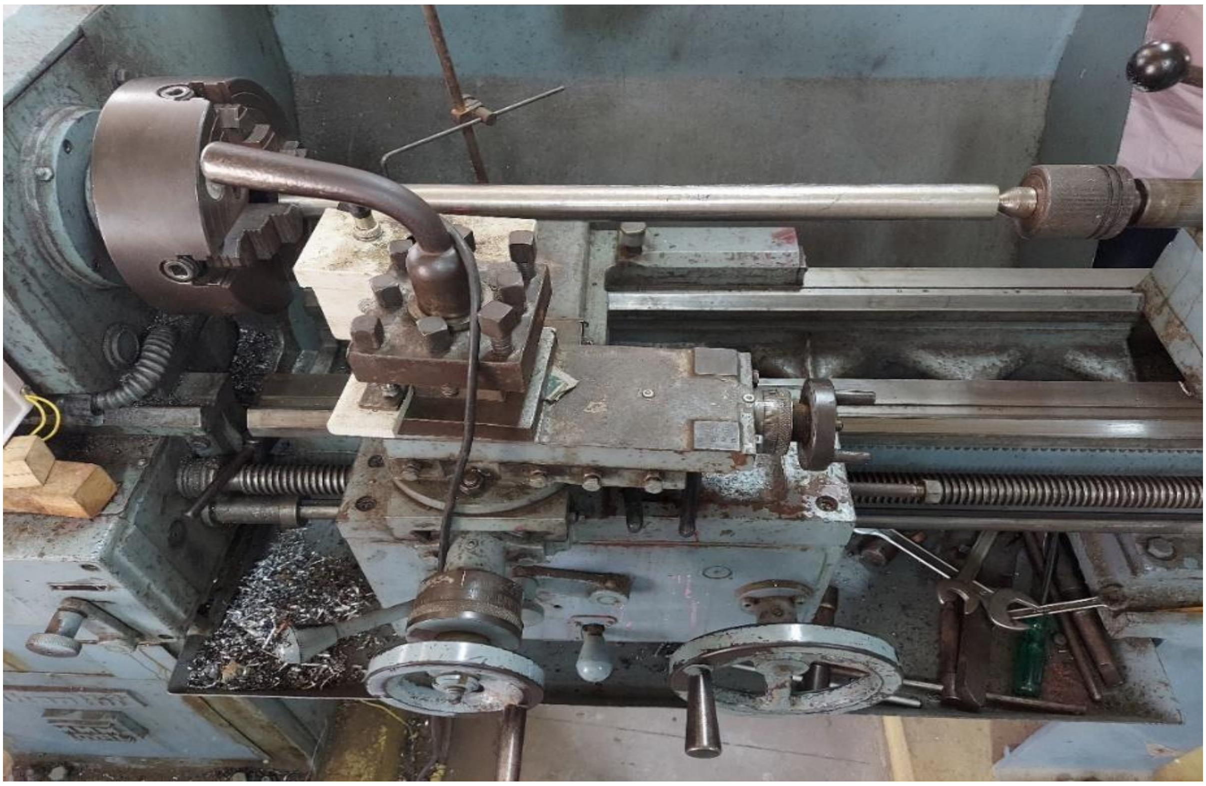


Fig 4.1 Lathe (All Geared Head)

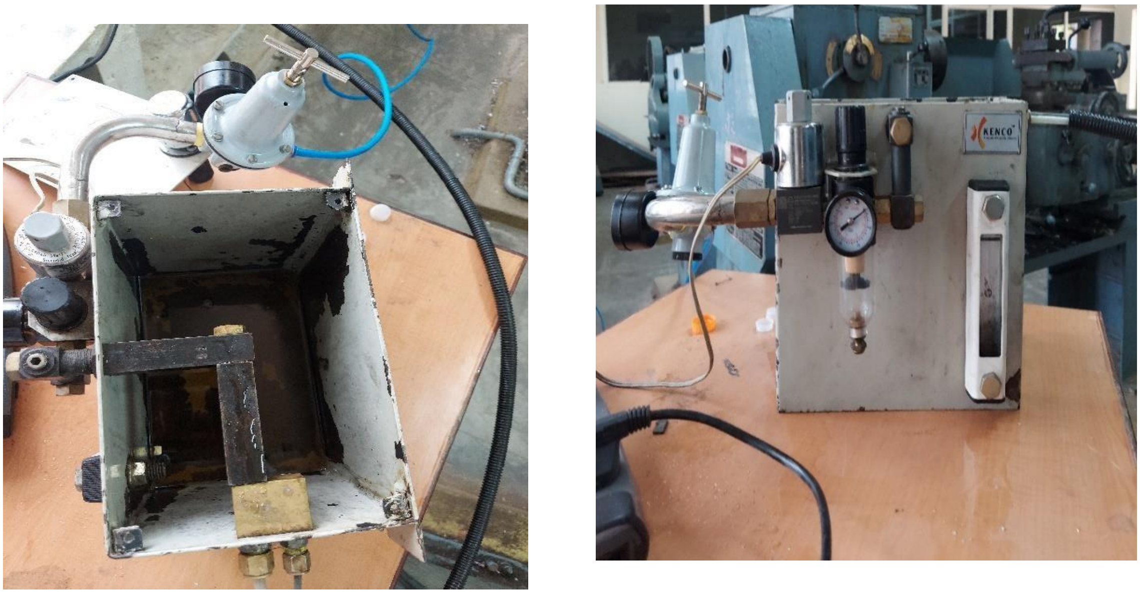


Fig 4.2 MQL Setup

Fig 4.3 IR gun

Fig 4.4 Dynamometer

Fig 4.5 Cemented Carbide Tool Insert

4.3 EXPERIMENTAL ANALYSIS

Experimentation on lathe all geared head were carried out under MQL of cotton seed oil. In the present study, SS303 is considered as the workpiece material to study the influence of process parameters such as speed, feed, depth of cut on cutting forces, machining cost and tool tip temperature of different flow rates at 120 ml/hr and 240 ml/hr. Experiments (9) were carried out for different speed, feed and depth of cut. The values are tabulated in the table 4.5.2

4.4 MEASUREMENT OF CUTTING FORCES

Cutting forces has been measured by using dynamometer as shown in Fig 4.4.4. Cutting forces values are tabulated in Table 4.6.1 are the forces recorded.

4.5 CALCULATION OF MACHINING COST

Table 4.5.1 Machining Parameters and their Levels

Input Parameters	**Level 1**	**Level 2**	**Level 3**
Speed (RPM)	465	740	1000
Feed(mm/rev)	0.101	0.299	0.511
DOC (mm)	0.4	0.8	1.2

Table 4.5.2 Experimental input parameters for both 120 and 240

S.No	**SPEED (RPM)**	**FEED (mm/rev)**	**D.O.C (mm)**
1	465	0.101	0.4
2	465	0.299	0.8

3	465	0.511	1.2
4	740	0.299	0.4
5	740	0.511	0.8
6	740	0.101	1.2
7	1000	0.511	0.4
8	1000	0.101	0.8
9	1000	0.299	1.2

Table 4.5.3 Measurement of Tool temperatures for 120 and 240ml/hr

S.No	TOOL TEMPERATURE (120 ml/hr)	TOOL TEMPERATURE (240 ml/hr)
1	64.8	48
2	44	36.6
3	53.6	42.4
4	43.4	38.6
5	55.6	50.2
6	55.1	52.8
7	49.5	40.2
8	68.4	57.2
9	53.2	49.4

Table 4.5.4 Measurement of Cutting forces for 120ml/hr and 240ml/hr

S.No	**MQL Mist 120 ml/hr**			**MQL Mist 240 ml/hr**		
	F(x) Feed Force	**F(y) Thrust Force**	**F(z) Cutting Force**	**F(x) Feed Force**	**F(y) Thrust Force**	**F(z) Cutting Force**
1	727	133	120	491	111	80
2	533	135	393	484	113	111
3	875	151	998	755	129	427
4	407	86	479	236	50	362
5	443	110	569	388	82	340
6	697	190	283	480	157	205
7	417	64	161	196	59	132
8	651	183	335	489	120	301
9	495	105	590	439	100	535

CHAPTER 5

RESULTS AND DISCUSSIONS

This chapter reports about the experimental results obtained and corresponding results and discussions

5.1 EXPERIMENTAL RESULTS

The study conducted experiments on lathe using cotton seed oil as MQL to investigate the impact of process parameters (speed, feed, depth of cut) on cutting forces and tool tip temperature when using SS303 as workpiece material.

Selection of Orthogonal Array-Taguchi Method: -

Design of Experiments (DOE) is a statistical technique for systematically planning and carrying out experiments to examine the impact of various variables on the response of a process or product. The use of Orthogonal Arrays is a key tool in Taguchi Methods. An orthogonal array is a collection of carefully chosen experimental combinations that provide a balanced representation of all the possible combinations of the levels of the factors being studied while reducing the number of experimental runs required.

The L9 array is a common Orthogonal Array for three input parameters (cutting seed, feed rate, DoC). This array has 9 rows and 3 columns and is used when three factors are studied at three levels each as shown in Table. The results were analyzed statistically to determine which factors have the greatest influence on the response and to identify any interactions between the factors. This data can be used to improve the process or product by adjusting the levels of the variables to achieve the desired result.

In overview, the use of Taguchi Methods and Orthogonal Arrays for three input parameters provides a structured approach for systematically identifying the factors that influence a process or product's response and optimizing the levels of these factors to achieve the desired outcome while minimizing the number of experimental runs required.

Table 5.1.1 Input Parameters

SI No	Speed (RPM)	Feed (mm/rev)	DoC (mm)
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

5.2 GREY RELATION ANALYSIS (120ml/hr)

Gray Relational Analysis (GRA) is a multi-criteria decision-making method that uses grey relational coefficients to measure the degree of association between a reference series and a comparison series. It is widely used in engineering, management, and other fields to evaluate and optimize complex systems. Here are the steps involved in GRA and the formulas used:

Step 1: Normalize the data

Convert the original data into dimensionless values between 0 and 1 using a normalization formula such as:

x_ij = (x_ij - min(x_j))/(max(x_j) - min(x_j)) where x_ij is the original value of the ith factor for the jth alternative, min(x_j) and max(x_j) are the minimum and maximum values of the jth factor, respectively.

Step 2: Calculate the grey relational coefficients

Calculate the grey relational coefficient (GRC) between each alternative (i.e., factor) and the reference series as follows:

δ_ij = |y_j - x_ij| / (Σ|y_j - x_ij|) where δ_ij is the grey relational coefficient between the ith factor and the jth alternative, Σ is the sum of the absolute differences between y_j and x_ij across all alternatives.

Step 3: Calculate the grey relational grade

Calculate the grey relational grade (GRG) for each alternative by averaging the GRCs across all factors: $\xi_i = \Sigma\delta_{ij} / n$ where ξ_i is the grey relational grade for the ith alternative, n is the number of factors.

Step 4: Rank the alternatives

Rank the alternatives based on their grey relational grades, with higher grades indicating better performance.

The output parameters are optimized using individual optimality and Grey Relation Analysis (GRA). The table 5.2.1 represents input parameters and output parameters which are obtained from experimentation. the table 5.2.2 and 5.2.3 represents normalization and Deviation Sequence of responses respectively using GRA. The values Obtained for output responses are to be normalized using Minitab software.

The values Obtained for output responses are to be normalized using Minitab software. The below values Obtained as output responses are to be normalized using Minitab software and reported in table 5.2.2 further carried out the deviations in comparisons with experimental values were also reported table 5.2.3

The obtained normalized and deviation values are further validated for finding grey relation coefficient is reported in 5.2.4 Gray Relational Grade and Rank. The values are reported in table 5.2. 5. it is inferred that the experiment number 4 is having rank 1 for flow rate 120ml/hr. which is best optimum COMBINATION OF INPUT parameters (speed, feed and depth of cut).

It is further observed that the experiment number 7 and 2 are having ranks of 2 and 3 respectively for flow rate 120ml/hr. which are also another set of optimum set of combination of input values.

Table 5.2.1 Mist 120ml/hr

SI.No	Actual parameters			Responses			
	Speed (RPM)	Feed (mm/rev)	DoC (mm)	Tool Temp (ºC)	f(x) Feed Force (N)	f(y) Thrust force (N)	f(z) cutting force (N)
1	465	0.101	0.4	64.8	727	133	120
2	465	0.299	0.8	44	533	135	393
3	465	0.511	1.2	53.6	875	151	998
4	740	0.299	0.4	43.4	407	86	479
5	740	0.511	0.8	55.6	443	110	569
6	740	0.101	1.2	55.1	697	190	283
7	1000	0.511	0.4	49.5	417	64	161
8	1000	0.101	0.8	68.4	651	183	335
9	1000	0.299	1.2	53.2	495	105	590

Table 5.2.2. Normalization of Responses Using GRA

Tool Temp(ºC)	f(x) Feed Force	f(y) Thrust Force	F(z) Cutting Force
0.144	0.316	0.452	1.000
0.976	0.731	0.437	0.689
0.592	0.000	0.310	0.000
1.000	1.000	0.825	0.591
0.512	0.923	0.635	0.489
0.532	0.380	0.000	0.814
0.756	0.979	1.000	0.953
0.000	0.479	0.056	0.755
0.608	0.812	0.675	0.465

Table 5.2.3 Deviation Sequence of Responses Using GRA

SI No	Tool Temp (^oC)	f(x) Feed Force	f(y) Thrust Force	F(z) Cutting Force
1	0.856	0.684	0.548	0.000
2	0.024	0.269	0.563	0.311
3	0.408	1.000	0.690	1.000
4	0.000	0.000	0.175	0.409
5	0.488	0.077	0.365	0.511
6	0.468	0.620	1.000	0.186
7	0.244	0.021	0.000	0.047
8	1.000	0.521	0.944	0.245
9	0.392	0.188	0.325	0.535

Table 5.2.4 Grey Relation Coefficient

Si No	Tool Temp (^OC)	F(X) Feed Force (N)	F(Y) Thrust Force (N)	F(Z) Cutting Force (N)
1	0.369	0.422	0.477	0.333
2	0.954	0.650	0.470	0.420
3	0.551	0.333	0.420	1.000
4	1.000	1.000	0.741	0.458
5	0.506	0.867	0.578	0.506
6	0.517	0.447	0.333	0.380
7	0.672	0.959	1.000	0.344
8	0.333	0.490	0.346	0.398
9	0.561	0.727	0.606	0.518

Table 5.2.5 Grey Relational Grade and Rank

SI No	GRG	Rank
1	0.400	8
2	0.624	3
3	0.576	6
4	0.800	1
5	0.614	4
6	0.419	7
7	0.744	2
8	0.392	9
9	0.603	5

5.3 GREY RELATION ANALYSIS (240 ml/hr)

The output parameters are optimized using grey relation analysis for flow rate 240 ml/hr. The input parameters and output parameters after the experimentation are reported in table 5.3.1. Normalization of responses are reported in table 5.3.2. Deviation Sequences of responses are reported in table 5.3.3. Gray Relation Coefficient of responses are reported in table 5.3.4. Gray
Relational Grade and Rank are represented in table 5.3.3

Table 5.3.1 Responses for Mist 240 ml/hr

SI No	Speed (RPM)	Feed (mm/rev)	Doc (mm)	Tool Temp (^{O}C)	F(X) Feed Force (N)	F(Y) Thrust Force(N)	F(Z) Cutting Force (N)
1	465	0.101	0.4	48	491	111	80
2	465	0.299	0.8	36.6	484	113	111

3	465	0.511	1.2	42.4	755	129	427
4	740	0.299	0.4	38.6	236	50	362
5	740	0.511	0.8	50.2	388	82	340
6	740	0.101	1.2	52.8	480	157	205
7	1000	0.511	0.4	40.2	196	59	132
8	1000	0.101	0.8	57.2	489	120	301
9	1000	0.299	1.2	49.4	439	100	535

Table 5.3.2. Normalization of Responses Using GRA

SI No	**Tool Temp (^{O}C)**	**F(X) Feed Force (N)**	**F(Y) Thrust Force (N)**	**F(Z) Cutting Force (N)**
1	0.447	0.472	0.430	1.000
2	1.000	0.485	0.411	0.932
3	0.718	0.000	0.262	0.237
4	0.903	0.928	1.000	0.380
5	0.340	0.657	0.701	0.429
6	0.214	0.492	0.000	0.725
7	0.825	1.000	0.916	0.886
8	0.000	0.476	0.346	0.514
9	0.379	0.565	0.533	0.000

Table 5.3.3 Deviation Sequence of Responses Using GRA

SI No:	**Tool Temp (^{O}C)**	**F(X) Feed Force (N)**	**F(Y) Thrust Force(N)**	**F(Z) Cutting Force (N)**
1	0.553	0.528	0.570	0.000

2	0.000	0.515	0.589	0.068
3	0.282	1.000	0.738	0.763
4	0.097	0.072	0.000	0.620
5	0.660	0.343	0.299	0.571
6	0.786	0.508	1.000	0.275
7	0.175	0.000	0.084	0.114
8	1.000	0.524	0.654	0.486
9	0.621	0.435	0.467	1.000

Table 5.3.4 Grey Relation Coefficient

SI No	Tool Temp (ºC)	F(x) Feed Force (N)	F(y) Thrust Force (N)	F(z) Cutting Force (N)
1	0.475	0.487	0.467	0.333
2	1.000	0.493	0.459	0.349
3	0.640	0.333	0.404	0.678
4	0.837	0.875	1.000	0.568
5	0.431	0.593	0.626	0.538
6	0.389	0.496	0.333	0.408
7	0.741	1.000	0.856	0.361
8	0.333	0.488	0.433	0.493
9	0.446	0.535	0.517	1.000

Table 5.3.5 Grey Relational Grade and Rank

SI No	Grey Relation Grade	Rank
1	0.440	7
2	0.575	4
3	0.514	6

4	**0.820**	**1**
5	0.547	5
6	0.407	9
7	0.739	2
8	0.437	8
9	0.624	3

5.4 INDIVIDUAL OPTIMALITY

The tabulated response values thus generated while machining Stainless steel material using Taguchi DOE L27 experiments are taken for determining individual response (Tt, Ra, MRR) using signal-to-noise (S/N) ratios. S/N ratios are calculated using equations,

$$(S/N)_{\text{Smaller-is-Better}} = -10\log\left(\frac{1}{n}\sum_{i=1}^{n} y_i^2\right)$$

$$(S/N)_{\text{Lager-is-Better}} = -10\log\left(\frac{1}{n}\sum_{i=1}^{n} 1/y_i^2\right)$$

The calculated S/N ratios are used to determine the individual optimality of the generated responses basing on the equations.

$\eta_{\text{optimum}} = \eta_{\text{average}} + \sum_{i=1}^{n}(\eta_{\text{ideal}} - \eta_{\text{average}})$

$$\text{Response}_{\text{optimum}} = \sqrt{10 \pm \frac{\eta_{\text{optimum}}}{10}}$$

Where ‘n’ is observation number, η opt is optimum S/N ratio, η avg is average S/N ratio, η ideal is ideal level of each S/N ratio parameter.
Sample calculation of individual optimality of Tool tip temperature

The average of S/N ratio (η average) = -34.58

Response table for S/N rations for Tool tip temperature (Smaller is better)

Table 5.4.1 Calculation of Individual Optimality of Tool Tip Temperature

Level	Speed	Feed	DoC
1	-34.56	-35.92	-34.29
2	-34.16	-33.3	-34.82

3	-35.04	-34.46	-34.64

OPTIMAL DESIGN: A2-B2-C1

The S/N ideal speed (η ideal speed) = -34.16

The S/N ideal feed (η ideal feed) = -33.3

The S/N ideal depth of cut (η ideal doc) = -34.29

η optimum = η average + Σi=1 n (η ideal – η average)

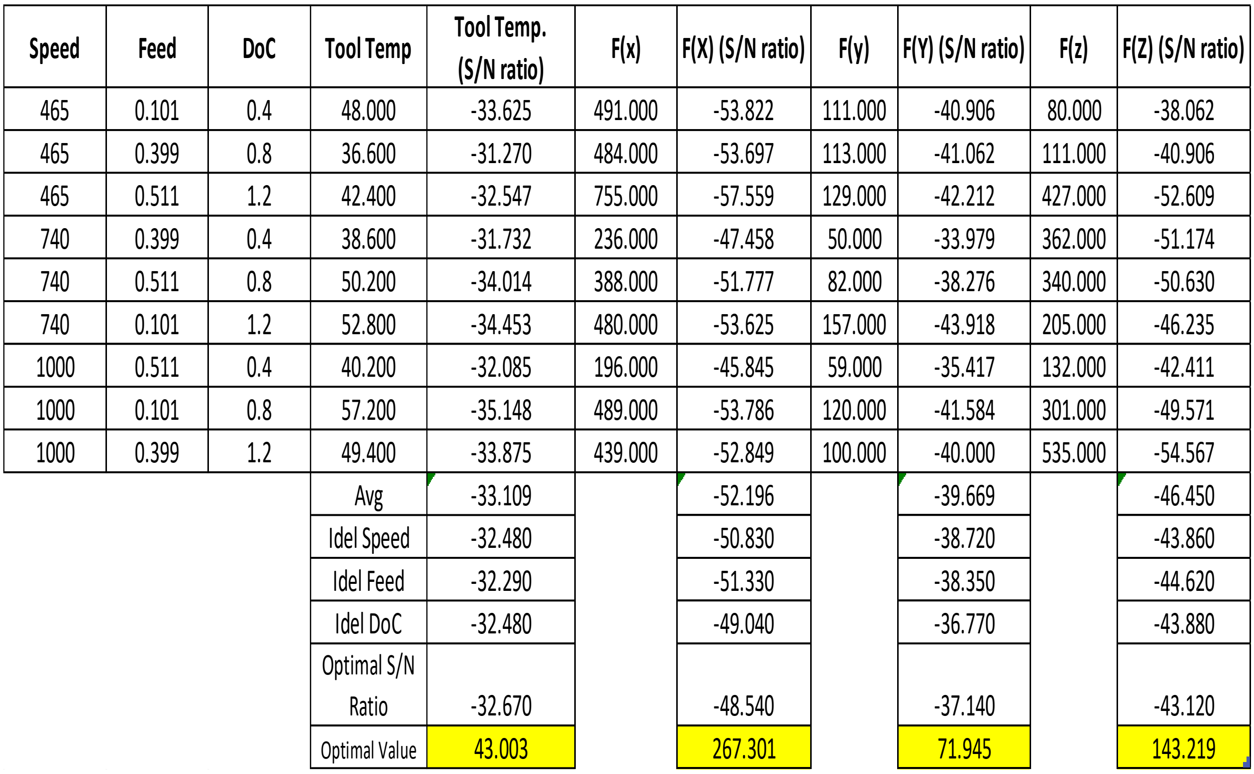
= -34.58+(((-34.16-(-35.58)) +(-33.3-(-35.58)) +(-34.29-(-34.29))) = -32.65

Response optimum = (10 ± η_{optimum} /10) ^0.5 = (10((32.65/10)) ^0.5 = 42.94

Table 5.4.2 Individual Optimal Values of Tool Tip Temperature and cutting forces Using SN Ratio for 120ml/hr flow rate.

Speed	Feed	DoC	Tool Temp	Tool Temp. (S/N ratio)	F(x)	F(X) (S/N ratio)	F(y)	F(Y) (S/N ratio)	F(z)	F(Z) (S/N ratio)
465	0.101	0.4	64.8	-36.2315	727	-57.231	133	-42.477	120	-41.584
465	0.399	0.8	44	-32.869054	533	-54.535	135	-42.607	393	-51.888
465	0.511	1.2	53.6	-34.583296	875	-58.840	151	-43.580	998	-59.983
740	0.399	0.4	43.4	-32.749795	407	-52.192	86	-38.690	479	-53.607
740	0.511	0.8	55.6	-34.901496	443	-52.928	110	-40.828	569	-55.102
740	0.101	1.2	55.1	-34.823032	697	-56.865	190	-45.575	283	-49.036
1000	0.511	0.4	49.5	-33.892104	417	-52.403	64	-36.124	161	-44.137
1000	0.101	0.8	68.4	-36.701122	651	-56.272	183	-45.249	335	-50.501
1000	0.399	1.2	53.2	-34.518233	495	-53.892	105	-40.424	590	-55.417
			Avg	-34.585514		-55.017		-41.728		-51.250
			Idel Speed	-34.16		-53.990		-40.600		-50.020
			Idel Feed	-33.38		-53.540		-40.180		-53.070
			Idel DoC	-34.29		-53.940		-42.980		-52.500
			Optimal S/N Ratio	-32.658971		-51.435		-40.304		-53.089
			Optimal Value	42.9485543		373.045		103.560		451.29

Table 5.4.3 Individual Optimal Values of Tool Tip Temperature and cutting forces Using SN Ratio for 240ml/hr flow rate.



Speed	Feed	DoC	Tool Temp	Tool Temp. (S/N ratio)	F(x)	F(X) (S/N ratio)	F(y)	F(Y) (S/N ratio)	F(z)	F(Z) (S/N ratio)
465	0.101	0.4	48.000	-33.625	491.000	-53.822	111.000	-40.906	80.000	-38.062
465	0.399	0.8	36.600	-31.270	484.000	-53.697	113.000	-41.062	111.000	-40.906
465	0.511	1.2	42.400	-32.547	755.000	-57.559	129.000	-42.212	427.000	-52.609
740	0.399	0.4	38.600	-31.732	236.000	-47.458	50.000	-33.979	362.000	-51.174
740	0.511	0.8	50.200	-34.014	388.000	-51.777	82.000	-38.276	340.000	-50.630
740	0.101	1.2	52.800	-34.453	480.000	-53.625	157.000	-43.918	205.000	-46.235
1000	0.511	0.4	40.200	-32.085	196.000	-45.845	59.000	-35.417	132.000	-42.411
1000	0.101	0.8	57.200	-35.148	489.000	-53.786	120.000	-41.584	301.000	-49.571
1000	0.399	1.2	49.400	-33.875	439.000	-52.849	100.000	-40.000	535.000	-54.567
			Avg	-33.109		-52.196		-39.669		-46.450
			Idel Speed	-32.480		-50.830		-38.720		-43.860
			Idel Feed	-32.290		-51.330		-38.350		-44.620
			Idel DoC	-32.480		-49.040		-36.770		-43.880
			Optimal S/N Ratio	-32.670		-48.540		-37.140		-43.120
			Optimal Value	43.003		267.301		71.945		143.219

Table 5.4.4 Taguchi Analysis: f(x) versus speed, feed, DoC

Response Table for Signal to Noise Ratios

Smaller is better

Level	Speed	Feed	DOC	Optimal design
1	-56.87	-56.79	-53.94	**A2-B2-C1**
2	-53.99	-53.54	-54.58	
3	-54.19	-54.72	-56.53	

Table 5.4.5 Taguchi Analysis: f(y) versus speed, feed, DoC

Response Table for Signal to Noise Ratios

Smaller is better

Level	**Speed**	**Feed**	**DOC**	**Optimal design**
1	-42.89	-44.43	-39.10	**A3-B3-C1**
2	-41.70	-40.57	-42.89	
3	-40.60	-40.18	-43.19	

Table 5.4.6 Taguchi Analysis: f(z) versus speed, feed, DoC

Response Table for Signal to Noise Ratios

Smaller is better

Level	**Speed**	**Feed**	**DOC**	**Optimal design**
1	-51.15	-47.04	-46.44	**A3-B3-C2**
2	-52.58	-53.64	-52.50	
3	-50.02	-53.07	-54.81	

Table 5.4.7 Final Set of Individual Optimal Values and Process Parameters in Machining

	Optimal Design			**T_T**	**F(x)**	**F(y)**	**F(z)**
Tool temp(°c)	**f(x) Feed Force**	**f(y) Thrust force**	**F(z) cutting force**				
A2-B2-C1	**A2-B2-C1**	**A3-B3-C1**	**A3-B3-C2**	43.033	267.3	71.944	143.21

5.5 GENETIC ALGORITHM (GA):

A genetic algorithm (GA) is a search-based optimization algorithm inspired by the process of natural selection. It is a type of evolutionary algorithm that uses the principles of genetics and natural selection to find solutions to problems.

Step 1: Initialization

The first step in a genetic algorithm is to create an initial population of candidate solutions. In this case, we randomly generate a population of 50 solutions.

Step 2: Evaluation

We evaluate each candidate solution by computing its fitness score, which is the value of the objective function we want to optimize. In this case.

Step 3: Selection

We use a selection mechanism to choose the best solutions from the population to be parents for the next generation. In this case, we use tournament selection, where we randomly select two solutions from the population and choose the one with the highest fitness score to be a parent.

Step 4: Crossover

We use crossover to create new solutions by combining the genetic information of two parents. In this case, we use one-point crossover, where we randomly choose a point in the solution and swap the genetic information of the parents before and after that point.

Step 5: Mutation

We introduce random mutations to the new solutions to increase the diversity of the population. In this case, we randomly select a small percentage of the solutions and replace their values with a new random value in the range.

Step 6: Repeat

We repeat steps 2 to 5 for a number of generations or until a termination criterion is met. In this case, we repeat the process for 100 generations.

Step 7: Termination

The terminate algorithm when a certain criterion is met. In this case, we stop the algorithm when the fitness score of the best solution in the population does not improve for a certain number of generations.

The fitness functions are generated with references of experimental values by using mini-tab software for tool temperature and cutting forces at 120ml/hr and 240ml/hr flow rates respectively. The fitness function for tool temperature and cutting forces (f_x, f_y ,f_z) are represented in the below equations.

1) $z1=59.0+0.0053*x(1)-30.1*x(2)+1.75*x(3)$

fitness function for tool temperature at 120ml/hr

2) $z2=519-0.381*x(1)-147*x(2)+313*x(3)$

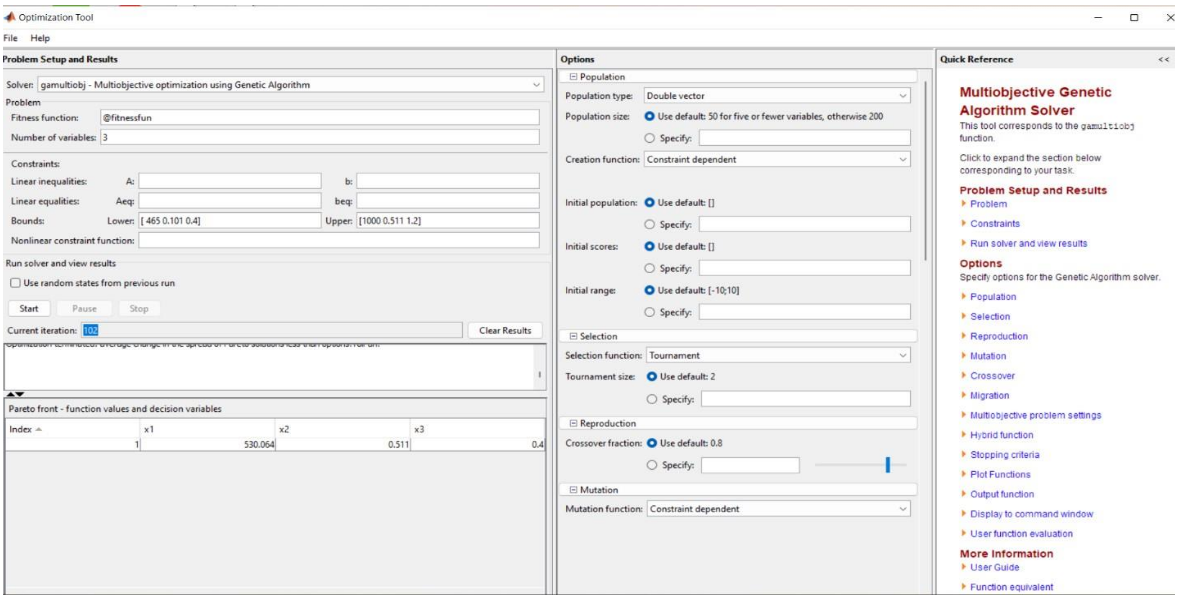
fitness function for feed force at 120ml/hr

3) $z3=137.1-0.0543*x(1)-129*x(2)+27.5*x(3)$

fitness function for Thrust force at 120ml/hr

4) $z4=182+0.105*x(1)+9*x(2)+77*x(3)$

fitness function for cutting force at 120ml/hr



Problem Setup and Results

Solver: gamultiobj - Multiobjective optimization using Genetic Algorithm

Problem
Fitness function: @fitnessfun
Number of variables: 3

Constraints:
Linear inequalities: A: b:
Linear equalities: Aeq: beq:
Bounds: Lower: [465 0.101 0.4] Upper: [1000 0.511 1.2]
Nonlinear constraint function:

Run solver and view results
☐ Use random states from previous run
Current iteration: 102

Pareto front - function values and decision variables

Index	x1	x2	x3
1	530.064	0.511	0.4

Options

Population
Population type: Double vector
Population size: ● Use default: 50 for five or fewer variables, otherwise 200
○ Specify:
Creation function: Constraint dependent
Initial population: ● Use default: []
○ Specify:
Initial scores: ● Use default: []
○ Specify:
Initial range: ● Use default: [-10;10]
○ Specify:

Selection
Selection function: Tournament
Tournament size: ● Use default: 2
○ Specify:

Reproduction
Crossover fraction: ● Use default: 0.8
○ Specify:

Mutation
Mutation function: Constraint dependent

Multiobjective Genetic Algorithm Solver

This tool corresponds to the `gamultiobj` function.

Click to expand the section below corresponding to your task.

Problem Setup and Results
- Problem
- Constraints
- Run solver and view results

Options

Specify options for the Genetic Algorithm solver.
- Population
- Selection
- Reproduction
- Mutation
- Crossover
- Migration
- Multiobjective problem settings
- Hybrid function
- Stopping criteria
- Plot Functions
- Output function
- Display to command window
- User function evaluation

More Information
- User Guide
- Function equivalent

Fig 5.1 genetic algorithm optimization at 120 ml/hr

The genetic algorithm was used to optimize the system's performance at a flow rate of 120 ml/hr and the optimum conditions for the system were found to be a speed of 530.064, feed of 0.511, and DoC of 0.4.

The success of the genetic algorithm in identifying the optimum conditions suggests that this method is an effective tool for optimizing the system's performance at this specific flow rate

1) $z1=37.22 + 0.01239*x (1) - 20.1*x (2) + 7.42*x(3)$

fitness function for tool temperature at 240 ml/hr

2) $z2= 498 - 0.381*x (1) - 94*x (2) + 313*x (3)$

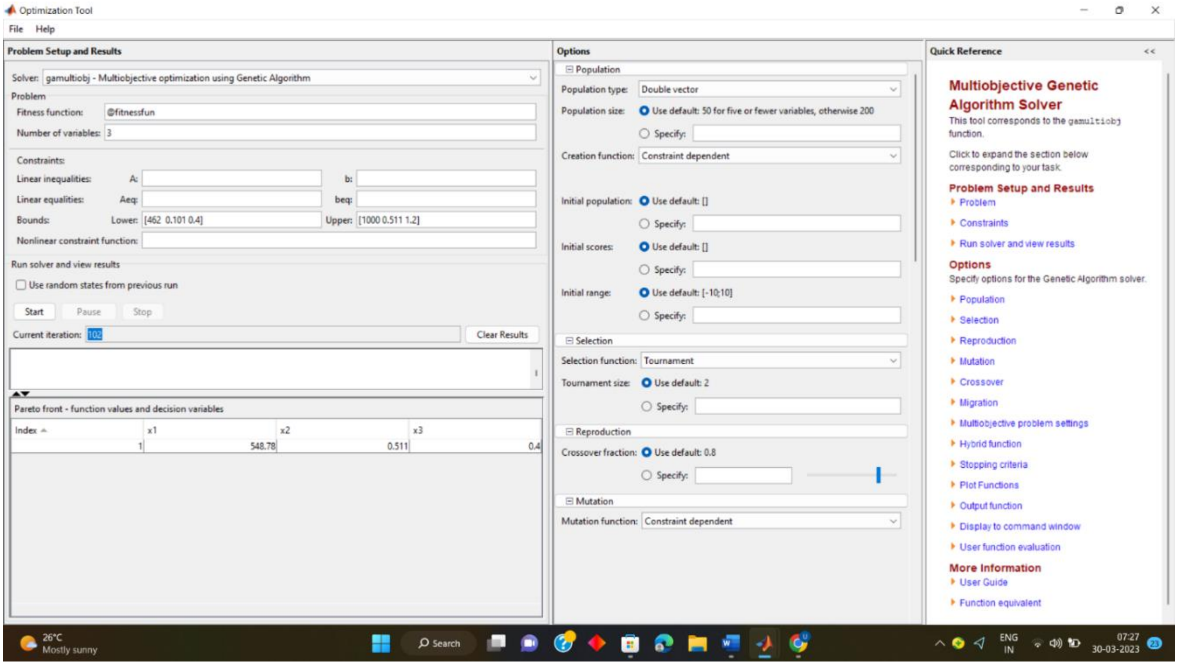
fitness function for feed force at 240 ml/hr

3) $z3= 109.9 - 0.0464*x (1) - 94.7*x (2) + 69.2*x (3)$

fitness function for thrust force at 240 ml/hr

4) $z4= -158 + 0.219*x (1) + 249*x (2) + 247*x (3)$

fitness function for cutting force at 240 ml/hr



Solver: gamultiobj - Multiobjective optimization using Genetic Algorithm

Problem

Fitness function: @fitnessfun

Number of variables: 3

Constraints:

Linear inequalities: A: b:

Linear equalities: Aeq: beq:

Bounds: Lower: [462 0.101 0.4] Upper: [1000 0.511 1.2]

Nonlinear constraint function:

Run solver and view results

☐ Use random states from previous run

Current iteration: 102

Pareto front - function values and decision variables

Index	x1	x2	x3
1	548.78	0.511	0.4

Population

Population type: Double vector

Population size: ● Use default: 50 for five or fewer variables, otherwise 200 ○ Specify:

Creation function: Constraint dependent

Initial population: ● Use default: [] ○ Specify:

Initial scores: ● Use default: [] ○ Specify:

Initial range: ● Use default: [-10;10] ○ Specify:

Selection

Selection function: Tournament

Tournament size: ● Use default: 2 ○ Specify:

Reproduction

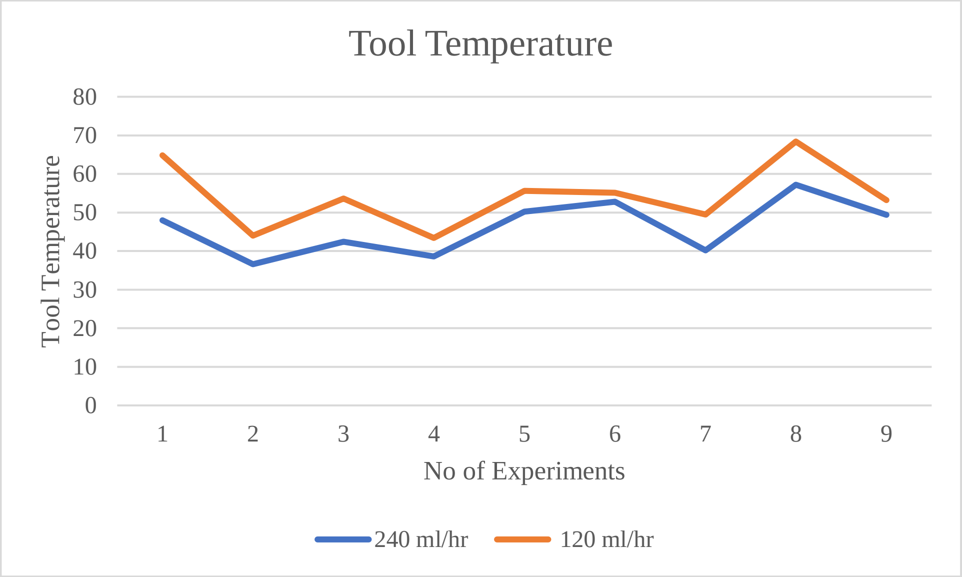
Crossover fraction: ● Use default: 0.8 ○ Specify:

Mutation

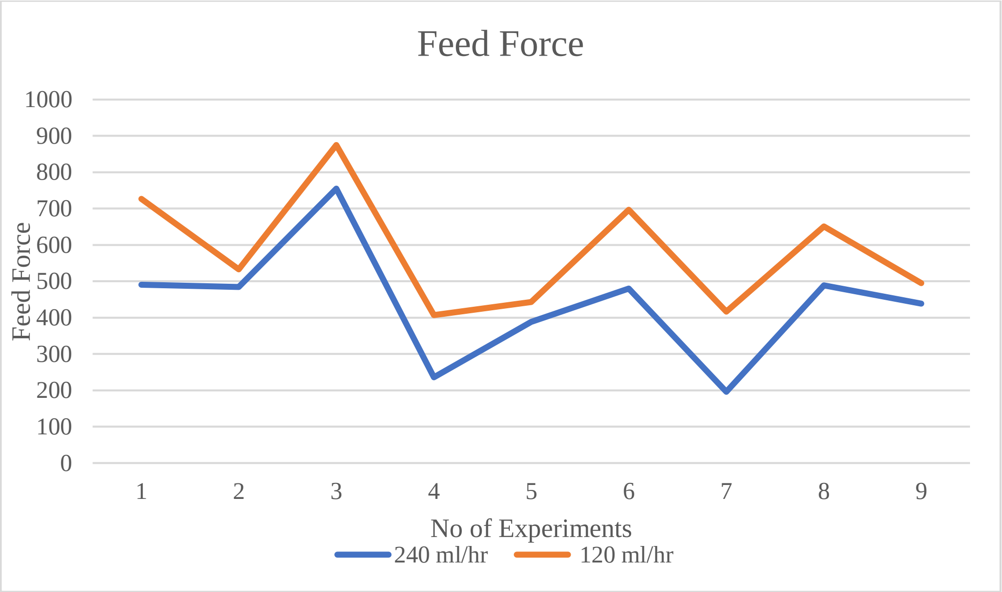
Mutation function: Constraint dependent

Fig 5.2 genetic algorithm optimization at 240ml/hr

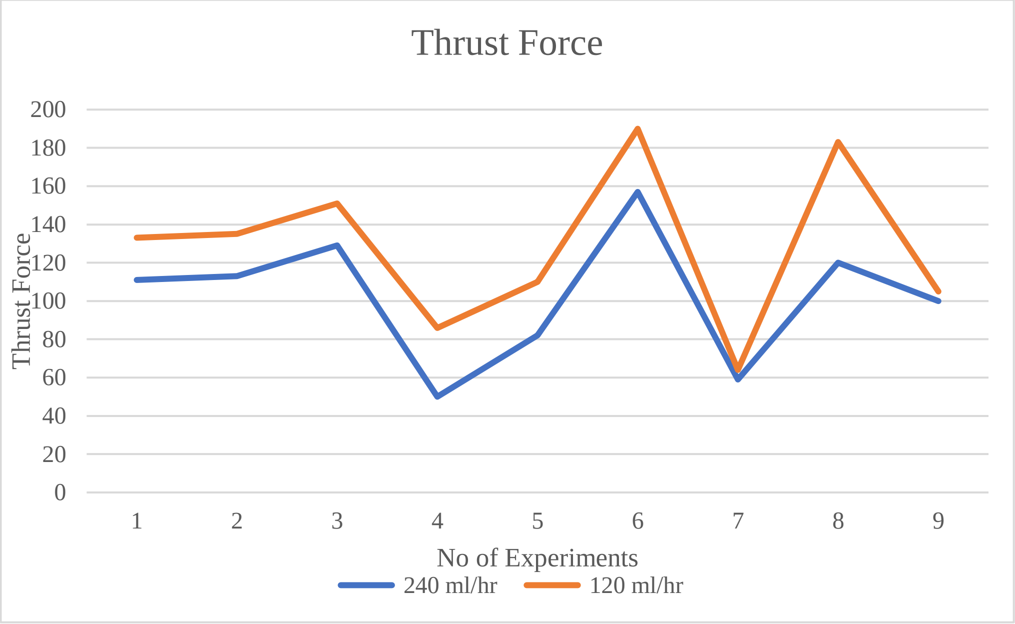
The genetic algorithm applied in this study has been effective in identifying the optimal process parameters for a flow rate of 240 ml/hr. The results showed that the optimum conditions were achieved at a speed of 548, a feed rate of 0.511, and a depth of cut of 0.4. The genetic algorithm proved to be a reliable and efficient tool in optimizing complex manufacturing processes, which can result in significant improvements in productivity and cost-effectiveness. This study demonstrates the potential of using genetic algorithms in various industrial applications to optimize manufacturing processes and achieve optimal results.



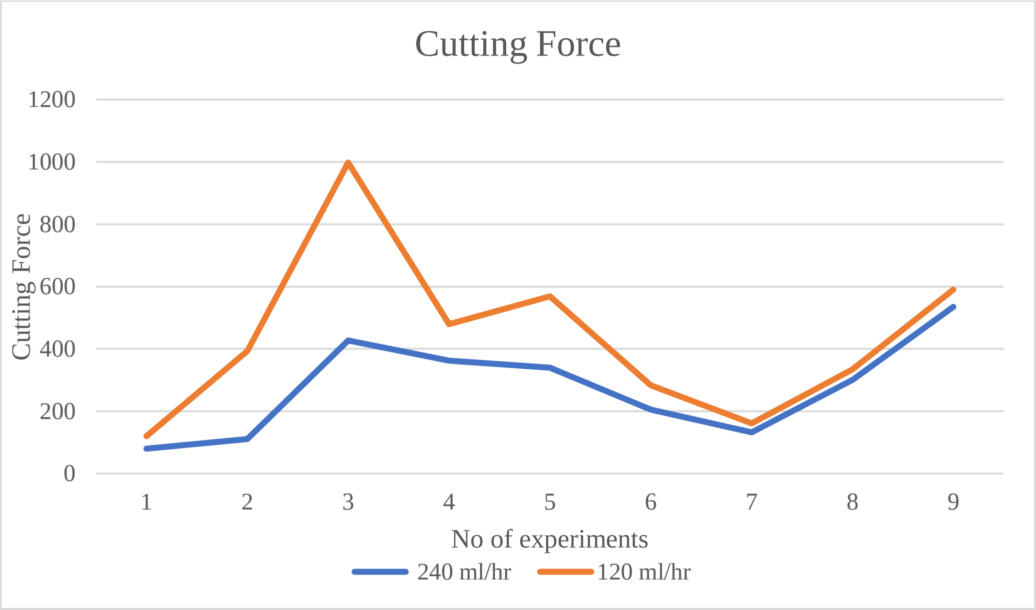
The temperature analysis performed for turning operation at a flow rate of 120 ml/hr and 240 ml/hr has revealed that the temperatures are higher for the 120 ml/hr flow rate than for the 240 ml/hr flow rate. Therefore, it can be concluded that using a flow rate of 240 ml/hr for the turning operation is more efficient in terms of reducing the heat generated during the process. This study highlights the importance of selecting the appropriate flow rate for optimizing the turning operation and reducing the heat generated during the process. The results of this study can be useful in industrial applications to optimize the turning operation and achieve the desired machining results while minimizing the heat generated during the process



The analysis of feed force for turning operation at flow rates of 120 ml/hr and 240 ml/hr has indicated that the feed force is higher for the 120 ml/hr flow rate compared to the 240 ml/hr flow rate. Based on this finding, it can be concluded that using a flow rate of 240 ml/hr is more efficient in terms of reducing the feed force during the turning operation. This study emphasizes the importance of selecting the appropriate flow rate for optimizing the turning operation and minimizing the feed force generated during the process. The results of this study can be useful for industrial applications to optimize the turning operation and achieve the desired machining results while minimizing the feed force generated during the process.



The analysis of thrust force for the turning operation at flow rates of 120 ml/hr and 240 ml/hr has shown that the thrust force is higher for the 120 ml/hr flow rate compared to the 240 ml/hr flow rate. Therefore, it can be concluded that using a flow rate of 240 ml/hr for the turning operation is more efficient in terms of reducing the thrust force generated during the process. This study highlights the importance of selecting the appropriate flow rate for optimizing the turning operation and minimizing the thrust force generated during the process. The findings of this study can be useful in industrial applications to optimize the turning operation and achieve the desired machining results while minimizing the thrust force generated during the process.



The analysis of cutting force for the turning operation at flow rates of 120 ml/hr and 240 ml/hr has revealed that the cutting force is higher for the 120 ml/hr flow rate compared to the 240 ml/hr flow rate. Based on this finding, it can be concluded that using a flow rate of 240 ml/hr for the turning operation is more efficient in terms of reducing the cutting force generated during the process. This study emphasizes the importance of selecting the appropriate flow rate for optimizing the turning operation and minimizing the cutting force generated during the process. The results of this study can be useful in industrial applications to optimize the turning operation and achieve the desired machining results while minimizing the cutting force generated during the process.

CHAPTER 6

CONCLUSION

6.1 BROAD CONCLUSION

The comparison of the results obtained from GRA and Genetic Algorithm for optimizing flow rates at different rates has provided useful insights into the performance of these two methods. The results suggested that both methods are effective in identifying the optimum conditions for the system and there are some differences in the specific values of the parameters obtained by each method.

At a flow rate of 120 ml/hr, GRA identified the optimum conditions as a speed of 465, feed of 0.299, and DoC of 0.4, while Genetic Algorithm found the optimum conditions as a speed of 530.064, feed of 0.511, and DoC of 0.4. Similarly, at a flow rate of 240 ml/hr, GRA identified the optimum conditions as a speed of 465, feed of 0.299, and DoC of 0.4, while Genetic Algorithm found the optimum conditions as a speed of 548.7, feed of 0.511, and DoC of 0.4.

In conclusion that both GRA and Genetic Algorithm are effective methods for optimizing flow rates, and the choice between them will depend on the specific requirements of the optimization problem at hand. In general, GRA may be more suitable for problems with a smaller optimization space, while Genetic Algorithm may be more effective for larger optimization spaces, after analyzing the various flow rates for machining, it can be inferred that the 240 ml/hr flow rate is the most suitable option for achieving better forces and tool temperature. This flow rate ensures a consistent and adequate supply of coolant to the cutting zone, which helps in reducing frictional forces and dissipating the heat generated during machining. As a result, the tool temperature is maintained within a desirable range, minimizing the chances of tool wear and damage. Additionally, the 240 ml/hr flow rate also helps in improving the overall machining efficiency. Hence, it can be considered as the ideal flow rate for achieving high-quality machining results.

6.2 FUTURE SCOPE OF WORK:

1. The experimentation may be conducted on different materials under the pressure of different MQL fluids which are eco-friendly.
2. The other optimizations techniques may adopt such as genetic logarithms, fuzzy, ANN techniques for optimizing process parameters.
3. There is potential for future research regarding the integration of nanoparticles in lubrication processes and the advancement of Minimum Quantity Lubrication (MQL) technology through the use of nanofluids for sustainable cutting processes.
4. It is necessary to publish a field survey on the practical implementation of MQL, and a suitable approach could be conducting a life cycle assessment

5 The incorporation of advanced computational algorithms and data science is crucial in integrating MQL-assisted machining with smart manufacturing techniques.

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APPENDIX

Problem Formulation

The gamultiobj solver attempts to create a set of Pareto optima for a multiobjective minimization. You may optionally set bounds or other constraints on variables. gamultiobj uses the genetic algorithm for finding local Pareto optima. As in the ga function, you may specify an initial population, or have the solver generate one automatically.

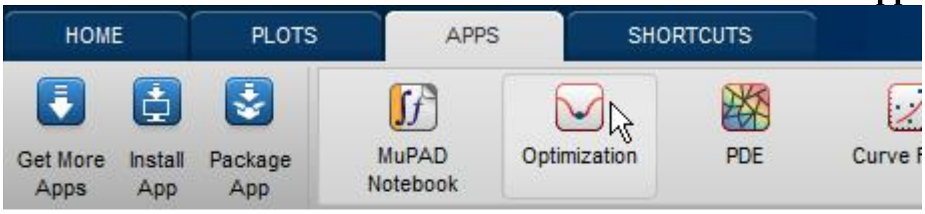
The fitness function for use in gamultiobj should return a vector of type double. The population may be of type double, a bit string vector, or can be a custom-typed vector. As in ga, if you use a custom population type, you must write your own creation, mutation, and crossover functions that accept inputs of that population type, and specify these functions in the following fields, respectively:

- **Creation function** (CreationFcn)
- **Mutation function** (MutationFcn)
- **Crossover function** (CrossoverFcn)

You can set the initial population in a variety of ways. Suppose that you choose a population of size *m*. (The default population size is 15 times the number of variables *n*.) You can set the population:

- As an *m*-by-*n* matrix, where the rows represent *m* individuals.
- As a *k*-by-*n* matrix, where $k < m$. The remaining $m – k$ individuals are generated by a creation function.
- The entire population can be created by a creation function.

- **Use gamultiobj with the Optimization app**

- You can access gamultiobj from the Optimization app. Enter
- optimtool('gamultiobj')
- at the command line, or enter optimtool and then choose gamultiobj from the **Solver** menu. You can also start the tool from the MATLAB® **Apps** tab.
- 

- If the **Quick Reference** help pane is closed, you can open it by clicking the ">>" button on the upper right: >>. The help pane briefly explains all the available options.
- You can create an options structure in the Optimization app, export it to the MATLAB workspace, and use the structure at the command line. For details, see Importing and Exporting Your Work in the Optimization Toolbox™ documentation.

Multiobjective Optimization with Two Objectives

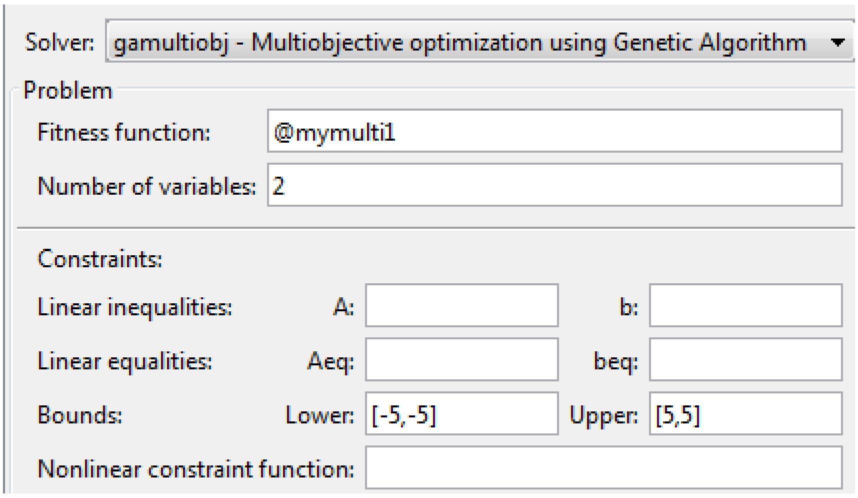
This example has a two-objective fitness function *f*(*x*), where *x* is also two-dimensional:

```
function f = mymulti1(x)


f(1) = x(1)^4 - 10*x(1)^2+x(1)*x(2) + x(2)^4 -(x(1)^2)*(x(2)^2);

f(2) = x(2)^4 - (x(1)^2)*(x(2)^2) + x(1)^4 + x(1)*x(2);
```

Create this function file before proceeding.

Performing the Optimization with Optimization App

1. To define the optimization problem, start the Optimization app, and set it as pictured.



Solver: gamultiobj - Multiobjective optimization using Genetic Algorithm

Problem

Fitness function: @mymulti1

Number of variables: 2

Constraints:

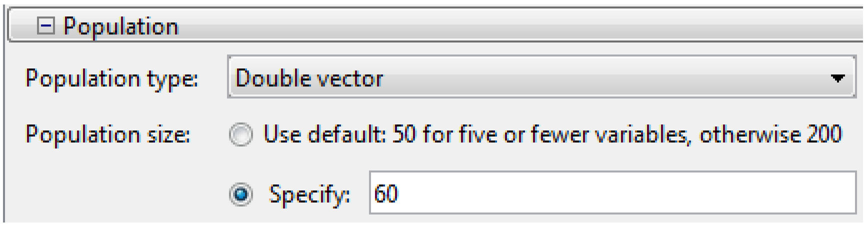
Linear inequalities: A: b:

Linear equalities: Aeq: beq:

Bounds: Lower: [-5,-5] Upper: [5,5]

Nonlinear constraint function:

2. Set the options for the problem as pictured.

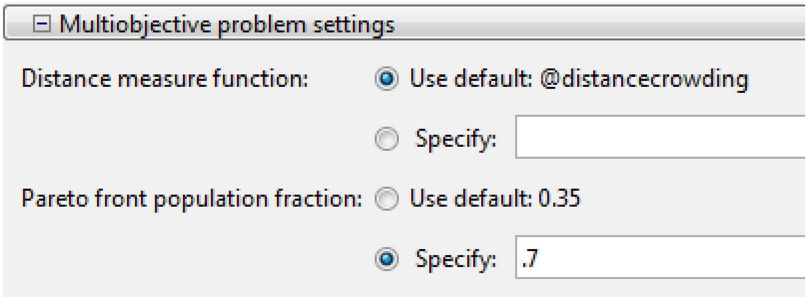


⊟ Population

Population type: Double vector

Population size: ○ Use default: 50 for five or fewer variables, otherwise 200

● Specify: 60



⊟ Multiobjective problem settings

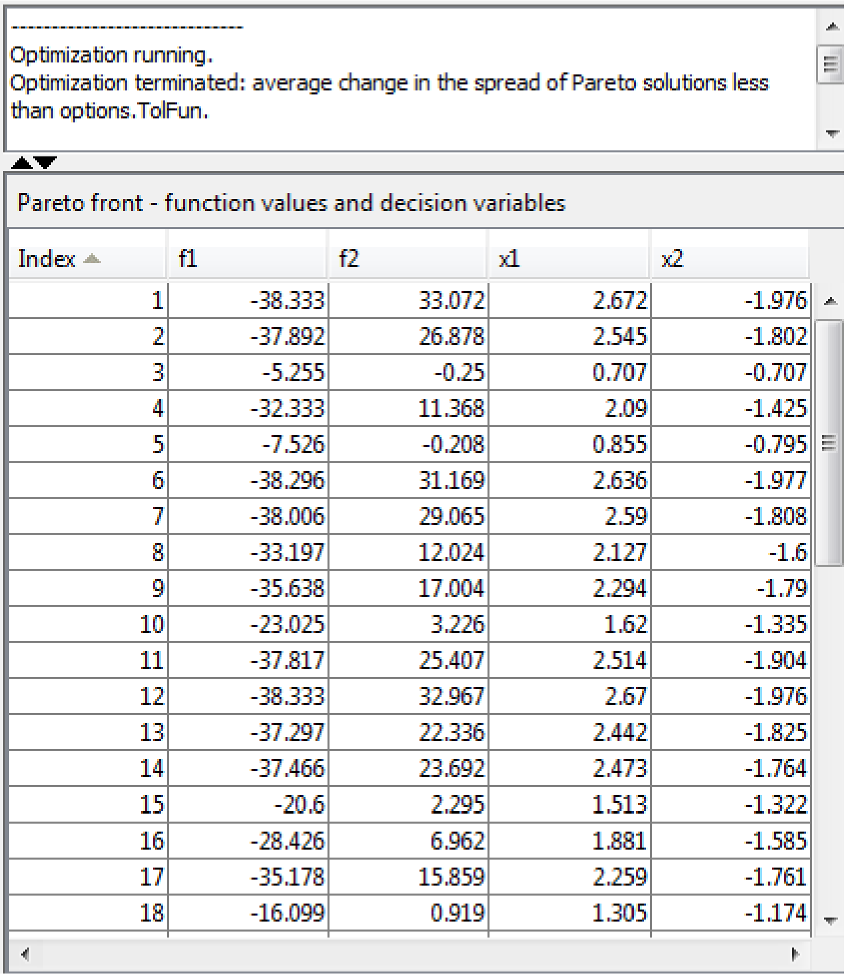
Distance measure function: ● Use default: @distancecrowding

○ Specify:

Pareto front population fraction: ○ Use default: 0.35

● Specify: .7

The results of the optimization appear in the following table containing both objective function values and the value of the variables.

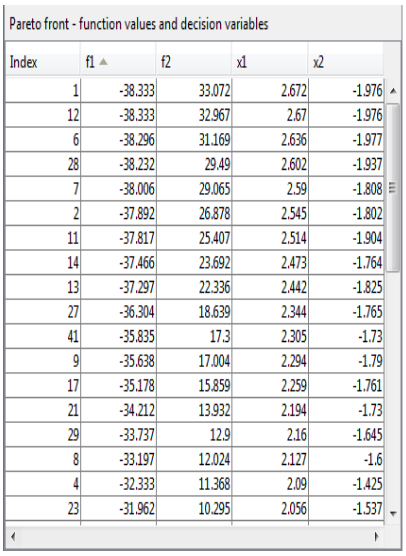


```
------------------------------
Optimization running.
Optimization terminated: average change in the spread of Pareto solutions less
than options.TolFun.
```

Pareto front - function values and decision variables

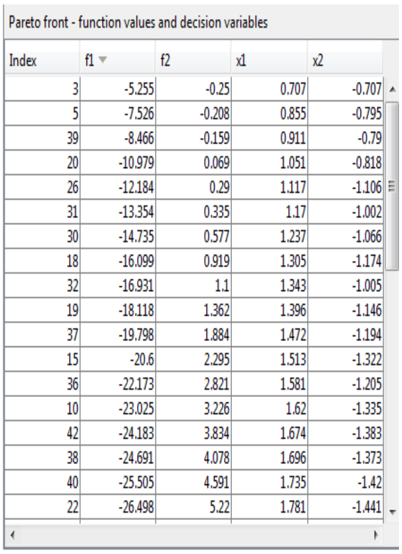
Index	f1	f2	x1	x2
1	-38.333	33.072	2.672	-1.976
2	-37.892	26.878	2.545	-1.802
3	-5.255	-0.25	0.707	-0.707
4	-32.333	11.368	2.09	-1.425
5	-7.526	-0.208	0.855	-0.795
6	-38.296	31.169	2.636	-1.977
7	-38.006	29.065	2.59	-1.808
8	-33.197	12.024	2.127	-1.6
9	-35.638	17.004	2.294	-1.79
10	-23.025	3.226	1.62	-1.335
11	-37.817	25.407	2.514	-1.904
12	-38.333	32.967	2.67	-1.976
13	-37.297	22.336	2.442	-1.825
14	-37.466	23.692	2.473	-1.764
15	-20.6	2.295	1.513	-1.322
16	-28.426	6.962	1.881	-1.585
17	-35.178	15.859	2.259	-1.761
18	-16.099	0.919	1.305	-1.174

You can sort the table by clicking a heading. Click the heading again to sort it in the reverse order. The following figures show the result of clicking the heading f1.



Pareto front - function values and decision variables

Index	f1	f2	x1	x2
1	-38.333	33.072	2.672	-1.976
12	-38.333	32.967	2.67	-1.976
6	-38.296	31.169	2.636	-1.977
28	-38.232	29.49	2.602	-1.937
7	-38.006	29.065	2.59	-1.808
2	-37.892	26.878	2.545	-1.802
11	-37.817	25.407	2.514	-1.904
14	-37.466	23.692	2.473	-1.764
13	-37.297	22.336	2.442	-1.825
27	-36.304	18.639	2.344	-1.765
41	-35.835	17.3	2.305	-1.73
9	-35.638	17.004	2.294	-1.79
17	-35.178	15.859	2.259	-1.761
21	-34.212	13.932	2.194	-1.73
29	-33.737	12.9	2.16	-1.645
8	-33.197	12.024	2.127	-1.6
4	-32.333	11.368	2.09	-1.425
23	-31.962	10.295	2.056	-1.537



Pareto front - function values and decision variables

Index	f1	f2	x1	x2
3	-5.255	-0.25	0.707	-0.707
5	-7.526	-0.208	0.855	-0.795
39	-8.466	-0.159	0.911	-0.79
20	-10.979	0.069	1.051	-0.818
26	-12.184	0.29	1.117	-1.106
31	-13.354	0.335	1.17	-1.002
30	-14.735	0.577	1.237	-1.066
18	-16.099	0.919	1.305	-1.174
32	-16.931	1.1	1.343	-1.005
19	-18.118	1.362	1.396	-1.146
37	-19.798	1.884	1.472	-1.194
15	-20.6	2.295	1.513	-1.322
36	-22.173	2.821	1.581	-1.205
10	-23.025	3.226	1.62	-1.335
42	-24.183	3.834	1.674	-1.383
38	-24.691	4.078	1.696	-1.373
40	-25.505	4.591	1.735	-1.42
22	-26.498	5.22	1.781	-1.441

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