Investigation on effect of Tool Nose Radius when turning operation is performed on Aluminium based Hybrid Composite

A project report submitted in partial fulfilment of the requirements for the award of the Degree of

BACHELOR OF TECHNOLOGY

IN

MECHANICAL ENGINEERING

By

VAKKALANKA SRINIKETH	(319126520056)
AGARAPU LEELADHAR	(319126520002)
ADIVARAPU KRISHNA VAMSI	(319126520001)
KORPAKA ABHISHEK	(319126520020)
BARATAM MUKESH	(319126520007)

Under the guidance of

Mrs. P. Bala Divya

Assistant Professor, Mechanical Engineering Department

PRAGNANAM BRAHMA

ANITS

ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY AND SCIENCES

Permanently Affiliated to Andhra University, Approved by AICTE, Accredited by NBA & NAAC, Sangivalasa-531162, Bhemunipatnam (Mandal) Visakhapatnam (District), Andhra Pradesh, India.

April 2023

DEPARTMENT OF MECHANICAL ENGINEERING

ANIL NEERUKONDA INSTITUTE OF TECHNOGY & SCIENCES

(UGC Autonomous & Permanently Affiliated to Andhra University)

PRAGNANAM BRAHMA

ANITS

CERTIFICATE

This is to certify that the Project Report entitled **"Investigation on effect of tool nose radius when turning operation is performed on aluminium based hybrid composite"** being submitted by **V. Sriniketh (319126520056), A. Leeladhar (319126520002), A. Krishna Vamsi (319126520001), K. Abhishek (319126520020), B. Mukesh (319126520007)** to the Department of Mechanical Engineering, ANITS is a record of the bonafide work carried out by them under the esteemed guidance of **Mrs. P. Bala Divya.** The results embodied in the report have not been submitted to any other University or Institute for the award of any degree or diploma.

P. Bala Divya

Project Guide

Mrs. P. Bala Divya
Assistant Professor
Dept. of Mechanical Engineering,
ANITS

17.4.23

Head of the Department

Dr. B. NAGA RAJU
Professor
Dept. of Mechanical Engineering
ANITS

THE PROJECT IS APPROVED BY THE BOARD OF EXAMINERS

INTERNAL EXAMINER: Nethravathy 17/4/23

EXTERNAL EXAMINER: 17/4/2023

ABSTRACT

It is difficult to take into account all the parameters in any machining process since a variety of factors affect the parameters such as surface roughness (Ra, Rz), material removal rate (MRR), and tool wear rate (TWR). The nose radius, depth of cut, speed and feed rate are the main factors that can be considered.

In this study, experiments are carried out on a CNC lathe machine using three different levels for each parameter, including speed (900, 1200, and 1500 rpm), depth of cut (0.5, 1.0, and 1.5 mm), feed rate (0.1, 0.15, and 0.2 mm/rev), and tool nose radius (0.4 and 0.8 mm), forming an L18 orthogonal array.

The combined quality loss (CQL) and weighted multiple response performance index (WMPI) are used to optimise multiple responses, and Taguchi's approach is then used to improve CQL. The results of the Taguchi method are validated using the analysis of variance. Aluminium (Al2024) is used as the base metal, together with 3.5% silicon carbide and 0.5% boron carbide, to form the composite using the stir casting method (ANOVA).

Feed Rate (0.2 mm/rev), Speed (1500 rpm), Depth of Cut (1.5 mm), and Tool Nose Radius (0.4 mm) are the most ideal circumstances. It is clear from ANOVA that the Depth of Cut (DOC) has a greater impact on machining.

Keywords: Principal Component Analysis (PCA), Weighted Multi Response Performance Index (WMPI), Material Removal Rate (MRR), Average Surface Roughness (Ra), Ten Point Mean Roughness (Rz), and Combined Quality Loss (CQL).

ACKNOWLEDGEMENT

We are extremely fortunate to work under the guidance of **Mrs. P. Bala Divya**, Assistant Professor of Mechanical Engineering Department, Anil Neerukonda Institute of Technology and Sciences. She provided extraordinary guidance and support. Her ideas during the entire course of this work have been really one of its kinds. Her suggestion in experiment stage, interpretation of results and thesis writing has been a real great help.

We are thankful to **Prof. K. Siva Rama Krishna**, Principal and **Prof. B. Naga Raju**, Head of the Mechanical Engineering Department, Anil Neerukonda Institute of Technology and Sciences for their valuable suggestions.

We express our sincere thanks to members of non-teaching staff of Mechanical Engineering Department for their kind cooperation and support to complete this work.

Last but not the least we would like to convey our thanks to all who have contributed either directly or indirectly for the completion of our work.

Vakkalanka Sriniketh	**(319126520056)**
Agarapu Leeladhar	**(319126520002)**
Adivarapu Krishna Vamsi	**(319126520001)**
Korapaka Abhishek	**(319126520020)**
Baratam Mukesh	**(319126520007)**

CONTENTS

Description	Pg. No
Abstract	i
Acknowledgement	ii
List of Figures	v
List of Tables	vi
Nomenclature	vii
CHAPTER-1: INTRODUCTION	1
1.1 Composites	1
1.1.1 Different classification of Composites	2
1.1.2 Benefits of Composites	2
1.1.3 Applications of Composites	3
1.2 Casting	3
1.2.1 Types of Castings	3
1.2.2 Applications of Stir Casting	5
1.3 Machining Process	6
1.3.1 CNC Lathe	6
1.3.2 General Machining Operations on Lathe	8
1.3.3 Turning Operation	11
1.3.4 Turning Parameters	12
1.3.5 Tool Geometry	14
1.3.6 Cutting Tools	16
1.3.7 Cutting Tool Material	18

1.3.8 Cutting Fluids 22

1.3.8.1 Types of Cutting Fluids 22

1.3.8.2 Functions of Cutting Fluids in Turning 23

CHAPTER-2: Literature Survey 25

CHAPTER-3: Methodology 37

3.1 Taguchi Method 37

3.2 ANOVA 38

CHAPTER-4: Experimental Procedure 40

4.1 Selection of Work Material 40

4.2 Stir Casting 41

4.3 Selection of Process Parameters and their levels 43

4.4 Selection of Orthogonal Array (OA) 44

CHAPTER-5: Results and Discussion 46

5.1 Experimental Results and responses 46

5.2 Pearson Coefficient of Correlations 48

5.3 Principal Component Analysis 48

5.4 Taguchi Analysis 52

5.5 ANOVA Results 53

CHAPTER-6: Conclusion 55

6.1 Conclusion 55

6.2 Future Scope of project 56

References 57

List of Figures

Figure No.	Description	Pg. No
Figure 1.1	Classification of Composites	2
Figure 1.2	CNC Lathe Machine	8
Figure 1.3	Operations on Lathe (1)	11
Figure 1.4	Operations on Lathe (2)	11
Figure 1.5	Turning Operation	12
Figure 1.6	Cutting Tool Nomenclature	14
Figure 1.7	Single Point Cutting Tool	16
Figure 1.8	Double Point Cutting Tool	17
Figure 1.9	Multi Point Cutting Tool	17
Figure 4.1	Stir Casting Setup	42
Figure 4.2	Casting Pieces	42
Figure 4.3	0.4mm Nose Radius	43
Figure 4.4	0.8mm Nose Radius	43
Figure 4.5	CNC Lathe Machine	45
Figure 4.6	Machining of Composite	45
Figure 4.7	SJ-210 Roughness Gauge	45
Figurer 5.1	Main Effect Plots for SN Ratio	53
Figure 5.2	Residual Plots for CQL	54

List of Tables

Table No.	Description	Pg. No
Table 4.1	Chemical Composition of Al2024	40
Table 4.2	Mechanical Properties of Al2024	41
Table 4.3	Process Parameters and Levels	43
Table 4.4	Input Parameters & L18 OA	44
Table 5.1	Output Responses	46
Table 5.2	Normalized Values	47
Table 5.3	Correlation between Responses	48
Table 5.4	Eigen Values, AP and CAP	48
Table 5.5	Eigen Vectors	49
Table 5.6	Weight of Responses	49
Table 5.7	Major Principal Component	50
Table 5.8	WMPI and CQL	51
Table 5.9	Taguchi Analysis: CQL versus r,s,f,d	52
Table 5.10	Optimal Parameters for MRR and Surface Roughness	52
Table 5.11	ANOVA for CQL	53

NOMENCLATURE

v	Cutting Speed, Rpm
f	Feed, mm/rev
d	Depth of Cut, mm
MRR	Material Removal Rate, cm^3/sec
Ra	Arithmetic Surface Roughness Average, µm
Rz	Ten Point Mean Roughness, µm
CNC	Computerized Numerical Control
DOE	Design of Experiments
OA	Orthogonal Array
S/N	Signal-to-Noise Ratio
ANOVA	Analysis of Variance
DF	Degree of Freedom
SS	Sum of Squares
MS	Mean Square
F	Variance Ratio
PCA	Principal Component Analysis
CQL	Combined Quality Loss
WMPI	Weighted Multi Responses Performance Index

CHAPTER-1

INTRODUCTION

1.1Composites

A composite may be a material comprised of 2 or a great deal of constituent materials that area unit having considerably completely different physical or chemical properties. In stuff individual constituents might not utterly mix or lose their identities. However, one will get hybrid and contributed properties of the ultimate product. They combined to provide a cloth that characterizes the various individual parts. To distinguish composites from mixes and pure solid solutions, these individual components remained unique and separate in the final structure. The new content might also be the most well-liked for the following reasons: Such examples are materials that, as compared to older materials, are stronger, lighter, or less expensive. Composites area units are usually created for specific use like strength, potency, or sturdiness. A composite is to be any multi-phase material that exhibits a big proportion of the properties of each constituent phase such an improved combination of properties is accomplished. In-line with this principle of combined action, higher property combos' area unit designed by the mixture of 2 or a lot of distinct materials. A composite may be a multi-phase material that by artificial means created as a critical one that happens or forms naturally. Additionally, the constituent phases should be with chemicals dissimilar and separated by a definite interface. Most composites are created to enhance combos of mechanical properties like stiffness, toughness, and close and extreme temperature strength. Several composite materials are only made up of two phases; the matrix, which surrounds the other part and is continuous, is commonly referred to as the phase in one of these materials. The properties of a composite are a result of the mathematical properties of the phase as well as the relative amounts and constituent phases. Phase pure mathematics in this case refers to the distribution, size, and orientation of the particles as well as their shape and size.

1.1.1 Different classification of Composites

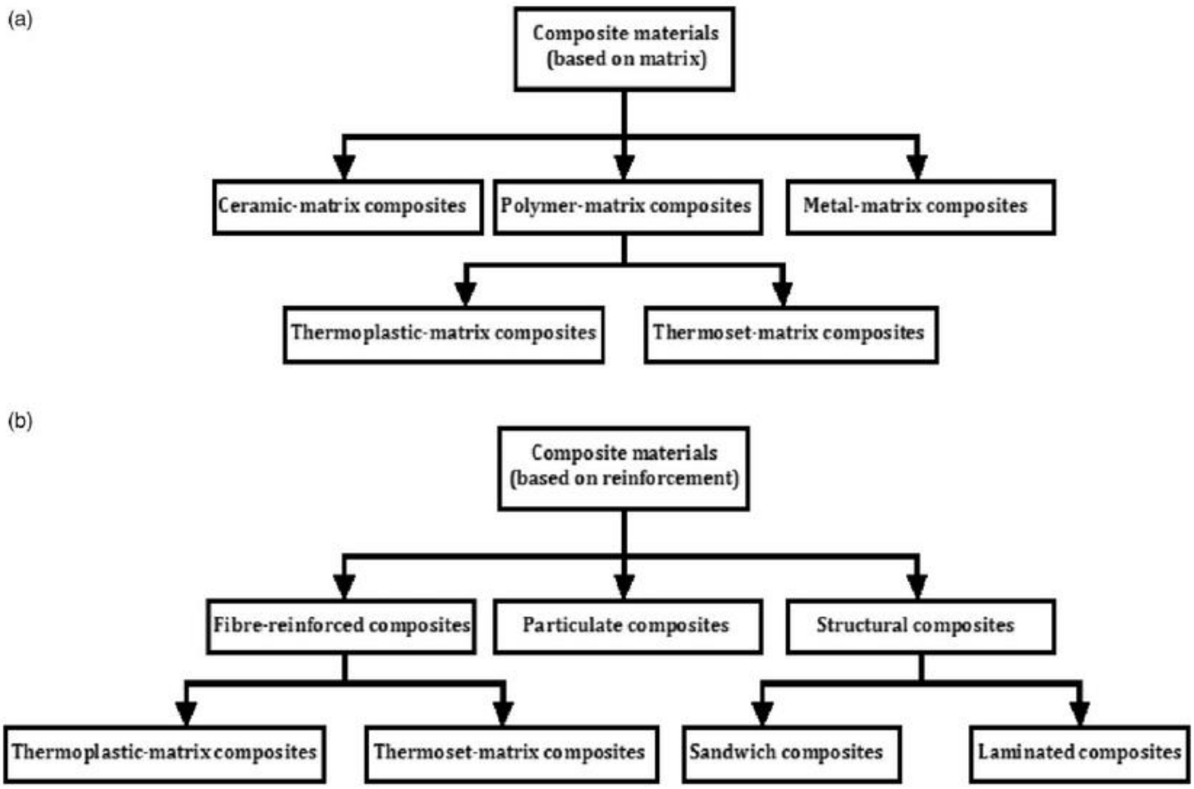

Figure 1.1 Classification of Composites

1.1.2 Benefits of Composites

Composites supply several blessings over alternative materials. Among the region and marine markets, wherever exceptional performance is needed however weight is vital, composites still grow in importance.

- Light Weight: Composites area unit lightweight in weight, compared to most woods and metals.
- High strength: Composites may be designed to be way stronger than metal or steel.
- Corrosion Resistance.
- More-Impact Strength.

1.1.3 Applications of Composites

Composites region unit one among the principal wide utilized materials attributable to their capacity to totally various things and thusly the moderately simple blend with elective materials to serve explicit capacities and display entrancing properties. In surface transportation, supported plastics region unit the kind of composites utilized attributable to their massive size. they supply adequate degree and receptiveness to style changes, materials, and cycles. The strength-weight quantitative connection is over elective materials. Their solidness and worth viability offered, beside the direct accommodation of crude materials, make them the clear option for applications in surface transportation. In unimportant vehicles, the composites region unit utilized in course of component parts with value adequacy. Savvy reproductively and flexibility dealing with by semi-talented representatives region unit the necessities of good stuff. While the costs of accomplishing progressed composites probably won't legitimize the investment funds got as far as weight vehicle creation, carbon filaments reinforced epoxies are utilized in sports vehicles and as of late for the security of vehicles.

1.2 Casting

The casting process is a manufacturing step in which molten material, such as metal, is poured into a hole or mould with the desired shape and allowed to harden or solidify there. The casting is then removed by ejecting the material from the mould or by shattering the mould after it has solidified.

1.2.1 Types of Castings

Sand casting

Sand casting is a versatile casting technique that can be used to cast any metal alloy, ferrous or not. It is regularly used in industrial settings for the bulk production of metal-cast automotive parts like engine blocks, cylinder heads, crankshafts, etc. The process involves using a mould constructed of silica-based materials, such as naturally bound or synthetic sand, to produce the smooth mould surface. The mould surface has 2 parts, cope (the upper half) and drag (the lower half). Molten metal is poured into the pattern using a pouring cup and left to solidify to take the final shape. Finally, trimming off extra metal is done for the finishing of the final metal casting product.

Investment casting

Investment casting uses a disposable wax pattern for each cast part. The wax is injected directly into a mould, removed, then coated with refractory material and a binding agent, usually in several stages to build up a thick shell. Multiple patterns are assembled onto common sprues. The wax is removed from the patterns by heating them in ovens once the shells have solidified. The remaining shells are then filled with molten metal, which is then poured into them and cooled to form the wax patterns. The finished casting is exposed after the refractory shell has been removed.

Die casting

This technique, which involves moulding materials under intense pressure, is most frequently used with non-ferrous metals and alloys, such as tin, copper, and aluminium. A lubricant is applied to the reusable mould to aid with component ejection and temperature control of the die. Afterwards, molten metal is continuously pumped into the die at high pressure until the workpiece solidifies. As the pressured insertion is quick, no portion of the material can harden before being cast.

Centrifugal casting

Roto casting, commonly referred to as centrifugal casting, is a method for producing cylindrical pieces industrially using centrifugal forces. In this kind of metal casting, molten metal is poured into a hot spinning die. The high-pressure molten metal is distributed throughout the die with the aid of centrifugal forces.

True centrifugal casting, semi-centrifugal casting, and vertical centrifugal casting are the three types of centrifugal casting that are available. In contrast to genuine centrifugal casting, semi-centrifugal casting uses a sprue to entirely fill the mould. Yet, because of the constant rotation used in genuine centrifugal casting, the molten metal adheres to the sides. On the other hand, vertical centrifugal casting uses directional moulding in a manner similar to genuine centrifugal casting, as the name implies.

Vacuum Casting

casting in which creation takes place under a vacuum of 100 bar or less in order to exhaust gas from the mould cavity. In this procedure, bubbles and air pockets are removed by pouring molten metal into the cavity of the mould inside a vacuum chamber. The die cavity is evacuated under vacuum to prevent gases from becoming trapped there during the metal injection process. The metal is then taken from the mould after being cured in a heating chamber.

Shell Moulding

Shell moulding is a disposable method of casting a mould. It is identical to the sand-casting process, with the exception that the mould cavity is formed by a solid shell of sand rather than a flask of sand. The sand used is finer than that used in sand casting, and it is combined with resin to create the shell around the pattern, which can then be heated. Industrial items including gearbox housing, connecting rods, small boats, truck hoods, cylindrical heads, camshafts, valve bodies, etc. are produced using shell moulding. The casting products have accurate dimensions and a nice surface finish.

Stir Casting

Stir casting process involves stirring of melt, in which the melt is stirred continuously which exposes the melt surface to the atmosphere which tend to continuous oxidation of aluminium melt. As a result of continuous oxidation, the wettability of the aluminium reduces, and the reinforcement particles remain unmixed.

1.2.2 Applications of Stir Casting

1. Aerospace: Stir casting is used to produce high-strength, lightweight alloys for aircraft and spacecraft components.
2. Automotive: Stir casting is used to manufacture high-performance engine blocks, pistons, and other automotive components.
3. Defense: Stir casting is used to produce armor materials and lightweight bulletproof vests for military applications.
4. Medical: Stir casting is used to create biocompatible alloys for medical implants such as dental implants and prosthetic joints.

5. Electronics: Stir casting is used to produce high-conductivity alloys for electronic components such as connectors, switches, and heat sinks.
6. Marine: Stir casting is used to manufacture corrosion-resistant alloys for marine applications such as boat propellers and offshore drilling equipment.
7. Energy: Stir casting is used to produce high-temperature alloys for energy applications such as gas turbines and nuclear reactors.

1.3 Machining Process

1.3.1 CNC Lathe

A machine that rotates material around a central spindle and a stationary cutting tool is a computer numerical control lathe. Instead of using manual labour, a computer is fed with coded instructions that control the movement of your material. Several processes can be set simultaneously, preventing the need for your material to leave the lathe between manufacturing processes and ensuring accurate cut placement. Because their movement is controlled by code, computer-operated lathes are highly precise. Increased accuracy during the manufacturing process results in fewer errors, less expensive operation, and less material waste. When turning, manual lathes are susceptible to human error. Manufacturing times are quicker, with more CNC machines on the go at one time, and all products created are nearly identical due to the reliability of computer numerical control. While CNC lathes create the same products as manual machines, they can do so faster and more efficiently. Parts machined with a CNC lathe could be used in automotive creation, electronics, medical equipment, and sporting goods. CNC lathes can operate with such precision that they create intricate parts for firearm manufacturing. A few important components of CNC lathes are:

Headstock:

The primary motor of a CNC lathe machine is located in the headstock and drives the main spindle. On this main spindle, Chuck is installed. The headstock covers have been taken off, allowing you to examine the main motor's gears and the main drive. With the help of the CNC programming instructions, gears can be chosen.

CNC Lathe Bed:

The tool turret travel over the CNC lathe bed, which is specially hardened so any kind of machining can't affect them.

Chuck:

CNC lathe machine chuck grips the components which are to be machined. Chuck itself has many parts. Jaws are mounted on the chuck to grip the part.

Tailstock:

Tailstock is mostly used to give an extra gripping force for component machining. For long components machining they provide extra force on the other end so machining process can complete smoothly. You can see in the above picture at the one end chuck is gripping the component and on the other end tailstock is providing the extra force.

Tailstock Quill:

Actually, you move the whole tailstock forward or reverse, but in that way it is not used to grip the part, but tailstock is travelled to a point near the component and then it is set there, after that you actuate the tailstock quill which travel either with hydraulic pressure or pneumatic pressure to grip the component.

Foot Switch or Foot Pedals:

Foot switches are used to actual the chuck and tailstock quill. Through these pedals CNC machinist's open and close the chuck to grip the component, the same way tailstock quill is taken to forward position or reversed through theses pedals.

Tool Turret:

For component machining, the tool is positioned on a tool turret. Tool turrets come in a variety of designs and can hold a variety of tools.

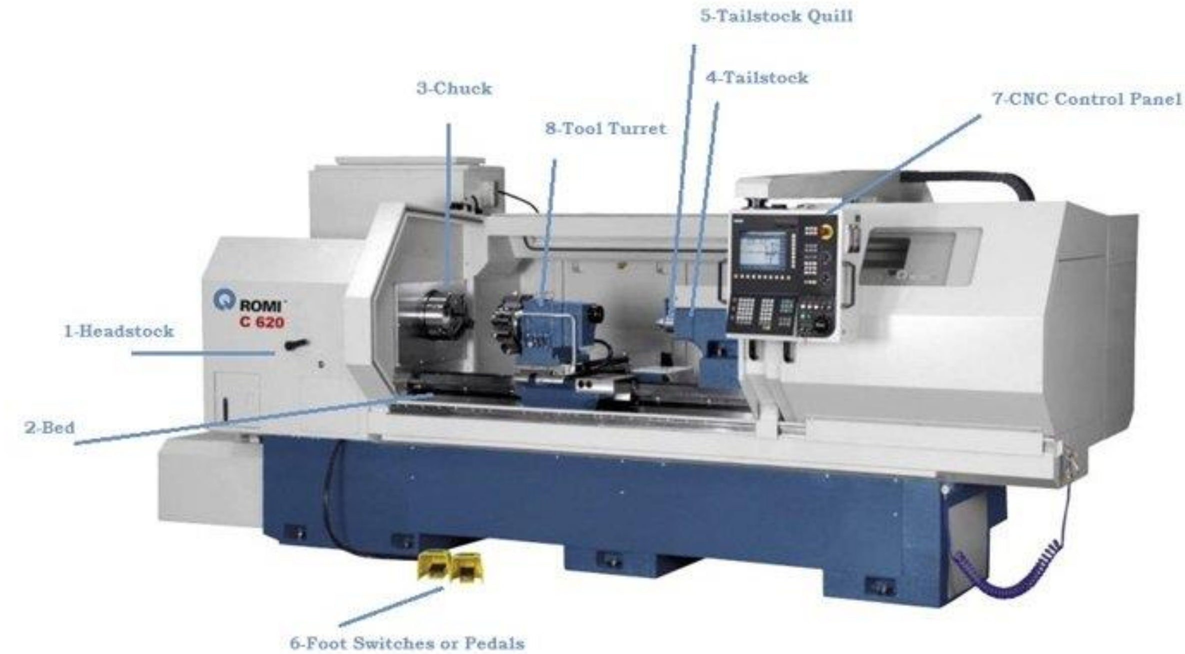

Figure 1.2 CNC Lathe Machine

1.3.2 General Machining Operations on Lathe

A lathe machine is a type of industrial equipment that performs numerous operations to shape any metal or component to the desired shape. On the lathe, a machine tool, metal is machined by combining job rotation and tool feed that is perpendicular to the workpiece. It is the most traditional and prevalent category of machine tools. A lathe can be used for the majority of other tasks carried out on general purpose machine tools, either directly or through attachments, while being primarily designed to produce cylindrical surfaces with a single point cutting tool. Now days, large numbers of modern machine tools are found, still the lathe machines are used in all modern tool rooms, repair shops and training workshops. There are many operations that can be done on a lathe machine a few of them are mentioned below:

Straight Turning: The work on a lathe is often machined for two reasons, to cut it to size and to make a perfect diameter. The work which has to be cut in size and its diameter has to be kept the same for the entire length and then straight turning is done on it.

Rough Turning:

Rough turning is used to cut the waste metal as quickly as possible and to make the diameter of the work as accurate.

Finish Turning:

The purpose of finish turning is to produce the work to the required size and achieve a good surface finish. Make sure that the cutting edge of the tool used for finish turning is sharp. It requires high cutting speed, low feed and very low-cut depth.

Step Turning:

When more than one diameter is machined on a shaft, the joining section of each diameter is called a shoulder or step. Step turning is the process of turning which produces different surfaces diameter.

Taper Turning:

In a taper turning the operation of the lathe machine is performed in a manner of uniform increasing the diameter of a workpiece or a job along its length.

Facing:

Facing is a process in which a flat surface is formed by cutting metal at right angles to the axis of the lathe. The tool should be set such that its cutting face makes an angle of about 2^o with the metal surface and must be cantered. In facing operation feeding tool is always perpendicular to the axis of the rotation of a job or a workpiece.

Grooving:

Grooving is an operation often called recessing. It is often performed at the ends of the thread, on the side of the shoulder, or to enhance the appearance. In grooving process produces a narrow groove on the cylindrical surface of the workpiece. In grooving process produces a groove like a square, radial, and also in a bevelled type shape.

Undercutting:

The process of internal cutting in a hole is called under cutting. The undercutting is widely used for internal threading and cutting a groove. Like threading in a nut and bolt or internal machine part. For this, the square nose parting tool is used. Undercutting is done at the end of an internal thread or counter bore to provide clearance for the tool or any mating part.

Knurling:

Knurling is done by pressing the two hardened steel wheels called knurls and the process of impressing the straight indentations on the surface of a workpiece is called knurling.

Drilling:

Drilling in the lathe can be done in the following two ways 1) By rotating the work and feeding the drill into it, 2) By rotating the drill and feeding the work to it. In this process, the drill bit tool is used for drilling the workpiece.

Reaming:

Reaming is a process that consists of the accurate size, round and fine finishing of a hole after the drilling. The tool used for this is called a reamer. Reamer has the cutting edges and is gripped in the drill chuck. Reaming on the lathe is done in exactly the same way as drilling is done. For the reaming at the lathe, the workpiece is rotated at slow speed and reaming is done by tailstock head wheel.

Boring:

Boring is the process in which a hole made by drilling, punching, casting, or forging is enlarged and trued. A hole cannot be made by boring. For boring on the lathe, a special tool holder called a boring bar is used.

Thread Cutting:

Thread cutting is a method of cutting thread on a lathe which is done by making sequential light cuts with a thread-shaped thread cutting tool bit.

Tapping:

Tapping is the operation of cutting internal threads of small diameter using a cutting tool called a tap.

Parting off:

Parting off is a method in which metal is cut into two pieces using a special cutting tool.

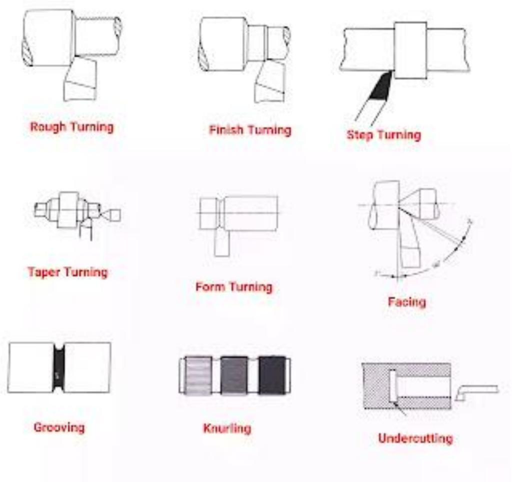

Figure 1.3, Operations on Lathe(1)

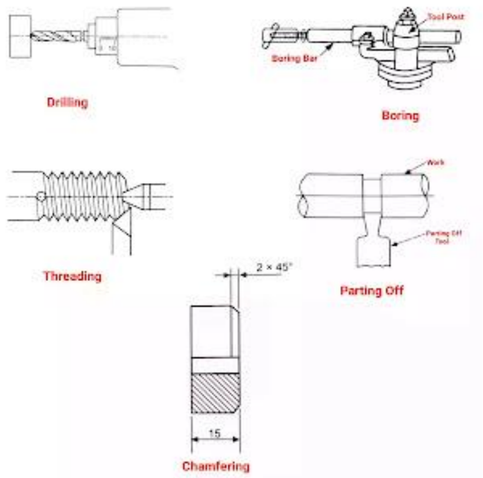

Figure 1.4, Operations on Lathe(2)

1.3.3 Turning Operation

Our focus is largely on the turning operation since our experiment is carried out using a CNC lathe machine. Turning is the process of removing metal from a revolving cylindrical workpiece's outer diameter. Turning is used to achieve a smooth finish on the metal and reduce the workpiece's diameter, usually to a predetermined dimension. It is common practise to rotate the workpiece such that neighbouring sections have varied diameters. The machining process of turning creates cylindrical pieces. The simplest definition of it is the machining of an external surface.

- With the workpiece rotating
- With a single point cutting tool
- With the cutting tool feeding parallel to the axis of the workpiece and at a distance that will remove the outer surface of the work.

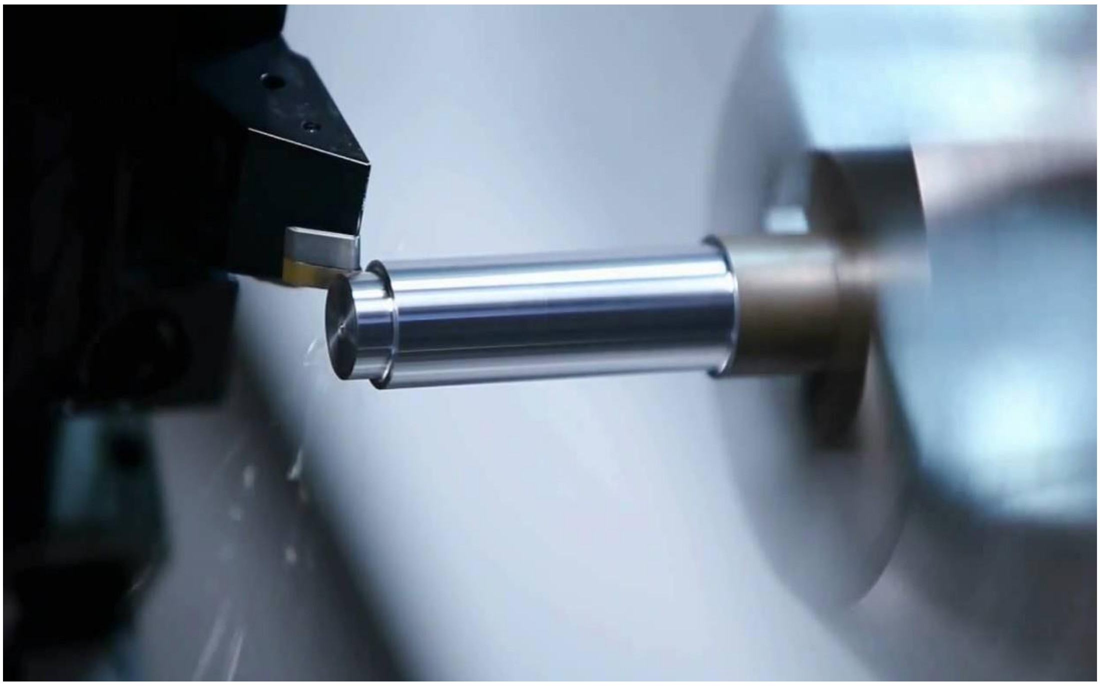

Figure 1.5 Turning Opration

1.3.4 Turning Parameters

Speed, feed, and depth of cut are the three main variables in any simple turning process. Of course, there are other important aspects, such as the type of material and the type of tool, but the operator can vary these three by adjusting the controls.

Speed:

Speeds of the workpiece and spindle are discussed. It represents the rate at which things rotate when given in rpm. Surface speed, or the pace at which the material of the work piece is moving past the cutting tool, is the most important factor for a particular turning process. It is just the result of multiplying the rotation speed by the workpiece circumference just before the cut is initiated. It solely applies to the work component and is measured in metres per minute (m/min). Even though the rotation speed is constant, the cutting speed will vary depending on the diameter of the work piece.

$V=3.14DN/1000(m/min)$

Here V is the cutting speed in turning, and D is the initial diameter of workpiece in mm and N is the spindle speed in rpm.

Feed:

A cutting tool's feed refers to how quickly it travels along its cutting path. The feed rate is expressed in millimetres (of tool advance) per revolution (of the spindle), or millimetres/rev, in the majority of power-fed lathes.

$F_m = f.N$ mm/min

Thus, N is the spindle speed in rpm, Fm is the feed rate in mm/min, and f is the feed rate in mm/rev.

Depth of Cut:

The thickness of the layer being removed from the work piece in a single pass or the distance between the work's uncut and cut surfaces is the depth of cut, which is measured in millimetres. It's important to keep in mind that the diameter of the piece is decreased by twice the depth of cut because this layer is being removed from both sides of the workpiece.

Dcut = (D-d)/2mm

The job's initial and final diameters (in mm) are shown here as D and d, respectively.

1.3.5 Tool Geometry

The geometry of cutting tools is dependent on the characteristics of the materials used for the tool and the work. The rake angles as well as the end and side relief angles are crucial for single point tools.

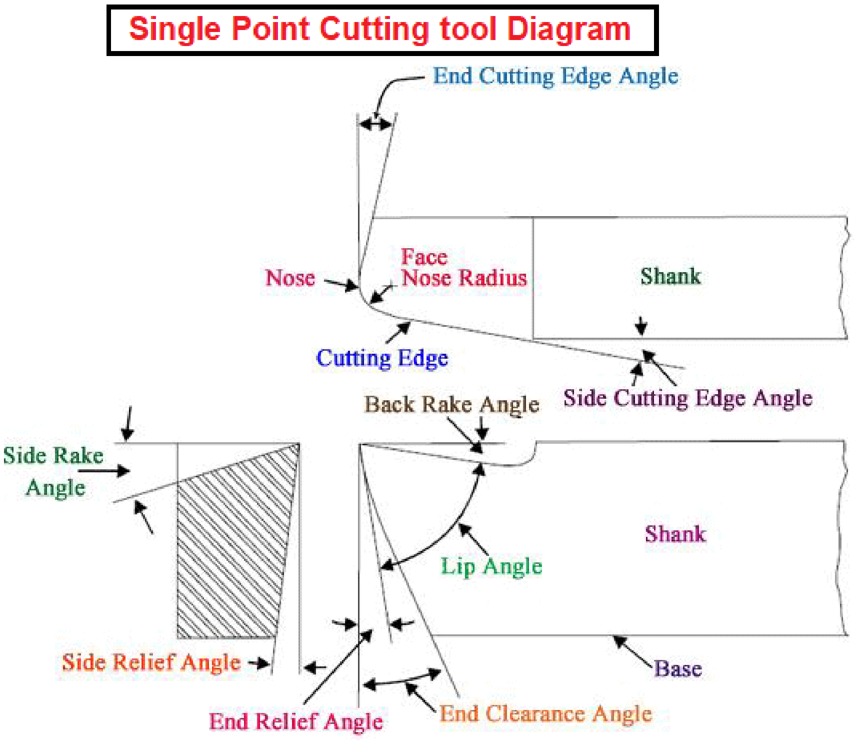

Figure 1.6 Cutting Tool Nomenclature

Flank:

The flat surface next to a single-point tool's tool face. The side flank of the tool turns to face that direction as it is placed into the workpiece.

Face:

The face of a tool is the flat portion of a single point tool across which the work piece rotates during a turning operation. The tool's face is positioned upwards in a standard turning setting.

Back rake angle:

As viewed from the side facing the end of the work piece, it is the angle formed between the tool's face and a line parallel to the base. Positive back rake angles tilt the tool's face upward and backward, while negative back rake angles tilt it downward and forward.

Side rake angle:

As viewed from behind the tool and along the length of the tool holder, it is the angle formed by the face of the tool and the centreline of the workpiece. The tool's face is tilted either up and towards the work piece when the side rake angle is negative and down and towards the floor when the side rake angle is positive.

Side cutting edge angle:

It is the angle, as seen from above and looking down on the cutting tool, formed between the side flank of the tool and a line perpendicular to the centreline of the work piece. A positive cutting-edge angle pulls the side flank into the cut, whereas a negative angle pulls it out.

End cutting edge angle:

End cutting edge angle is the angle created by the end flank of the tool and a line parallel to the centreline of the work piece when viewed from above looking down on the cutting tool. The far end of the cutting edge is tilted away from the work piece when the end cutting edge angle is increased.

Side relief angle:

As viewed from behind the tool, the side relief angle is the angle created by the side flank of the tool and a vertical line that runs the entire length of the tool holder. The side flank is angled away from the work piece when the side relief angle is increased.

End relief angle:

End relief angle refers to the angle created by the tool's end flank and a vertical line that descends to the ground when viewed from the side facing the end of the work piece. The end flank tilts away from the work piece when the end relief angle is increased.

Nose radius:

It is the rounded end of a single point tool's cutting edge. A zero-degree nose radius of the cutting tool results in a sharp tip.

Lead Angle:

The lead angle is another name for the side cutting edge angle. All modifications to an insert's angle brought on by the design of a tool holder are taken into account by the lead angle.

1.3.6 Cutting Tools

Cutting tools are wedge-shaped, sharp-edged tools used during machining to shear away extra layers of material from a workpiece in order to achieve the desired shape, size, and accuracy. It has a secure connection to the machine tool. This category includes three different kinds of cutting tools, which are as follows:

Single -Point Cutting Tool

Turning and shaping tools are examples of single-point cutting tools. Single-point cutting tools have only one cutting edge by which the material is removed.

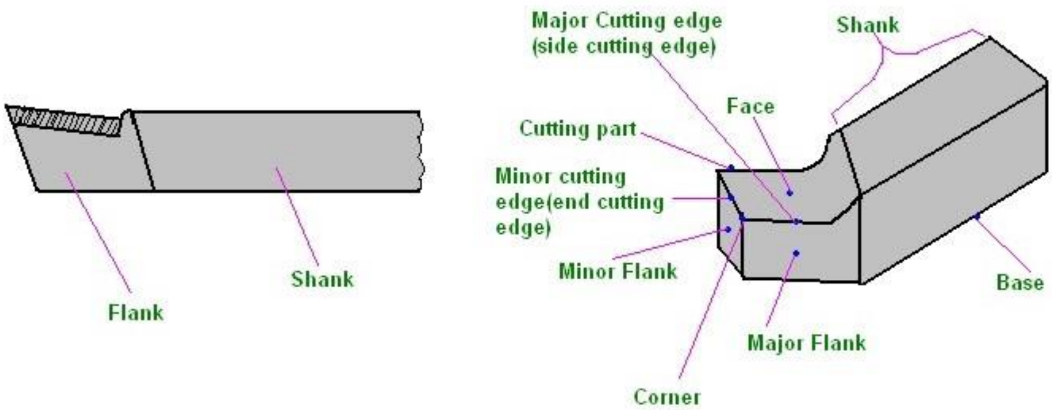

Figure 1.7 Single Point Cutting Tool

Double-Point Cutting Tool

Two edges of this kind of cutting tool, like a twist drill, are used to cut the material.

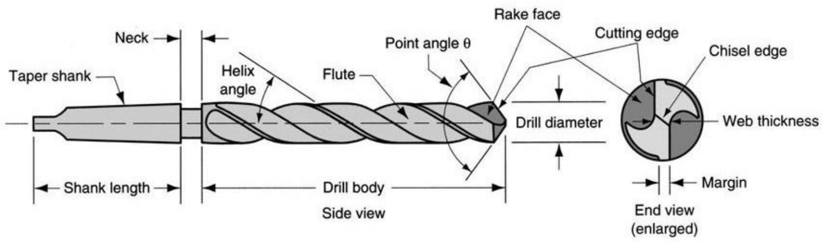

Figure 1.8 Double Point Cutting Tool

Multi-Point Cutting Tool

Examples of multi-point cutting tools include drilling tools called milling cutters, broaching machines, etc. The material will be removed using a number of cutting edges in a multi-point cutting tool.

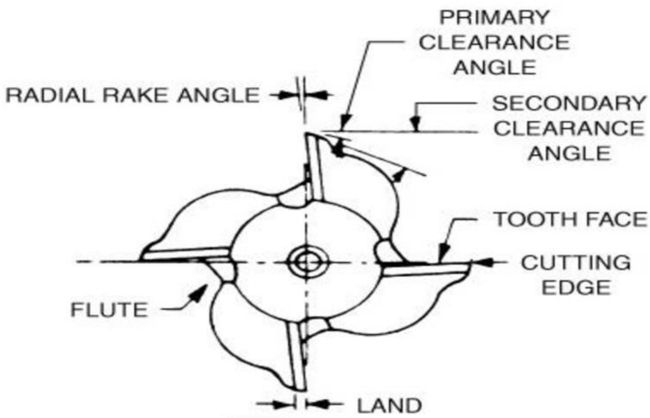

Figure 1.9 Multi Point Cutting Tool

1.3.7 Cutting Tool Material

The classifications of cutting tool materials utilised today for machining operations include high speed tool steel, cobalt-base alloys, cemented carbides, ceramic, polycrystalline cubic boron nitride, and polycrystalline diamond. For varied machining operations, several types of cutting tool materials are required. The optimum substance for cutting tools should have each of the criteria listed below:

- More difficult than the work it eliminates
- Strong temperature resistance
- Withstands abrasion and heat shock.
- Resistant to impact

Chemically inert to the cutting fluid and work material.

A machinist or engineer needs to be knowledgeable about the following in order to choose tools for machining:

- The starting and finished part shape.
- The work piece hardness
- The material's tensile strength
- The material's abrasiveness
- The type of chip generated.
- The work holding setup.
- The power and speed capacity of the machine tool.

The following is a list of some common cutting tools:

Carbon Steels:

Cutting tools have been made of carbon steel since the 1880s. Yet, at a temperature of roughly 1800C, carbon steels begin to weaken. Such tools are rarely utilized for metal cutting operations due to this constraint. Tools made of plain carbon steel, which has a carbon content of 0.9% and a manganese content of 1% and is hardened to around 62 Re, are frequently used for woodworking and may be used in a router to cut aluminum sheet up to about 3 mm thick.

High Speed Steels (HSS):

The moniker "HSS" refers to the fact that these tools were designed to cut faster. HSS, a type of tool steel developed around 1900, is the most alloyed. Originally developed tungsten (T series) typically contains 12–18% tungsten, 4%–5% chromium, and 4-12% cobalt. The majority of grades also include 0.5% to 0.5% molybdenum. Molybdenum (in smaller proportions) might take the place of the majority of the tungsten, resulting in a more cost-effective formulation with better abrasion resistance than the T series and less deformation following heat treatment. As a result, around 95% of all HSS tools are made from grades in the M series. Various grades of these contain 4% chromium, 4% vanadium, 4% tungsten, 1.5-10% cobalt, and 5-10% molybdenum.

HSS tools are used to make tools with complex shapes like drills, reamers, taps, dies, and gear cutters because they are durable and ideal for interrupted cutting. A coating may be applied on fools to increase wear resistance. The majority of tool materials used today, with typical cutting rates of 10–60 m/min, are HSS.

Cast Cobalt alloys:

These alloys from the early 1900s, which contain around 40–55% cobalt, 30% chromium, and 10–20% tungsten, cannot be heated any higher. The maximum hardness ratings range from 55 to 64 Rc. These can be used at somewhat higher rates than HSS, but they do not have the same level of durability. Currently only in sporadic use.

Carbides:

Sintered carbides, also referred to as cemented carbides or sintered carbides, were first developed in the 1930s. They have a high degree of hardness over a broad temperature range, good thermal conductivity, and a high Young's modulus, making them suitable for use as tool and die materials in a variety of applications. The two kinds of carbides used for machining are tungsten and titanium; both can be coated or left bare. In a cobalt matrix, tungsten carbide particles (1 to 5 micrometers) are joined via powder metallurgy. The powder is compressed and sintered to produce the desired insert shape. Niobium and titanium carbides can also be employed to add particular properties. For varied uses, a variety of grades are available. Sintered carbide tips are the most popular type of material used in cutting metal. The characteristics of carbide tools are significantly influenced by the amount of cobalt (the typical matrix material) present. Greater 8 hardness is produced by cobalt matrixes containing 3-6% cobalt, while cobalt matrixes using 6- 15% cobalt produce greater toughness while reducing hardness, wear resistance, and strength. Tungsten carbide tools are widely used for the machining of steels, cast irons, and abrasive non-ferrous materials. Titanium carbide has a higher wear resistance than tungsten, although it is not as robust. Because of its nickel-molybdenum alloy matrix, TIC can be machined more quickly than tungsten carbide. Cutting rates range from 30 to 150 m/min, or 100 to 250 m/min when coated.

Coatings:

Carbide tool tips are routinely coated to increase tool life or allow for faster cutting. Coated tips typically last ten times longer than uncoated tips. Aluminum oxide, titanium carbide, and titanium nitride are common coating materials that range in thickness from 2 to 15 microns. Several different layers may be applied, one on top of the other, depending on how the tip will be used. Coating application techniques include chemical vapour deposition (CVD), plasma assisted CVD, and physical vapour deposition (PVD) Diamond coatings are also in use and being developed further.

Cermet's:

They were created in the 1960s and typically contain 30% titanium carbide and 70% aluminum oxide. Molybdenum, niobium, and tantalum carbides are all present in some formulations. Their performance is in the middle of that of carbides and ceramics, and coatings appear to have limited advantages. 150-350 m/min are typical cutting speeds.

Ceramics:

Alumina

Two classes of cutting tools were introduced in the early 1950s. Aluminum oxide (A1203) and silicon nitride (Si3N4) are sintered at high temperatures after being pressed into insert tip shapes. To improve properties, titanium carbide and zirconium oxide (702) may be added. However, while ZrO2 increases fracture toughness, it decreases hardness and thermal conductivity. To improve toughness and thermal shock resistance, silicon carbide (SiC) whiskers can be added. Metals are less likely to stick to the tips during cutting due to their higher chemical stability compared to HSS and carbides, as well as their excellent abrasion resistance and hot hardness. Negative rake angles are frequently used to prevent chipping due to their low tensile strength and toughness. When machining with ceramic tips, stiff machine tools and work setups should be used because vibration is likely to lead to premature tip failure. Typical cutting speeds: 150-650 m/min.

Silicon Nitride

In the 1970s, silicon nitride-based tool materials were developed; these may also contain aluminum oxide, yttrium oxide, and titanium carbide. SiN has an affinity for iron and is therefore unsuitable for steel machining. One type is known as "Sialon," and it contains the elements silicon, aluminum, oxygen, and nitrogen. Because it has greater thermal shock resilience than silicon nitride, it is recommended for machining cast irons and nickel-based super alloys at moderate cutting rates.

Cubic Boron Nitride (CBN)

This substance, which was first introduced in the early 1960s, is second only to diamond in terms of hardness. Little solid tips made of CBN or a layer of polycrystalline boron nitride that is 0.5 to 1 mm thick and sintered under pressure onto a carbide substrate can both be utilized as tools. In the latter case, the carbide layer provides shock resistance, while the CBN layer provides extremely high wear resistance and cutting-edge strength. Cubic boron nitride is the preferred material for machining alloy and tool steels with harnesses of 50 Re or higher. Cutting speeds of up to 310 m/min are common.

In today's industry, high-speed steels have been largely replaced by carbide tools. These coated carbide and carbide tools cut between three and five times more quickly than high-speed steels. Cemented carbide, a powdered metal product, is formed by bonding fine carbide particles together with a cobalt binder. The four main types of hard carbide are tungsten carbide, titanium carbide, tantalum carbide, and niobium carbide. Ceramic cutting tools are more brittle, but also harder and more heat resistant than carbide tools. They excel at machining cast iron, hard steels, and super alloys. There are two types of ceramic cutting tools available: alumina-based ceramics and silicon nitride-based ceramics. Alumina-based ceramics are used in the high-speed semi- and final-finishing of ferrous and non-ferrous materials. Ceramics based on silicon nitride are commonly used for rougher and heavier machining of cast iron and super alloys.

1.3.8 Cutting Fluids

Cutting fluid, also known as coolant or lubricant, is used to improve the cutting condition and the tool's life. It can exist as a liquid or as a gas.

1.3.8.1 Types of Cutting Fluids

Soluble Oil:

Water, mineral oil, and coupling agents combine to form soluble oil. Soap is commonly used as a coupling agent. Depending on the operation, insoluble oil, an emulsion of mineral oil in water, is used at a ratio of 1:10 to 1:100. This type of cutting fluid is used in lathe operations, drilling operations, and shaping operations.

Cutting Oil:

It is a mineral oil and fatty oil blend. It is primarily employed in hand-cutting machinery. It can be used as a coolant as well as a lubricant for both low and high cutting rates.

Synthetic Coolant:

It has a higher cooling rate and, as its name implies, contains no mineral oil. Typically, grinding activities employ this kind of coolant.

Solid Lubricant:

Soap bars, molybdenum disulphide, graphite, and wax sticks can all be used as solid lubricants because they are in the solid phase.

1.3.8.2 Functions of Cutting Fluids in Turning

Cooling:

Heat is generated in the workpiece, chips, and cutting tool during metal cutting machining processes as a result of friction between the cutting tool and the workpiece surface. In the shear zone, heat is also produced as a result of the metal's plastic deformation. Several unwelcome repercussions of this heat include thermal expansion, chemical reactions including oxidation, welding of surfaces, and many more. By chilling the tool and the workpiece, a cutting fluid stops these consequences from occurring.

Lubrication:

The main cause of warmth during milling is friction. Surfaces have a propensity to fuse when friction and heat are combined. Cutting fluids work by creating a thin layer between the chip and the tool, thereby minimising contact between them and lowering friction. Moreover, lubrication reduces the energy requirement for the machining process and minimises cutting tool abrasion.

Prevention of corrosion:

Cutting fluids contain rust and corrosion inhibitors that stop rust and corrosion on machined surfaces and parts. Cutting fluids made of mineral oils stop oxidation by generating a very thin layer of protection on exposed surfaces.

Improvement of tool-life:

Because cutting fluids disperse heat, reduce friction and abrasion, and shield tools from corrosion and rust, they greatly reduce tool wear and lengthen tool life.

Chip removal:

During some machining operations, such as milling and drilling, chips often gather near the cutting zone. These chips can accumulate and prevent cutting. Furthermore, cutting fluids are used to flush chips out of the cutting area.

Improvement of surface finish:

Cutting fluids reduce thermal expansion and property changes in a workpiece, which helps machined products have a good surface finish.

CHAPTER-2

LITERATURE SURVEY

Numerous studies have been conducted in the area of optimizing the operating parameters of CNC lathes by taking into account various input parameters, such as cutting speed, feed rate, and depth of cut, in order to improve the output characteristics, such as material removal rate (MRR), surface roughness (Ra), tool wear, and dimensional accuracy, among others. Some of these studies were covered in this chapter.

Sachin Ashok *et.al.* (2018) [1]: In this experiment, they used Wire Electrical Discharge Machining (WEDM) of the Nimonic-75 alloy to investigate the effects of machining parameters such as pulse-on time, servo voltage, pulse-off time, peak current, wire feed rate, and cable tension on performance parameters such as surface roughness (SR) and metal removal rate (MRR). Experiments are carried out in accordance with Taguchi's L27 orthogonal collection. The principal component analysis is used to optimize the machining parameters. The ideal machining variable settings were discovered after investigation: pulse-on time 110 ms, pulse-off time 51 ms, servo voltage 40 volts, peak current 230 amps, wire feed rate 5 m/min, and cable tension 8 gramme. Using ANOVA (Analysis of Variance), they discovered that pulse-on time is the most influential factor influencing the performance characteristics. The results of the confirmation experiments show that the optimal machining parameters increased the value of the composite primary component (CPC) for the multiple responses from 1.2013 to 1.2443. The microstructure of the machined surfaces is examined using scanning electron microscopy (SEM).

Hari Vasudevan *et.al.* (2017) [2]: Glass Fibre Reinforced Polymers (GFRP) were used because they are widely used. They have numerous advantages over traditional reinforcements, such as extending the life of complex structures. They conducted research on the machining of randomly oriented GFRP composite rods. They looked into machining characteristics such as surface roughness and metal removal rate (Ra, Rp, Rq, Rv and Rsm). Turning factors such as tool nose radius, cutting speed, feed rate, and depth of cut are tuned to maximise performance. To determine the best factor level condition, they ran 27 experimental runs on L27 orthogonal arrays. They used fine grade carbide inserts as cutting inserts for machining. They used Principal Component Analysis (PCA) along with Grey

Relational Analysis was used to optimise the responses, which resulted in the parametric condition of A2B2C3D1, implying that the tool nose radius at Level-2(0.8mm), cutting speed at Level-2(160mm/min), feed rate at Level-3(0.25mm/rev), and depth of cut at Level-1(0.6mm) are the best combinations.

Bharat Chandra *et.al.* (2010) [3]: Through a case study in cylindrical grinding of UNS C34000 Medium Leaded Brass, their study highlights a multi-objective optimisation problem using Weighted Principal Component Analysis (WPCA) and the Taguchi method. Their main goal was to evaluate the best process quality in order to achieve the best surface quality. They used WPCA because Taguchi was unable to solve a multi-objective optimisation problem. In addition, WPCA was used in the study to remove response correlation and to evaluate independent or uncorrelated quality indices known as principal components. WPCA then aggregated the principal components to create an overall quality index known as the Multi-Response Performance Index. The estimated combined quality loss was then optimised. Their research combined WPCA and the Taguchi method to predict optimal settings. The optimal outcome was confirmed by a confirmatory test.

Karuna Kumar *et.al.* (2018) [4]: They conducted an investigation study to optimise the multiple responses of Material Removal Rate (MRR) and Surface Roughness (Ra, Rq and Rz). Their experiment was carried out on a CNC turret machine using the standard Taguchi's L9 orthogonal array. They chose three different factors: cutting velocity, speed, and depth of cut, and then performed a turning operation on AA7075 steel. They then used weighted principal component analysis (WPCA) in conjunction with combined quality loss (CQL) for optimisation, and CQL was improved using the Taguchi technique. They discovered the ideal cutting parameters based on the output responses using Taguchi, which showed good material removal rate and least surface roughness, namely 1500 rpm of speed, 0.2 mm/rev of feed, and 0.5 mm depth of cut. Using ANOVA, they determined that feed has more impact on responses than others.

Singarvel *et.al.* (2014) [5]: They conducted an experiment to determine the best machining parameters for turning E25 steel Chemical Vapour Deposition (CVD) and Physical Vapour Deposition (PVD) coated carbide tools using the Taguchi Method in conjunction with Principal Component Analysis (PCA). They used this method to reduce surface roughness, cutting force, and maximise material removal rate. PCA was used to determine the weight factors that were involved in all objectives. Finally, ANOVA was used on the Signal to Noise

(SN) ratio to determine which machining parameters have the greatest impact on the desired requirements.

Meenu Gupta et.al. (2014) [6]: The machinability of a Unidirectional Glass Fibre Reinforced Plastic (UD-GFRP) composite in a turning operation is investigated in this paper. They used six parameters to see which had an effect on output responses: Tool Nose Radius, Tool Rake Angle, Feed Rate, Cutting Speed, Cutting Environment (Dry, Wet, and Cooled), and Depth of Cut. They used a Taguchi L18 orthogonal array and Principal Component Analysis to analyse two response variables, Surface Roughness and Material Removal Rate (PCA). PCA is extremely useful when it is difficult to relate a large number of independent variables to a large number of dependent outcomes without having enough observations to carry out the analysis reliably. They discovered from their experiments that surface roughness increases with increase in fee rate. The machinability of Unidirectional Glass Fibre is investigated in this paper. They discovered that feed rate was the most important factor, followed by depth of cut and cutting speed. When the feed rate is 0.2 mm/rev, the depth of cut is 1.4mm, and the speed is 159.66 mm/min, the surface roughness is 1.498 m, and the material removal rate is 330.267 (mm)3/s.

Tian-Syung Lan *et.al.* (2018) [7]: The goal of this experiment is to optimize the influencing parameters of S45C steel while machining on a CNC machine. The varying parameters for this Taguchi method, along with fuzzy logic, are speed, cutting depth, and feed rate. A schematic rule was used to control the correlation between these parameters and production quality, and it was discovered that the proposed study is suitable for universal applications.

Nesredin Chekole Deresse et.al. (2019) [8]: This study is focused on the parameters which influence the metal removal rate while grinding operations on EN24 with dimensions 130mm length and 40mm diameter, before and after Heat Treatment Process, this experiment is carried out on hydraulic cylindrical grinding machine and Silicon Carbide (SiC) material is used as grinding tool. They considered Feed Rate, Depth of Cut, and Speed as processing variables. The chemical properties are completely altered after the heat treatment process; the material is gradually heated from 6500 C to 7000 C. They used signal to noise ratios and Analysis of Variance (ANOVA) to determine the effecting parameters, which show that the impact of depth of cut before HTP is 65.2% and feed rate after HTP is 57.3%. While the optimal parameters are 270 rpm, 0.025 mm depth of cut, and 0.02 mm feed rate.

Ning Li *et.al.* (2019) [9]: The processing parameters for this experiment are radial thrust, cutting power, and coefficient of friction at the tool chip interface, which are determined using Taguchi-based grey relational analysis coupled with kernel principal component analysis. The first Grey Relational Analysis approach is used to determine the correlation between the observed data and the reference data ranging from 0 to 1. From verification tests, it can be seen that there is a noticeable improvement in terms of radial thrust and power consumption, as well as a minor improvement in the coefficient of friction at the tool-chip interface for both of the operations. Kernel Principal Component Analysis (KPCA) was used to extract the kernel principal components and determine the corresponding weights. It is observed that the Feed rate has the most dominant effect on c, followed by depth of cut and type of insert.

Mustafa ÖZDEMİR (2019) [10]: have carried out research on the use of Taguchi L27 Orthogonal during machining on a CNC lathe machine to optimise cutting parameters including cutting speed, feed rate, and depth of cut. A 360 mm long piece of AISI 409 material with a diameter of 60 mm was used for the machining. In order to get the best surface roughness, it has been found that the smaller the S/N (sound to noise) ratio, the better the cutting conditions. It was also found that as the feed rate increased, the workpiece's Ra and Rz values increased. The feed rate was shown to be the parameter with the greatest impact on surface roughness based on the findings of the ANOVA. Lower feed rates result in better surface polish.

Abhang *et.al.* (2012) [11]: In the paper, an optimization methodology for the steel turning process is proposed using the Taguchi approach. The technique looks to find the ideal machining parameters in order to enhance surface roughness, tool wear, and material removal rate. The study investigates the effects of cutting speed, feed rate, and depth of cut on the performance measures. The Taguchi technique is used to design the experiments, and analysis of the results is used to establish the best parameter settings. The results show that the most effective machining settings are fast cutting speed, low feed rate, and shallow cutting depth. According to the research, it is possible to successfully optimize the machining parameters and enhance machining performance using the Taguchi approach. The approach can be used with a variety of machining methods and materials to improve process parameters and component quality.

Muthukrishnan *et.al.* (2012) [12]: The creation of Hybrid Metal Matrix Composites (Al/SiC/B4C - MMCs) using boron carbide (5% by weight of particles) and silicon carbide (10% by weight of particles) is covered in great length in this article. 200 mm long cylindrical rods with a 65 mm diameter are constructed and subsequently machined using a medium-duty lathe to investigate the machinability difficulties of hybrid MMC employing Polycrystalline Diamond inserts of 1600 grade. By using a composite desirability value from a desirability function analysis as the performance index, they have determined the ideal machining parameters. The analysis of variance can then be used to identify the variables that have a substantial impact on performance (ANOVA). Their findings demonstrate that adequate surface smoothness is achieved at greater cutting rates with faster tool wear. It is okay for there to be some variation between experimental and predicted findings. Moreover, tool wear analysis was investigated for 30 minutes while using the ideal values.

Jogendra Kumar *et.al.* (2021) [13]: The machinability and machining response optimization of the created hybrid nanocomposites are investigated in this work. The drilling responses of average surface roughness (Ra), mean roughness depth (Rz), and circularity error (Ce) were optimized using a combined approach of the Combined Compromise Solution and Principal Component Analysis (CoCoSo-PCA). Using a Responsive Surface Methodology-based array, drilling experiments are conducted (RSM). The optimal parameters are 1 weight% of graphene oxide (G%), 80 mm/min for the feed, and a drill speed of 2400 rpm. Both the circularity error and the surface roughness indices are demonstrated to be mostly governed by the feed rate. The high feed value has an impact on the occurrence of faults and cracks brought on by drilling. The high feed value has an impact on the occurrence of faults and cracks brought on by drilling. The SEM examination of the machined samples was done to evaluate the caliber of the machined holes and surface finishing. The model sufficiency of the hybrid model is determined by ANOVA. Whilst the PCA is utilized to minimize the data's dimensionality and pinpoint the key factors influencing machinability. A confirmatory test verified the findings, proving the recommended hybrid module's practicality in a manufacturing environment.

Kuppusamy *et.al.* (2018) [14]: Here, turning parameters for titanium alloy made of Ti-6Al-7Nb have been examined using orthogonal arrays, Grey relational analysis, and principal component analysis. Surface roughness, tool wear, roundness, material removal rate, temperature, and power consumption are some of the performance features of the turning process. Using an orthogonal array and the CNC machine, 18 experiments are run, with the turning parameters taken into account for the cutting environment, cutting speed, feed rate, depth of cut, nose radius, tool coating type, and insert shape angle. The grey relational grade was used to forecast the ideal turning parameters. The influence of various variations in turning parameter is assessed using analysis of variance. The following parameters are found to be better turning parameter levels from grey relational grade parameters: cutting environment: wet, feed rate: 0.08 mm/rev, cutting speed: 100 m/min, insert angle: 800, nose radius: 0.4 mm, tool coating type: Tian, and depth of cut: 0.4 mm. The research demonstrates that the proposed method may successfully improve machining performance and reduce manufacturing expenses for CNC turning titanium alloy. The approach can be used with various machining techniques and materials to enhance the process parameters and the accuracy of the produced components.

Chintan Kayastha *et.al.* (2013) [15]: The objective of this paper is to optimise the process parameters for turning operations using Taguchi and principal component analysis. The objective of the current work is to investigate the effects of process parameters on surface finish and material removal rate in order to manufacture a product with a good finishing surface and achieve the best configuration of these process parameters (MRR). Lowest possible machining cost is desired in the turning process. The material is copper. Moreover, copper is extensively used in a variety of industrial, medical, and electrical applications. In manufacturing firms, the turning process is commonly used. As a multi response optimisation problem that cannot be solved by standard optimisation techniques, the PCA approach in conjunction with the grey based Taguchi method is implemented for MRR and Surface roughness optimisation. Once the lathe machine has been inspected and prepped, the weight of the copper work piece needs to be measured. The adoption of PCA has been advocated to minimise response correlation since it converts correlated responses into uncorrelated quality indices known as principle components, which have been treated as response variables for optimisation. The grey based Taguchi strategy has been found to be helpful for figuring out the appropriate parameter setting and addressing such multi objective optimisation issues. Off-line quality control and continuing process/product improvement could both benefit from the aforementioned technique.

Rahman *et.al.* (2021) [16]: The combined impact of radial depth, cutting speed, and feed rate on cutting forces, tool life, and surface roughness during face milling of Ti6Al4V alloy is examined in this paper. High strength to density ratios, extreme corrosion and fracture resistance, and exceptional performance at high temperatures are just a few of the outstanding qualities of titanium and its alloys. By adjusting three cutting parameters as input factors and utilising the Taguchi method and ANOVA to conduct single objective optimisation of cutting forces and surface roughness. The optimal set of cutting parameters cannot be found in this investigation using single objective optimisation. A literature review finds that Taguchi-based grey rational has never been used for multi-objective optimisation of face milling of Ti6Al4V alloy. Using the Taguchi design of experiment and Taguchi L9 orthogonal array, titanium alloy face milling experiments were created using the Taguchi method. As input factors, cutting speed, feed rate, and radial depth of cut were chosen. The Taguchi and regression analyses were to be carried out using Minitab 19. The models may be used to accurately forecast cutting forces, surface roughness, and tool life. Further research will examine the significance of the radial depth of cut on the microstructure and residual stress produced during face milling of the Ti6Al4V alloy.

Ruby Halder *et.al.* (2022) [17]: Here, she uses the powerful Taguchi with the orthogonal array (L27) plan to control the optimisation level comparison of the metal copper (Cu) and aluminium (Al) bar. By using the Taguchi strategy for DOE and ANOVA to achieve the optimisation level for the best quality product at the lowest cost in the manufacturing processes, the machining boundaries (speed, feed rate, and depth of cut) of both the materials copper and aluminium are taken as a comparison to achieve the base surface roughness. For the purpose of obtaining crucial optimum yield outcomes for the materials, three levels of parametric esteems have been chosen as input parameters. The optimal value for copper bar is S2F2D1 (1800 rpm, 50 mm/rev and 0.3 mm) and optimal value for aluminium bar is S2F3D2 (1800 rpm, 60 mm/rev and 0.4 mm).

Harish Kumar *et.al.* (2013) [18]: They have considered surface finish and dimensional tolerance as their main attributes for this experimentation because they are key parameters to check the quality. They have worked to increase the quality of the output of the turning operation on the CNC machine by optimising the input parameters. The output parameter is the dimensional tolerance, and the input parameters are the feed rate, spindle speed, and depth of cut. For the purpose of optimising the input parameters, they used a L9 array in the experiment design. They have determined the important processing factors and optimised the surface roughness in turning using Taguchi. Their research has demonstrated that the critical element for reducing both dimensional variation and surface roughness is spindle speed.

Satish Kumar *et.al.* (2020) [19]: They use cutting-edge manufacturing techniques, like CNC turning, to produce high-quality, defect-free goods. Their primary goals are improved productivity and better quality. They have optimised the CNC turning settings for cutting EN19 alloy steel. Using a variety of independent parameters, including cutting speed, feed, and depth of cut, they have conducted a number of studies using the face-cantered central composite-based response surface methodology. Following the experiment, they calculated the surface roughness and the rate of material removal (MRR). ANOVA was used to evaluate how these parameters affected things. Moreover, regression analysis was performed. ess.

Vijay Kumar *et.al.* (2018) [20]: Their primary goal is to look at the machining characteristics of EN19 stainless steel when tuned on a CNC lathe, such as surface roughness and MRR. As input parameters, they took into account the feed rate, cut depth, spindle speed, and lubrication. This experiment employed a tool with a carbide tip. The experimentation design for the L18 mixed type orthogonal array has been chosen for analysis and Taguchi's Method optimisation. In order to determine the importance of process parameters, they have also employed ANOVA.

Nishat Akhtar *et.al.* (2021) [21]: By employing a CNC machine, their work optimises the process parameters for turning aluminium alloy 7075. They were interested in learning how process variables affected surface roughness and metal removal rate. Speed (800, 1200, and 1600 rpm), feed (0.15, 0.20, and 0.25 mm/rev), and depth are the process characteristics taken into account (1.0, 1.5 and 2.0 mm). The L27 array Taguchi approach enhanced the results in terms of MRR (highest) and surface roughness (lowest). Direct and indirect contact sensors were used to measure the reactions of 27 specimens. Diagrams depicting the primary effect were used to conclude the findings in favour of the SN ratio.

Arulraj *et.al.* (2019) [22]: Their primary concern is the reduction of surface roughness during the turning of an aluminium hybrid matrix (LM24-SiC-Coconut Shell Ash). Squeeze casting was used to create all of the composite samples, and L9 orthogonal array was used to choose the experimental trials. Surface roughness is the primary reaction that they have taken into consideration for the study, and feed, speed, depth of cut, and tool nose radius are the process characteristics that they have taken into account. A high-speed CNC lathe was used to test the composite materials. Using Taguchi and a general algorithm, they discovered the ideal circumstances, which were then verified by a confirmation experiment. In their analysis, a generic algorithm produced better outcomes than the Taguchi approach.

Sanjit Moshat *et.al.* (2010) [23]: Their main goal is to maximise the surface roughness and MRR quality qualities so that they can both be satisfied to the required degree. They then presented a multi-objective optimisation issue that was resolved using the Taguchi Method based on PCA. Principal components are uncorrelated or independent quality indexes that have been created from correlated responses. The greatest accountability proportion-imposing major component has been considered as a single objective function for optimisation (multi-response performance index). The Taguchi method has finally been modified to resolve this optimisation issue.

S. Jasper *et.al.* (2018) [24]: They examined the rate of material removal, machining time, and surface roughness on the Glass Fibre Reinforced Plastic (GFRP) composite material throughout the turning process while working under the constraints of cutting speed, feed rate, and depth of cut. Their goal is to examine the machining properties of GFRP using the Taguchi Design approach. Finally, analysis of means (ANOM) was carried out to establish the parameters' ideal values. Analysis of variance (ANOVA) has also been used to determine the significance of the machining parameters. Their results have shown that most influential factor for surface roughness is feed, for machining time speed is the influential factor and for MRR, DOC is the main influential factor.

Bhanodaya Reddy *et.al.* (2017) [25]: To determine the factors influencing the removal of material, they experimented using aluminium 7075 alloy on a turn master 350 lathe machine. For analysis, they used statistical software MINITAB and parameters included cutting tool material, cutting speed and spindle speed, depth of cut, feed rate, tool geometry, and coolant, as well as Signal to Noise (S/N), Analysis of variance (ANOVA), and Taguchi technique.

They discovered that feed effects surface roughness, machine speed influences cutting force, and depth of cut influences cutting temperature.

S.Ghosh *et.al.* (2022) [26]: Their study's primary goal was to determine the best cutting parameters (speed, feed rate, depth of cut, and cutting fluid) for lathe turning of low carbon steel AISI 1018. Taguchi and ANOVA methods with L9 Orthogonal were used to carry out the optimisation. The experimental results showed that the Taguchi parameter design is a useful method for determining the ideal cutting parameters for achieving low Tool Wear and high MRR. Cutting Speed (67.07%) and Depth of Cut (24.13%) were found to contribute the greatest percentages.

Ramanathan Arunachalam *et.al.* (2019) [27]: This study analyses all the essential aspects of the stir casting process, including furnace design, composites' characteristics, and production issues. They have tested many casting processes to determine which is most effective for casting Metal Matrix Composites. The manufacture of MMCs is most likely to be successful using stir/squeeze casting, powder metallurgy, and semi-solid. Al is a more often used matrix material due to its simplicity of handling throughout the manufacturing process. The most widely employed reinforcing particles are SiC, Al_2O_3, and B_4C because they can offer higher mechanical qualities including strength and hardness.

Rajeshkumar Gangaram Bhandare *et.al.* (2014) [28]: In this study, which concerns the preparation of an aluminium composite made of silicon, graphite, and aluminium oxide, the effecting factors of stir casting are primarily discussed. According to the study's findings, the number of blades and angle of the blades should be four for uniform material dispersion. Mould preheating improves mechanical characteristics while also reducing porosity. Maintaining the working temperature at the semisolid stage is necessary for good wettability; at the full liquid condition, it is challenging to distribute the reinforcement in the molten metal uniformly.

G. G. Sozhamannan *et.al.* (2012) [29]: For decades, metal matrix composites with discontinuous particle reinforcement have been made using the traditional stir casting process. The main challenges in this method are getting enough liquid metal to moisten the particles and getting a uniform distribution of the ceramic particles. To better understand how processing temperatures and holding times affect the distribution of particles in the matrix and the resulting mechanical properties, aluminium metal matrix composites were created in the current work. As processing temperatures are raised, the viscosity of the Al matrix decreases. Al-SiCp has an approximately 38% higher suspending liquid viscosity than the Al matrix without reinforcement. When processing temperatures are increased from 750°C to 800°C with a 20-minute holding period, the hardness values increase more or less linearly.

Palash Poddar *et.al.* (2007) [30]: The preparation of magnesium alloy with silicon carbide (SiC) to create a metal matrix composite is the main topic of this study. It is possible to create reinforced magnesium-based metal matrix composites with negligible porosity using the stir casting method, which entails melting and stirring at a temperature of 680 °C. In the presence of SiC particles, hardness, elastic modulus, and yield strength all dramatically rise, whereas ultimate tensile strength falls. The limited Mg oxidation shows that oxygen penetration into the liquid metal was prevented by the experimental setup used in the current work.

J. David Raja Selvam *et.al.* (2013) [31]: The creation of AMCs reinforced with varying weight percentages of SiC particles and a fixed weight % of Fly Ash is the main goal of this work, which uses a modified stir casting process. One of the simplest methods for creating composites made of aluminium matrix is stir casting (AMCs). With a fixed weight % of fly ash in the aluminium matrix and an increase in the weight percentage of SiC particles, the mechanical qualities such as hardness and tensile strength were enhanced. The addition of reinforcing particles increased the tensile strength of composites with aluminium matrix from 173 MPa to 213 MPa.

R.Jojitha and N.Radhika (2018) [32]: This study uses liquid metallurgy to fabricate an unreinforced alloy and hybrid metal matrix composite, and it evaluates its mechanical and adhesive wear properties. With regards to hardness and tensile qualities, the composite outperformed the alloy by 16.5 and 35%, respectively. Wear rates increased with load and sliding velocity for both the alloy and the composite, but declined with increasing sliding distance for the composite and vice versa for the alloy.

K.Sagar and L.RadhaKrishnan (2017) [33]: This study focuses on the effects of stirring various amounts of nickel metal into aluminium alloy to create a composite. The composite is then tested to determine its hardness, strength, and impact loads. The findings demonstrate that as nickel amount rises, hardness and impact strength follow suit. Nevertheless, when nickel level reaches 2.3wt%, characteristics drastically decline when compared to base alloy AA 6061.

A limited amount of study has been done on multi-objective optimisation of MRR, Ra, and TWR properties when turning Al 2024 using coated tungsten carbide tools, according to the aforementioned literature survey. No results were obtained when nose radius was taken into account as one of the controlling factors. In the present investigation, PCA and CQL were employed in conjunction with multi-objective replies. The ideal machining parameter combination (speed, feed, nose radius, and depth of cut) was discovered for maximum material removal rate (MRR) and minimal surface roughness (Ra).

CHAPTER-3

METHODOLOGY

There are many methods for improving output characteristics and obtaining the best value, but from all optimization methods. The Taguchi experimental design method is straightforward and suitable for a wide range of technical problems. The Taguchi approach makes it possible to examine a variety of aspects without conducting a lot of unnecessary experiments. With the information currently available, it can be used to quickly narrow the focus of a research study or identify problems in a manufacturing process. Also, it makes it possible to recognize the critical variables that have the most effects on the performance characteristic value in order to focus further tests on these variables and ignore the ones with little effects.

3.1 Taguchi method

Dr. Genichi Taguchi has created a methodical statistical approach to product and process improvement. The method places a strong emphasis on bringing the quality issue upstream, to the design stage, and on defect prevention through process improvement. Taguchi has emphasized again how crucial it is to reduce variance as the main strategy for raising quality. The total loss suffered by society as a result of a product's failure to perform as intended and as a result of a product's negative side effects, including the operating cost, is how Taguchi defines a product's quality level. Some loss occurs as soon as a product is delivered to the customer; smaller loss results in more aesthetically pleasing products. It is critical to quantify this loss in order to contrast various product designs and production processes. Using a quadratic loss function, this is accomplished. The producer often provides a target value of the performance characteristic and a tolerance range around that value when doing manufacturing quality control. Any performance characteristic value that falls within the tolerance range of three or less is considered a desirable product. The emphasis is on obtaining the goal value of the performance characteristic and departure from the value is punished when using the loss function as a definition of quality. A bigger quality loss occurs with a larger departure from the goal value.

Signal-to-noise ratio (S/N)

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

the better the smaller

Since S/N = -10 log10 [y2], the smaller is higher quality characteristic can be expressed.

Higher-the-Better

Since S/N = -10 log10 [1/y2], the higher is better quality feature can be expressed.

3.2 Analysis of Variance (ANOVA)

The ANOVA is employed to identify the process variables that significantly affect the performance qualities. This is accomplished by dividing the contributions from each of the process parameters and the error into the S/N ratio variability, which is determined as the sum of the squared deviations from the S/N ratio's overall mean. Secondly, the total squared deviations SST from the overall mean of the S/N ratios can be determined as follows:

$$SS_T = \sum_{i=1}^{m}(\eta_i - \bar{\eta})^2 = \sum_{i=1}^{m}\eta_i^2 - \sum_{i=1}^{m}2\eta_i\bar{\eta} + \sum_{i=1}^{m}\bar{\eta}^2$$

$$= \sum_{i=1}^{m}\eta_i^2 - 2m\bar{\eta}^2 + m\bar{\eta}^2 = \sum_{i=1}^{m}\eta_i^2 - m\bar{\eta}^2$$

$$= \sum_{i=1}^{m}\eta_i^2 - \frac{1}{m}\left[\sum_{i=1}^{m}\eta_i\right]^2$$

where ηi is the mean S/N ratio for the ith experiment and "m" is the number of experiments in the orthogonal array, for example, m = 9. The sum of the squared deviations SST from each process parameter and the sum of the squared error SSe are combined to form the total sum of squared deviations SST. SSP can be determined by:

$$SS_P = \sum_{j=1}^{t} \frac{(S\eta_i)^2}{t} - \frac{1}{m}\left[\sum_{i=1}^{m} \eta_i\right]^2$$

where "p" stands for one of the experiment's parameters, "j" is the parameter's level number, "t" is how many times the parameter will be repeated at each level, and " sηj" is the total S/N ratio for both parameter "p" and level "j." The squares of the error parameters SSe are

$$SS_e = SS_T - SS_A - SS_B - SS_C$$

The tested parameter's degrees of freedom are Dp = t 1, and the overall degrees of freedom are DT = m 1. The parameter under test has a variance of VP = SSP/DP. The F-value is then just the ratio of the mean square deviation to the mean square error (FP = VP/Ve) for each design parameter. Calculating the corrected sum of squares SP is as follows:

Ŝp = SSp - DpVe

The proportional contribution q can be thought of as:

$q = \hat{S}_p / SS_T$

Which process variables have a significant impact on the performance characteristic can be ascertained statistically using the Fisher F-test. Before performing the F-test, the mean of the squared deviations SSm originating from each process parameter must be calculated. The mean of the squared deviations SSm is obtained by dividing the sum of the squared deviations SSd by the number of degrees of freedom associated with the process parameter. In this case, the F-value is simply the ratio of the mean squared deviation (SSm) to the mean squared error (SSe) for each process parameter. Typically, the larger the F-value, the more the change in the process parameter has an impact on the performance characteristic.

CHAPTER-4

EXPERIMENTAL PROCEDURE

This chapter provides a detailed explanation of the experimental steps involved in the current work, including the choice of workpiece material, the choice of process parameters and their levels, the choice of an appropriate orthogonal array, etc.

4.1 Selection of Work Material

In this experiment, we employed a composite consisting of silicon carbide (SiC), boron carbide, and aluminium (Al2024) as the basis metal (B4C). The amount of composite used is distributed as follows: Al2024 is comprised of 96%; SiC, 3.5%; and B4C, 0.5%. Stir casting was used to create the composite. Al2024 has a wide range of uses in a variety of industries, including aerospace (for the manufacture of wing skins, wing spars, and fuselage frames), automotive (for the manufacture of engine components, suspension systems, and wheel rims), marine (for the manufacture of hulls, decks, and masts of boats and ships), and sporting goods. This is the primary reason why we chose it (for manufacturing of tennis rackets, golf clubs and bicycle parts). The Tables 4.1 and 4.2, respectively, list the chemical composition and mechanical properties.

Table 4.1 Chemical Composition of Al2024

ELEMENTS	COMPOSITION
Aluminium	Min 90.7% to Max 94.7%
Copper	Min 3.8% to Max 4.9%
Magnesium	Min 1.2% to Max 1.8%
Manganese	Min 0.3% to Max 0.9%
Additional elements (Si, Fe, Zn, Cr, Ti, etc)	Not more than 0.05% each or not more than 0.15% in total

Table 4.2 Mechanical Properties of Al2024

PROPERTIES	VALUES
Hardness	120
Ultimate Tensile Strength	469 MPa
Tensile Yield Strength	324 MPa
Elongation	20%
Modulus of Elasticity	73.1 GPa
Shear Strength	283 MPa

4.2 Stir Casting Process:

The stir casting arrangement includes a feeder, a stirrer, reinforcements, and a furnace. In a different furnace, strengthening ingredients like silicon carbide and boron carbide are preheated. The stirrer's function is to create a vortex in which the reinforcing components and molten metal are combined. The reinforcing elements are put into the molten matrix after it has been agitated for a while to generate a vortex. The feeder is used to accomplish this at a steady rate. After the reinforcing elements have been entirely poured, the stirring process goes on for a while. By doing this, the molten matrix and reinforcing material are thoroughly and uniformly combined. The mould is filled with the molten matrix. The final casting is produced following the solidification process. The composite material is formed into a cylindrical piece and then machined on a lathe under different circumstances (speed, feed rate, depth of cut). Figures 4.1 and 4.2 depict the stir casting experimental setup and the piece being produced utilising the procedure, respectively.

Figure 4.1 Stir Casting Setup

Figure 4.2 Casting Pieces

4.3 Selection of Process Parameters and their Levels

Determining the parameter range and selecting the ideal set of process parameters are essential tasks in an uncommon process. Even the slightest variation in the process parameters will have a negative effect on the surface roughness and accuracy of machined components. Process parameters often come in two types.: 1) Fixed Parameters and 2) Controlled Parameters.

While cutting speed, feed, depth of cut, and nose radius are taken as controlled parameters that will change for each experiment using the Taguchi approach, workpiece hardness, mechanical characteristics, and environmental conditions are taken as fixed parameters that will not change throughout the investigation. Table 4.3 lists the chosen process parameters for the experiment along with their upper and lower bounds, notations, and units. In figures 4.3 and 4.4, the two tool nose radii of 0.4 mm and 0.8 mm, respectively, are displayed.

Table 4.3 Process Parameters and Levels

Parameters	1	2	3
Radius (mm)	0.4	0.8	-
Speed (rpm)	900	1200	1500
Feed Rate (mm/rev)	0.10	0.15	0.20
Depth of Cut (mm)	0.50	1.0	1.5

Figure 4.3 0.8 mm Nose Radius

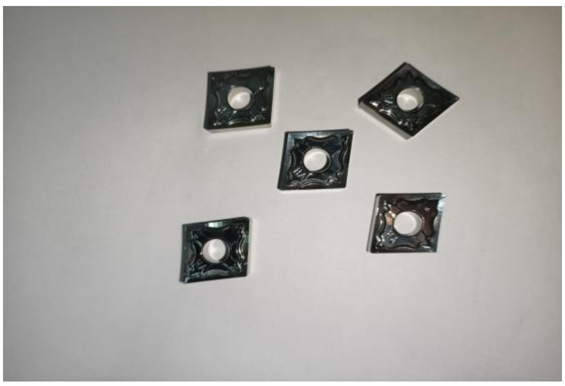

Figure 4.4 0.4 mm Nose Radius

4.4 Selection of Orthogonal Array (OA)

Table 4.4 displays Taguchi's standard L18, which has been chosen to study the full experiment.

Table 4.4 Input Parameters and L18 OA

S.NO	Nose Radius (mm)	Speed (rpm)	Feed Rate (mm/rev)	Depth of Cut (mm)
1	0.4	900	0.1	0.5
2	0.4	900	0.15	1
3	0.4	900	0.2	1.5
4	0.4	1200	0.1	0.5
5	0.4	1200	0.15	1
6	0.4	1200	0.2	1.5
7	0.4	1500	0.1	1
8	0.4	1500	0.15	1.5
9	0.4	1500	0.2	0.5
10	0.8	900	0.1	1.5
11	0.8	900	0.15	0.5
12	0.8	900	0.2	1
13	0.8	1200	0.1	1
14	0.8	1200	0.15	1.5
15	0.8	1200	0.2	0.5
16	0.8	1500	0.1	1.5
17	0.8	1500	0.15	0.5
18	0.8	1500	0.2	1

Figures 4.5 and 4.6 demonstrate how the trials were carried out on a CNC lathe and how the workpiece was machined. The SJ-210 roughness gauge was used to test the completed components for roughness after machining, as shown in figure 4.7.

Figure 4.5 CNC Lathe Machine

Figure 4.6 Machining of Composite

Figure 4.7 SJ-210 Roughness Gauge

CHAPTER-5

RESULTS AND DISCUSSION

5.1 Experimental Results of the Responses

Following the conclusion of the experiment, the output responses, Material Removal Rate (MRR), Surface Roughness (Ra a Rz), and Tool Wear Rate (TWR), were calculated and are displayed in table 5.1.

Table 5.1 Output Responses

S. No	MRR (cm^3/min)	R_a (µm)	R_z (µm)	TWR (mm^3/min)
1	0.045	2.630	14.410	0.580
2	0.135	5.800	29.230	0.710
3	0.270	4.220	29.420	0.850
4	0.060	2.160	13.360	0.490
5	0.180	4.880	23.640	0.630
6	0.360	5.330	25.990	0.760
7	0.150	3.500	15.560	0.440
8	0.338	4.120	21.880	0.580
9	0.150	4.690	23.680	0.600
10	0.135	1.000	6.860	0.550
11	0.068	0.770	5.260	0.570
12	0.180	6.040	26.620	0.710
13	0.120	1.050	5.810	0.430
14	0.270	3.530	18.240	0.570
15	0.120	4.970	24.270	0.590
16	0.225	1.780	10.430	0.380
17	0.113	2.130	10.870	0.410
18	0.300	4.160	19.690	0.540

The normalised values of the aforementioned output responses should have minimal surface roughness, maximum material removal rate, and maximum tool wear rate, as shown in table 5.2.

Table 5.2 Normalized Values

S. No	MRR (cm^3/min)	R_a (µm)	R_z (µm)	TWR (mm^3/min)
Ideal	1	1	1	1
1	0.1250	0.2932	0.3650	0.6552
2	0.3750	0.1329	0.1800	0.5352
3	0.7500	0.1238	0.1788	0.4471
4	0.1667	0.3570	0.3937	0.7755
5	0.5000	01579	0.2225	0.6032
6	1.0000	0.1445	0.2024	0.5000
7	0.4167	0.2525	0.3380	0.8636
8	0.9375	0.1871	0.2404	0.6552
9	0.4167	0.1643	0.2221	0.6333
10	0.3750	0.7669	0.7668	0.6909
11	0.1875	0.9987	1.0000	0.6667
12	0.5000	0.1276	0.1976	0.5352
13	0.3333	0.7319	0.9053	0.8837
14	0.7500	0.2179	0.2884	0.6667
15	0.3333	0.1551	0.2167	0.6441
16	0.6250	0.4319	0.5043	1.0000
17	0.3125	0.3613	0.4839	0.9268
18	0.8333	0.1852	0.2671	0.7037

5.2 Pearson Coefficient of Correlation:

The most used metric for determining a linear correlation is the Pearson coefficient of correlation. A link between two variables' strength and direction is expressed as a number between -1 and +1. Assuming that the output answers are normalised, we pair them and calculate the Pearson correlation, which is displayed in table 5.3.

Table 5.3 Correlation between the responses

S. No	Correlation between the responses	Pearson Correlation Coefficient
1	MRR & R_a	-0.461
2	MRR & R_z	-0.460
3	MRR & TWR	-0.298
4	R_a& R_z	0.988
5	R_a& TWR	0.421
6	R_z& TWR	0.495

5.3 Principal Component Analysis (PCA):

The output answers were obtained, and the results were entered into the MINITAB programme to produce the Eigen Values and Eigen Vectors, which are displayed in tables 5.4 and 5.5, respectively.

Table 5.4 Eigen Values, AP and CAP

	MRR	R_a	R_z	TWR
Eigen Value	2.6248	0.704	0.6631	0.008
AP (accountability proportions)	0.656	0.176	0.166	0.002
CAP (cumulative accountability proportion)	0.656	0.832	0.998	1

Table 5.5 Eigen Vectors

	PC1	PC2	PC3	PC4
MRR	0.403	0.661	0.633	-0.008
Ra	-0.576	-0.070	0.431	-0.692
Rz	-0.587	0.011	0.372	0.719
TWR	-0.402	0.747	-0.525	-0.068
∑(MRR+Ra+Rz+TWR)	-1.162	1.349	0.911	-0.049

The Eigen Vectors table's PC1 column was squared to provide the weighted values for each output parameter. The calculated and discovered weights are as follows: WMRR = 0.1624, WRa = 0.3318, WRz = 0.3446, and WTWR = 0.1616. These values are displayed in table 5.6.

Table 5.6 Weights of Responses

	Wj
MRR	0.1624
R_a	0.3318
R_z	0.3446
TWR	0.1616
∑Wj	1.0000

Major Principal Component values were calculated just by multiplying Normalized value table (table 5.2) with Eigen Vector table (table 5.5).

Table 5.7 Major Principal Components

S. No	MRR	R_a	R_z	TWR
Ideal	-1.1620	1.3490	0.9110	-0.0490
1	-0.5962	0.5555	-0.0027	0.0140
2	-0.2462	0.6404	0.0806	-0.0020
3	-0.0537	0.8230	0.3599	0.0065
4	-0.6813	0.6688	-0.0013	-0.0180
5	-0.2626	0.7725	0.1507	0.0057
6	-0.0001	1.0266	0.5081	0.0035
7	-0.5232	0.9066	0.0449	0.0062
8	-0.1345	1.0986	0.4196	-0.0087
9	-0.3117	0.7395	0.0847	-0.0004
10	-1.0185	0.7187	0.4904	-0.0294
11	-1.3547	0.5630	0.5711	0.0189
12	-0.2031	0.7235	0.1640	0.0134
13	-1.1740	0.8392	0.3993	0.0817
14	-0.2605	0.9817	0.3259	0.0052
15	-0.3411	0.6930	0.0203	0.0020
16	-0.6949	1.1354	0.2444	-0.0092
17	-0.7388	0.8789	0.0470	0.0324
18	-0.2106	1.0665	0.3373	0.0094
Wj	-0.1624	0.3318	0.3446	0.1616

Weighted Multi Response Performance Index (WMPI) can be obtained by multiplying elements from Major Principal Component table with their individual weights and then summing them up. The combined quality loss (CQL) value can be calculated by subtracting the ideal WMPI value with corresponding value.

Table 5.8 WMPI and CQL

S. No	Weighted Multi Response Performance Index (WMPI)	Combined Quality Loss (CQL)
Ideal	0.5649	0.0000
1	0.0888	0.4761
2	0.1999	0.3650
3	0.3894	0.1755
4	0.1079	0.4570
5	0.2665	0.2984
6	0.5163	0.0486
7	0.2323	0.3326
8	0.4859	0.0790
9	0.2239	0.3410
10	0.2373	0.3276
11	0.1606	0.4043
12	0.2658	0.2991
13	0.2386	0.3263
14	0.3966	0.1683
15	0.1819	0.3830
16	0.3466	0.2183
17	0.1931	0.3718
18	0.4374	0.1275

5.4 Taguchi Analysis

In terms of CQL, the challenging multi-objective problem has now been reduced to a single objective problem. It is well-known that the value of CQL decreases as a number of performance attributes improve. Taguchi's smaller is better characteristic has been employed to ascertain the effect of cutting parameters on the multi-responses and to ascertain the best combination of process parameters.

Table 5.9 Taguchi Analysis: CQL versus r, s, f, d

Level	r	s	f	d
1	**12.760**	9.726	9.241	7.898
2	11.254	12.852	12.207	11.153
3	-	**13.443**	**14.573**	**16.970**
Delta	1.506	3.717	5.331	9.072
Rank	4	3	2	1

Table 5.9 demonstrates that depth of cut is the main factor influencing MRR and surface roughness. Next is speed, next comes feed rate (). (). The optimal CQL parameters according to the Taguchi analysis are as follows: Nose radius = 0.4 mm, Speed = 1500 rpm, Feed Rate = 0.2 mm/rev, and Depth of Cut = 1.5 mm. The matching levels and ideal characteristics are shown in Table 5.10.

Table 5.10 Optimal Parameters for MRR and Surface Roughness

Parameters	Level	Level Description	Units
Nose radius	R1	0.4	mm
Speed	S3	1500	rpm
Feed	F3	0.2	mm/rev
Depth of Cut	D3	1.5	mm

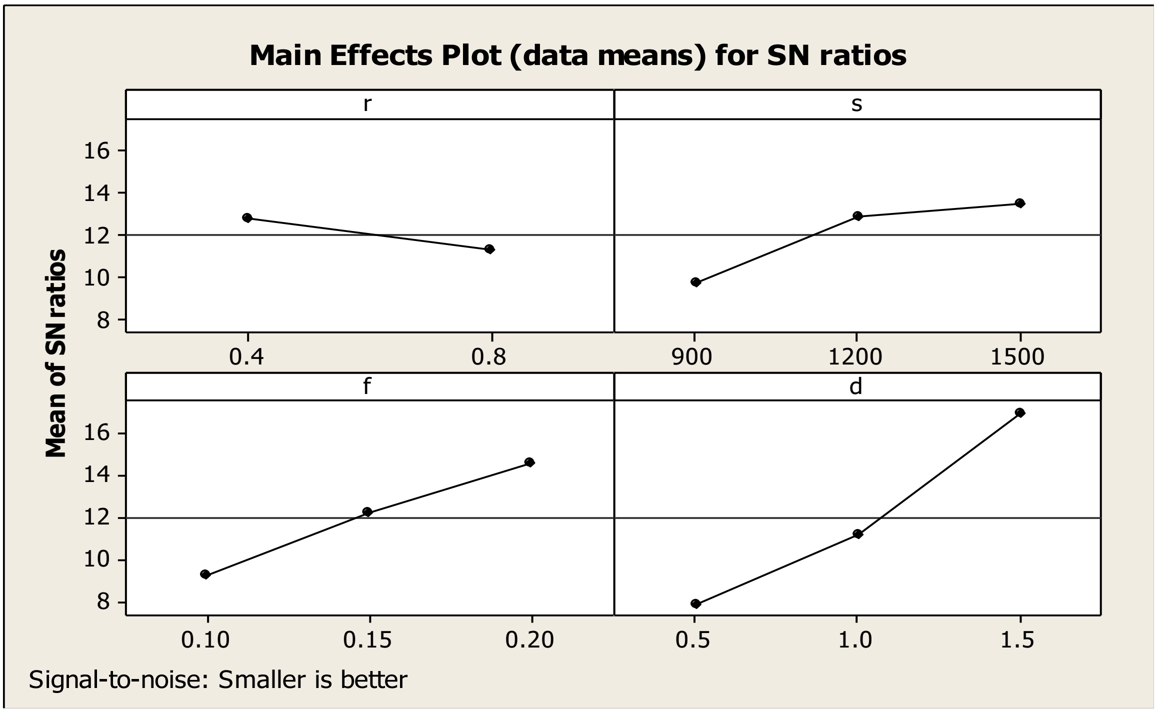

Figure 5.1 Main Effect Plots for SN Ratios

As compared to other process factors, it can be seen from figure 5.1 that the depth of cut has the most significance, followed by the feed rate, the cutting speed, and finally the nose radius.

5.5 ANOVA Results

It is a technique for allocating output response variability to various inputs. Which design parameter significantly affects the performance attributes is identified using ANOVA. The results in Table 5.11 clearly show that the depth of cut has the biggest impact, with feed rate, speed, and nose radius closely following.

Table 5.11 ANOVA for CQL

Source	DF	SS	Adj SS	Adj MS	F	P
r	1	0.000156	0.000156	0.000156	0.07	0.792
s	2	0.028446	0.028446	0.014223	6.68	0.014
f	2	0.049076	0.049076	0.024538	11.53	0.003
d	2	0.167127	0.167127	0.083563	**39.26**	0.000
Error	10	0.021287	0.021287	0.002129		
Total	17	0.0266092				

S	R-Sq	Adj R-Sq
0.0461377	92%	86.40%

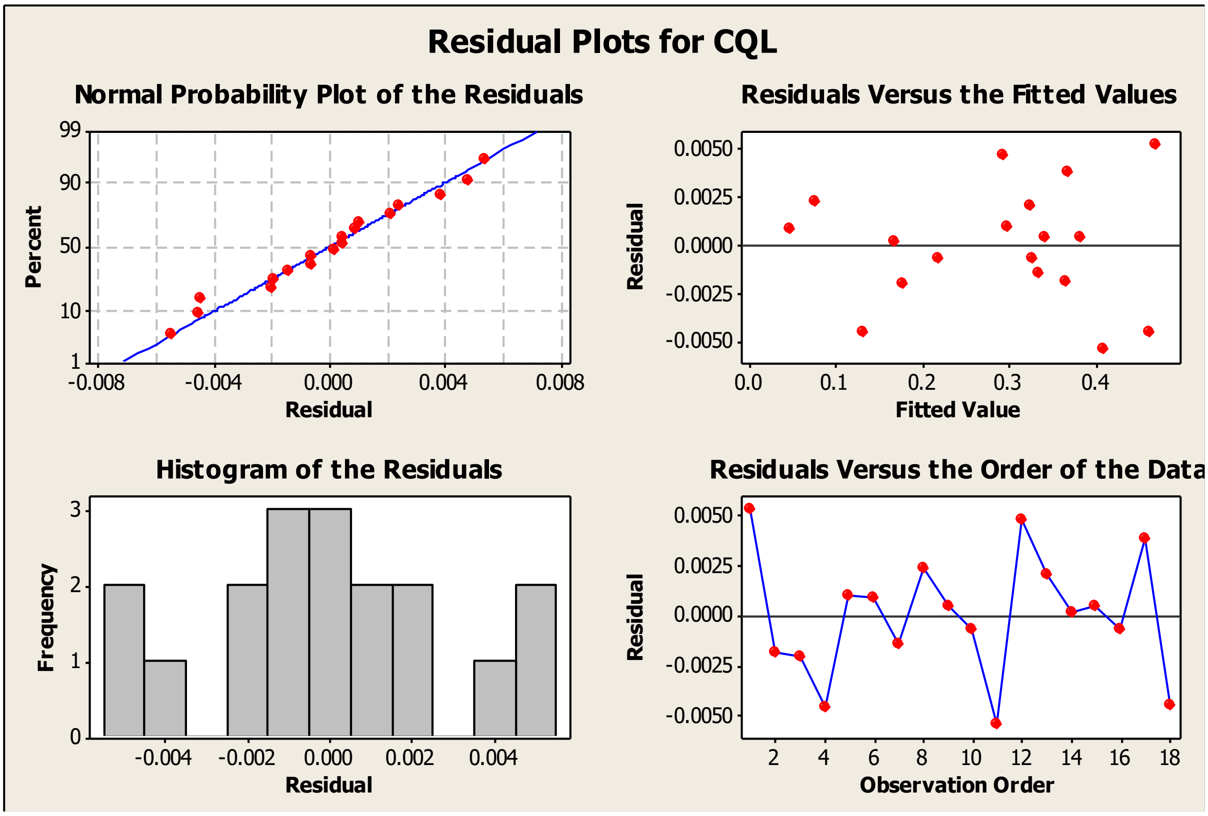

Figure 5.2 Residual Plots for CQL

The figure 5.2 shows the residual plots for CQL and from it we can clearly observe that all residuals are lying near the straight line hence following the normality and from the fits and orders plot it can be observed that they are not representing or following any regular patterns i.e., following the constant variance.

CHAPTER-6

CONCLUSION

6.1 Conclusion

From the experiment, where ANOVA was used to optimise Principal Component Analysis (PCA) and Combined Quality Loss (CQL), the following conclusions can be drawn:

- The results of this experiment showed that 0.4 mm for the nose radius, 1.5 mm for the depth of cut, and 1500 rpm for the speed are the best combinations of cutting parameters for the multi response.
- The results of the ANOVA test showed that the depth of cut, followed by feed and speed, is the characteristic that has the greatest influence on the various reactions.
- When comparing different methods, the suggested method for WPCA and CQL is the most effective at figuring out the right cutting parameters for variable multiple answers.
- Residual plots demonstrated that because the models were built to follow normal distributions with constant variance, they were more significant and accurate.
- The ideal tool nose radius for turning hybrid composites made of aluminium depends on a number of variables, including the material of the work piece, the cutting environment, and the machining goal. As a result, it's important to carefully evaluate these considerations while choosing the tool nose radius.

6.2 Future Scope of the project

Only four parameters, tool nose radius, cutting speed, depth of cut, and feed rate were considered in the current work. There are, however, a number of additional factors, such as the tool's coating and the type of lubrication. We have shown that the surface roughness is minimal and the material removal rate is high for smaller tool nose radii. Hence, a reduced tool nose radius can be tested in future studies.

We believe that it can be used in domestic airline applications, even if it is now used for low scale applications like bicycles and various sporting goods. For improved and more accurate response values in the future, we can apply several optimisation techniques as response surface methodology, fuzzy logic, or genetic algorithms.

REFERENCES

1) Sachin Ashok Sonawane and M.L. Kulkarni (2018) “Optimization of machining parameters of WEDM for Nimonic-75 alloy using principal component analysis integrated with Taguchi method” https://doi.org/10.1016/j.jksues.2018.04.001
2) Hari Vasudevan et.al. (2018) “Optimization of Multi-Performance Characteristics in the Turning Of GFRP(E) Composites using Principal Component Analysis combined with Grey Relational Analysis” https://doi.org/10.1016/j.matpr.2017.12.197
3) Bharat Chandra Routara et.al. (2010) “Combined quality loss (CQL) concept in WPCA-based Taguchi philosophy for optimization of multiple surface quality characteristics of UNS C34000 brass in cylindrical grinding” https://www.proquest.com/openview/6ffccaada0349ac6595c8eb522f3e438/1?pq-origsite=gscholar&cbl=2044010
4) G. Karuna Kumar et.al. (2019) “Application of WPCA & CQL Methods In The Optimization Of Multiple Responses” https://doi.org/10.1016/j.matpr.2019.04.273
5) B. Singarvel et.al. (2014) “Multi Objective Optimization in Turning of EN25 Steel Using Taguchi Based Utility Concept Coupled with Principal Component Analysis” https://doi.org/10.1016/j.proeng.2014.12.237
6) Meenu Gupta and Surinder Kumar (2015) “Investigation of surface roughness and MRR for turning of UD-GFRP using PCA and Taguchi method” https://doi.org/10.1016/j.jestch.2014.09.006
7) Tian-Syung Lan et.al. (2018) “Optimization of Machining Parameters Using Fuzzy Taguchi Method for Reducing Tool Wear” https://doi.org/10.3390/app8071011
8) Nesredin Chekole Deresse et.al. (2020) “Experimental investigation of the effects of process parameters on material removal rate using Taguchi method in external cylindrical grinding operation” https://doi.org/10.1016/j.jestch.2019.06.001
9) Ning Li et.al**.** (2019) **“**Multi-response optimization of Ti-6Al-4V turning operations using Taguchi-based grey relational analysis coupled with kernel principal component analysis” https://doi.org/10.1007/s40436-019-00251-8

10) Mustafa ÖZDEMİR(2019) "Optimization with Taguchi Method of Influences on Surface Roughness of Cutting Parameters in CNC Turning Processing" https://doi.org/10.5755/j01.mech.25.5.23005

11) L B Abhang and M Hameedullah (2012) "Optimization of Machining Parameters in Steel Turning Operation by Taguchi Method" dx.doi.org/10.1016/j.proeng.2012.06.007

12) N. Muthukrishnan et.al. (2012) "Fabrication and turning of Al/SiC/B4C hybrid metal matrix composites optimization using desirability analysis"dx.doi.org/10.1080/10170669.2012.728540

13) Jogendra Kumar and Rajesh Kumar Verma (2021) "A novel methodology of Combined Compromise Solution and Principal Component Analysis (CoCoSo-PCA) for machinability investigation of graphene nanocomposites" doi.org/10.1016/j.cirpj.2021.03.007

14) Sivasakthivel Kuppusamy and Dillibabu Ramalingam (2018) "Optimization of process parameters in CNC turning of Titanium alloy with carbide coated tool inserts using grey based Taguchi analysis" dx.doi.org/10.1299/jamdsm.2018jamdsm0094

15) Chintan Kayastha and Jaivesh Gandhi (2013) "Optimization of Process Parameter in Turning of Copper by Combination of Taguchi and Principal Component Analysis Method" https://www.ijsrp.org/research-paper-0613.php?rp=P181265

16) Al Mazedur Rahman et.al. (2021) "Modelling and optimization of process parameters in face milling of Ti6Al4V alloy using Taguchi and grey relational analysis" https://doi.org/10.1016/j.promfg.2021.06.023

17) Ruby Haldar and Santanu Duari (2022) "Optimization of Process Parameters in CNC Turning of Copper and Aluminium Alloy Using Taguchi Approach" https://doi.org/10.22214/ijraset.2022.41462

18) Harish Kumar et.al. (2013) "Optimization of cutting parameters in CNC Turning" https://www.ijera.com/papers/Vol3_issue3/BE33331334.pdf

19) M. V. Satish Kumar et.al. (2020) "Optimization of CNC Turning Parameters in Machining EN19 using Face Centered Central Composite Design Based RSM" http://dx.doi.org/10.35940/ijrte.B3923.079220

20) M. Vijay Kumar et.al. (2018) “Optimization of Machining Parameters in CNC Turning of Stainless Steel (EN19) By TAGUCHI’S Orthogonal Array Experiments” https://doi.org/10.1016/j.matpr.2018.02.107
21) Mohammed Nishat Akhtar et.al. (2021) “Optimization of Process Parameters in CNC Turning of Aluminum 7075 Alloy Using L27 Array-Based Taguchi Method” https://doi.org/10.3390/ma14164470
22) Munusamy Arulraj et.al. (2019) “Optimization of machining parameters in turning of Hybrid Aluminium-Matrix (LM24–SiCp–COCONUT SHELL ASH) Composite” http://dx.doi.org/10.17222/mit.2018.184
23) Sanjit Moshat et.al. (2010) “Optimization of CNC end milling process parameters using PCA-based Taguchi method” https://doi.org/10.4314/ijest.v2i1.59096
24) S. Jasper et.al. (2018) “Experimental investigation and Taguchi optimization of turning process parameters for glass fiber reinforced plastics (GFRP)” http://dx.doi.org/10.19101/IJATEE.2018.547001
25) Reddy, D.G. (2017) “Parametric optimization of lathe turning for Al-7075 alloy using Taguchi: An experimental study” https://doi.org/10.9790/1684-1403063945
26) S. Ghosh et.al. (2022) “Optimization of cutting parameters of AISI 1018 Low Carbon Mild Steel in turning using green cutting fluid by Taguchi method” https://doi.org/10.56697/jmep.2022.1108
27) Ramanathan Arunachalam et.al. (2019) “A review on the production of metal matrix composites through stir casting – Furnace design, properties, challenges, and research opportunities” https://doi.org/10.1016/j.jmapro.2019.04.017
28) Rajeshkumar Gangaram Bhandare et.al. (2014) “Preparation of Aluminium Matrix Composite by Using Stir Casting Method” http://inpressco.com/wp-content/uploads/2014/04/Paper31148-155.pdf
29) G. G. Sozhamannan et.al. (2012) “Effect of Processing Parameters on Metal Matrix Composites: Stir Casting Process” http://www.scirp.org/journal/PaperInformation.aspx?PaperID=16992

30) Palash Poddar et.al. (2007) “Processing and mechanical properties of SiC reinforced cast magnesium matrix composites by stir casting process” https://doi.org/10.1016/j.msea.2007.01.052

31) J. David Raja Selvam et.al. (2013) “Synthesis and Characterization of Al6061-Fly Ash_p-SiC_p Composites by Stir Casting and Compocasting Methods” https://doi.org/10.1016/j.egypro.2013.06.795

32) R.Jojitha and N.Radhika (2018) “Mechanical and tribological properties of LM13/TiO_2/MoS_2 hybrid metal matrix composite synthesized by stir casting” https://doi.org/10.1080/02726351.2017.1407381

33) K. Sagar and L. RadhaKrishnan (2017) “The Influence of Nickel Addition on the Mechanical Properties of AA6061 Fabricated by Stir Casting” http://www.ripublication.com/ijoms17/ijomsv12n4_10.pdf