OPTIMIZATION OF COMPOSITE QUALITY ATTRIBUTES IN TURNING OF SS410 USING PSI METHOD

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

Bachelor of Technology
in
Mechanical Engineering

Submitted by

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CERTIFICATE

This is to certify that the Project Report entitled **"Optimization of Composite Quality Attributes in Turning of SS410 Using PSI Method"** being submitted by P.N.B. SHIVA KRISHNA (319126520037), CH. SHAILENDRA KUMAR (319126520047), BANDARU SAI KIRAN (319126520006), K. SWAMI TARUN (319126520021), SUSHANT PAUL SEELAM (319126520050) to the Department of Mechanical Engineering, ANITS is a record of the Bonafide work carried out by them under the esteemed guidance of **Mrs. M. SAILAJA.** The results embodied in the report have not been submitted to any other University or Institute for the award of any degree or diploma.

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CONTENTS

ABSTRACT

In the current investigation, two carbide tool inserts—one coated (MT-CVD) and the other un-coated were used to test the machinability of SS410 grade material on a CNC turret lathe. Work materials are frequently used in petrochemical and mineral processing equipment, gate valves, Cutlery Petroleum Refining and Petrochemical Processing Equipment, Ore Processing Sugar Processing, Press Plat, Gate Valves etc. because they possess high strength, hardness, and corrosion resistance.

The trials were carried out in a dry environment with different feed rates (0.1, 0.15 & 0.2 mm/rev), cutting speeds (1000, 1250, and 1500 RPM), and depths of cut (0.5, 1 and 1.5 mm) by using the L_{18} (2^1*3^3) orthogonal array. Preference Selection Index (PSI) method, an MCDM tool, has been used to assess how changing process parameters affect Material removal rate (MRR), roughness characteristics (R_a and R_t), and Dimensional Deviation (DD) performance. The PSI data are used to determine the ideal process parameters and they found at Tool Type: Coated (level 1), 1250 RPM (level 2), 0.1mm/rev (level 1), and 0.5mm (level 1), accordingly, are the speed, feed, and DOC parameters. Finally, Signal to Noise ratios and ANOVA is used to analyze the generated composite index values. According to the investigation, Depth of cut significantly influences the various replies. It has been determined how parameters like depth of the cut and the tool type interact. The models were mostly created for the composite index, and the goodness of fit was assessed by plotting residual plots. It was determined that the errors follow normality and constant variance, making them the most accurate and adequate models because they are best fitted.

Key words: Orthogonal Array (OA), Preference Selection Index (PSI) method, The Material Removal Rate (MRR), Roughness Characteristics (R_a and R_t), Dimensional Deviation (DD), Signal-to-Noise (S/N) ratios and ANOVA.

LIST OF FIGURES **Pg. No**

LIST OF TABLES   Pg. No

NOMENCLATURE

v	Cutting Speed, Rpm
f	Feed, mm/rev
d	Depth of Cut, mm
MRR	Material Removal Rate, cm^3/sec
R_a	Arithmetic Surface Roughness Average, 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
P	Probability of Significance
PSI	Preference Selection Index

CHAPTER-1

INTRODUCTION

The main machining operations is turning, which involves cutting metal and removing metal chips to produce final products with the specified shape, size, and surface roughness.

1.1.Single Point Cutting Tool

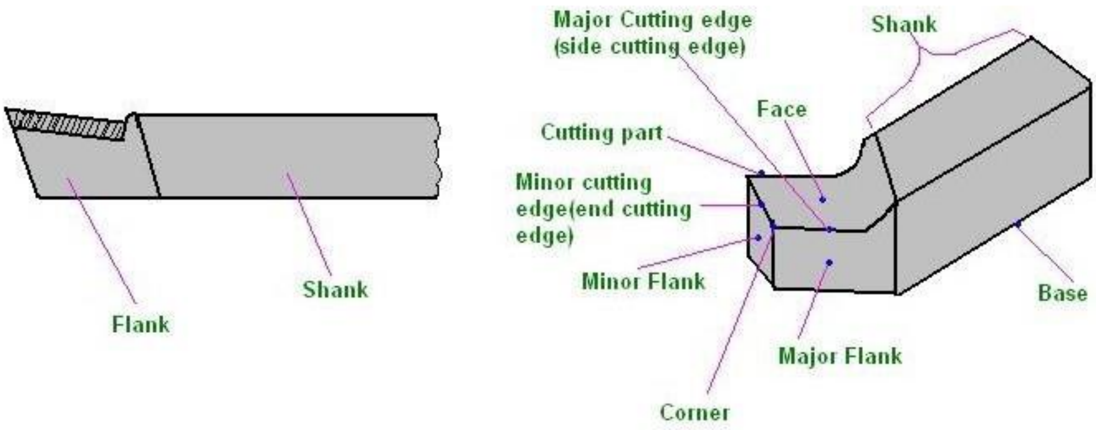


Figure. 1.1. Nomenclature of a Single Point Cutting Tool

The principal cutting edge of single point cutting tools is mostly utilized for cutting. These tools are used in machines like lathes, boring machines, and shaping machines for turning, boring, planing, etc. The following components are found on single point cutting tools: A shank- which serves as the tool's primary body, A flank which is located below the cutting edge, A face- which serves as the chip-sliding surface, and a nose radius (it is the

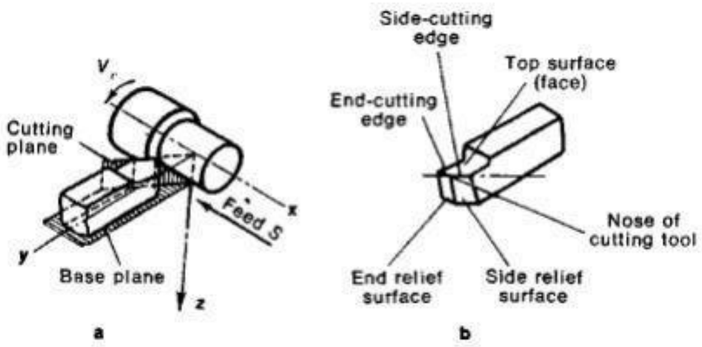


Figure. 1.2 Diagram of The Machining Process

point where cutting-edge interconnects with side cutting edge). Fig. 1.1 displays the single point cutting tool's schematic diagram.

The term "side relief angle" refers to the angle formed between the tool's side relief face and the machining plane. In order to prevent friction between the relief surface and the cutting edge, the relief angle depends on the feed rate parameter; as feed increases, the relief angle also increases. Lip angle is the name for the angle formed by the tool's topmost and side relief surfaces. The side rake angle is the angle formed by the plane perpendicular to the cutting plane and the tool's top surface. Fig. 1.2 depicts the turning process' mechanism.

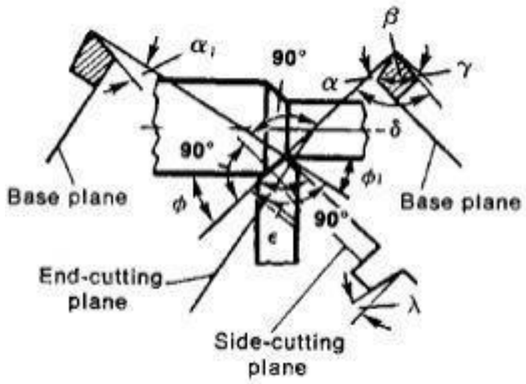


Fig. 1.3 Cutting Angles

In machining, larger rake angles make chip generation easier but reduce cutting force (less power consumption). A tool with a small rake angle is always used for hard materials. Finally, it is clear that the rake angle depends on the material's mechanical and physical characteristics. The projected point of view and the cutting angles that are employed for machining are represented in Figure 1.3. Turning is the process of removing metal from a revolving cylindrical work piece's outside diameter. Turning is the machining of an exterior surface where it is used to reduce the diameter of the work item, often to a given dimension and achieve a smooth finish on the metal:

- With the work piece rotating
- Using a single-point cutting tool,
- Feeding the cutting tool parallel to the work piece's axis at a
- The distance at which the work's exterior surface will be removed.

1.2. Cutting Factors in Turning

Feed, Speed, 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.

1.2.1. Speed

Spindle and work piece speed are discussed. When expressed in rpm, it indicates the speed at which they rotate. However, the most crucial element for a certain turning operation is the surface speed, which is the rate at which the material of the work piece is moving past the cutting tool. It is just the result of multiplying the rotation speed by the workpiece's 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.

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

Thus, v is the cutting speed in turning, and D is the workpiece's initial diameter in mm

1.2.2. Feed

Feed is a term used to describe how quickly a cutting tool moves along its cutting path. In the majority of power-fed lathes, the feed rate is proportional to the spindle speed and measured in millimetres (of tool advance) per revolution (of the spindle), or millimetres/rev.

1.2.3. Depth of Cut

The depth of cut, measured in millimetres is the thickness of the layer being detached from the work piece in a single pass or the separation between the work's uncut and cut surfaces. It is crucial to remember that because this layer is being removed from both sides of the work piece, the diameter of the piece is reduced by double the depth of cut.

1.3. Tool Geometry

The geometry of cutting tools, as shown in fig. 1.4, 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.

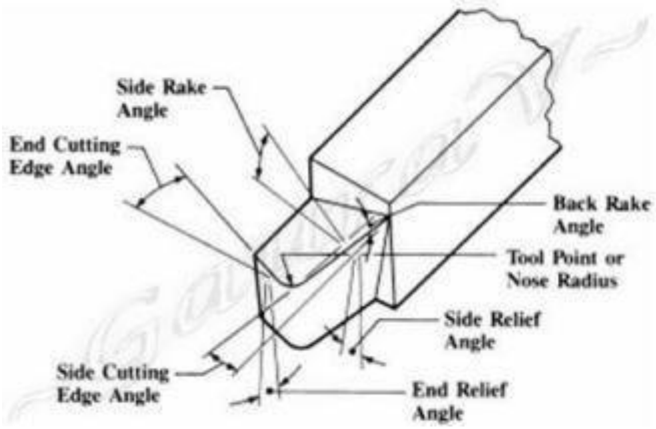


Figure. 1.4 Tool Geometry

1.3.1. Flank

A single-point tool's flat surface next to the face of the tool. The side flank turns to face the direction in which the tool is introduced into the work piece. The flank crosses the freshly machined surface at the conclusion.

1.3.2. Face

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

1.3.3. Back rake angle

It is the angle produced between the tool's face and a line parallel to the base, when viewed from the side facing the end of the work piece. The tool's face is tilted backward and upward by a positive back rake angle, and forward and down by a negative angle.

1.3.4. Side rake angle

It is the angle made by the tool's face and the workpiece's centreline when observed from behind the tool and along the length of the tool holder. 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.

1.3.5. Side cutting edge angle

It is the angle made between the side flank of the cutting tool and a line perpendicular to the centreline of the work piece, as seen from over looking down on the cutting tool. The side flank is moved into the cut by a positive cutting-edge angle and out of the cut by a negative angle.

1.3.6. 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 over looking down on the cutting tool. The far end of the cutting edge is slanted away from the work piece when the end cutting edge angle is increased.

1.3.7. Side relief angle

The angle created by the side flank of the tool and a vertical line that descends to the floor, as seen from behind the tool down the length of the tool holder, is known as the side relief angle. The side flank is tilted away as of the work piece when the side relief angle is increased.

1.3.8. 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.

1.3.9. 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.

1.3.10. Lead angle

The side cutting edge angle is also known as a lead angle. The lead angle accounts for any changes in an insert's angle that result from the construction of a tool holder.

1.4. Recent trends in manufacturing by machining

Recent advances in science and technology have placed enormous strain on the manufacturing sector. The manufacturing sectors are attempting to lower cutting expenses, improve the caliber of machined components, and work with more challenging materials. By using high speed machining, the efficiency of the machining process is increased. The softening temperature and chemical stability of the tool substantial limit the cutting speed when cutting ferrous and difficult-to-machine materials like cast iron, steels, and super alloys. Accelerating the creation and evolution of better cutting tools in order to obtain superior tribological attainment and wear-resistance is necessary to increase manufacturing processes' productivity. A thorough understanding of the mechanics of metal cutting is still missing and is therefore a great deal of research because of the highly nonlinear nature of metal cutting and the complicated coupling between deformation and temperature fields. a lot of recent study. Through the centuries, high speed machining has been the primary focus of mechanical engineering. Newer cutting tools with regard to materials and designs have been developed as a result of the tendency to increase output. High speed machining is more often linked with significant heat generation than with improved productivity and surface finish. where there is a significant quantity of cutting force involved, increasing the power requirement. With the help of a novel machining technique called finish hard turning, manufacturers can produce finished parts from hardened materials without the use of grinding. Hard turning along with multilayer layered carbide tools has a number of advantages over grinding, including lower production costs, higher productivity, and better material characteristics. Manufacturers can use this method to cut costs and processing time while improving product quality and efficiency. Manufacturers find hard turning to be very appealing because it can be done without the aid of cutting fluid or other fluids. Dry cutting has advantages over wet cutting because it eliminates the expense of the cutting fluid and the high cost of fluid removal. The manufacturing industry's growing need to increase output, machine more challenging materials, and improve quality in large quantities has been the impetus behind the creation of cutting tool materials. The hard coating for cutting instruments is one significant area that is the subject of active research and development. These hard coatings are thin sheets with thicknesses ranging from a few nanometers to a few millimeters, with layers ranging from one to hundreds. By reducing the rate at which cutting tools wear out, these hard coverings have been shown to up the tool life by a factor of up to 10. As a result of the longer tool life, tool variations become less frequent, allowing for larger batch sizes to be produced, which lowers setup costs and setup time while also lowering manufacturing costs. Hard coatings that are applied to cutting tools enable better and more reliable surface roughness of the machined work component in addition to extending tool life. In order to improve consistency and surface finish, the wear process must be slowed down. As the geometry of the cutting tool changes due to wear, the surface roughness of the machined work component changes.

By using high speed machining, the effectiveness of the machining process is increased. The chemical stability of the tool material and the softening temperature of ferrous and difficult-to-machine materials, such as cast iron, steels,, and super alloys, respectively, limit the cutting velocity. Tools must therefore be made of materials that are sufficiently inert and have good high-temperature mechanical qualities. Despite having high thermal strength, several ceramic materials, including TiC, Al2O3, and TiN, have lower fracture toughness than common tool materials, like high-speed steels and cemented tungsten carbides. By applying single- and multi-layer coatings to conventional tool materials, it is possible to combine the advantageous qualities of ceramics and conventional tool materials to improve the machining of hard and chemically reactive materials at greater speeds. Hard coatings created using physical vapour deposition (PVD) or chemical vapour deposition (CVD) are used on the majority of cutting instruments in use today. These coatings' high hardness, wear resistance, and chemical stability have been shown to improve tool life and machining efficiency. The CVD is the first method. Through a number of chemical interactions, this technique deposits thin layers on the cutting implements. Before the advent of PVD, the majority of tool coatings were usually applied using the CVD process. This technology uses physical processes, namely sputtering and evaporation, to produce thin layers on the cutting instruments. Since its introduction, coated hard metals have significantly increased production. Since then, high speed steel has also received coatings, particularly HSS drills. Coatings operate as diffusion barriers, preventing contact between the cutting material and the chip created during machining. Because of the highly hard materials utilized to create the coatings, they are very abrasion resistant. Alumina, titanium nitride (TiN), titanium carbide (TiC), titanium carbonitride (TiCN), and titanium nitride are common coating ingredients. (Al_2O_3).

1.5. Significance of Metal Cutting

To create a completed product with the proper size, shape, and surface polish, metal must be removed from the work piece in the form of chips. Almost all manufacturing companies, including those in the construction, home appliance, consumer electronics, railroad, shipbuilding, and transportation industries, have huge shops with a great deal of machining. More than 15% of the value of all produced goods in all industrialized nations is spent on machining. The circumstances of operation can be modified more in metal cutting than in any other method used to shape metals, improving quality and production rate at a lower cost.

1.6. Theory of Metal Cutting

Nearly all of the products used in contemporary society are made either directly or indirectly using the metal cutting process, which is the foundation of the engineering sector. The cutting 7 tool is one of the key components to maximizing the effectiveness of any metal cutting process is the tool. The demands of economic rivalry have driven extensive research in the area of metal cutting over the years, which has resulted in the development of new tool materials with remarkable performance and enormous potential for a striking increase in productivity. Cutting tools that can work with new materials at the highest potential productivity must be developed as manufacturers constantly search out and use new materials for products that are lighter, stronger, and therefore more efficient.

Any cutting substance must have these essential qualities in order to perform its function:

- Hardness to resist wearing out.
- Enough tenacity to endure vibration
- Hot strength to combat the heat involved

In general, rising hardness results in a decrease in toughness, so materials in the list's greater hardness region will break if used for heavy cuts, especially with work pieces that have holes or slots that cause interruption in the cut.

The following qualities must be present in an implement material:

- The capacity to maintain form stability at high temperatures and rapid cutting rates.
- Resistance to diffusion
- High resistance to brittle fracture
- Resistance to thermal and mechanical shock
- Low Cost and ease of fabrication

The cutting tools must be made of materials capable of withstanding

- High stresses
- High temperature
- Shock generated during chip formation

1.7. Chronological Development of Cutting Tool

Cutting tools have advanced to a glorious level to keep up with the modern advancement of science and technology.

The following is a timeline of the elements used to make cutting tools.

1.High speed steel

2.Carbides

3. UCON

4. Ceramics

5. Diamond

6.Cubic Boron Nitride (CBN)

7. Coated Carbides

Coated carbides, which are among the materials mentioned above, are the new generation material that best meets the needs of the time. Carbides have captured the market for machining, namely of ferrous materials, serving between 60 and 80 percent of needs.

1.8. Coatings

By using high speed machining, the efficiency of the machining process is increased. However, the cutting speed is constrained by softening temperature and chemical stability of the tool material. The softening temperature and chemical stability of the tool material limit the cutting speed when cutting ferrous and difficult-to-machine materials like steels, cast iron, and super alloys. As a result, superior high-temperature mechanical characteristics and adequate inertness are required for tool materials. While having high thermal strength, several ceramic materials, including Al2O3, TiC, and TiN, have lower fracture toughness than common tool materials, like high-speed steels and cemented tungsten carbides. By applying single- and multi-layer coatings to conventional tool materials, it is possible to combine the advantageous qualities of ceramics and conventional tool materials to improve the machining of hard and chemically responsive materials at greater speeds. Coatings operate as diffusion barriers, preventing contact between the cutting material and the chip created during machining. Because of the highly hard materials utilised to create the coatings, they are very abrasion resistant. Alumina, titanium nitride (TiN), titanium carbide (TiC), titanium carbonitride (TiCN), and titanium nitride are common coating ingredients (Al2O3). All of these chemicals are poorly soluble in iron and thus increase the cutting rate of inserts.

These lead to the usage of carbide substrates.

- Increased productivity due to high-speed machining
- Improved toughness and crack resistance due to ideal hard-particle dispersion.
- Increased welding resistance and plastic deformation resistance for high cutting speed applications.

The result of coatings is

• The cutting forces are reduced.

• Less diffusion between the chip and the tool's surface, especially at higher speeds (the coating acts as a diffusion barrier).

• Galling prevention, particularly at slower cutting speeds

Cutting tools also receive a strong coating to extend their useful lives. The common cutting tools have hard coatings created using chemical vapor deposition (CVD) or physical vapor deposition (PVD), which prolongs tool life and enhances machining efficiency.

1.8.1. Types of Coating Technology

Deposit temperatures linked with interfacial activities' surface coating range from room temperature to more than 1000 °C. Microns to several millimeters are the thickness range for the coating. The thinnest coatings are usually produced via atomistic techniques. High deposit temperatures are used in some styles, which could cause unwanted phase transitions, softening, or shape changes in the coated part. The high degree of compositional as well as structural flexibility offered by PVD and CVD techniques is a massive advantage, and these procedures are already being effectively used to coat a wide range of mechanical components.

1.8.2. CVD (Chemical Vapour Deposition)

The CVD process uses a variety of chemical reactions to produce thin layers on the cutting instruments. Ever since they were introduced in the late 1960s, CVD coated cemented carbides have had tremendous success. Since then, multi-layer variants of chemical vapor deposit technologies that combine TiN, TiCN, TiC, and Al2O3 have improved from single layer versions. Current CVD coatings provide excellent wear and tear resistant coatings with a total thickness of of 4- 20 µm.by combining high temperature and medium temperature processes in intricate cycles. The prolixity of chemical components from the carbide substrate to the coating during growth is caused by the high deposition temperature (950–1059 °C) during CVD. The coated edge becoming embrittled is the principal result. Furthermore, the chemistry of the CVD process causes more fast growth near the leading edge, resulting in a really thick coating. Finding coatings that could be applied at lower temperatures was therefore strongly encouraged in order to coat equipment with sharper edges without creating an embrittlement effect. PVD is the answer since the deposition temperature can be maintained at about 500 °C.

1.8.3. How does CVD Works?

High-performance, purified solid materials are made using a chemical process called chemical vapour deposition. During a normal CVD procedure, the wafer (substrate) is exposed to one or more volatile precursors, causing the precursors to react and/or decompose on the substrate surface to produce the desired deposit. Additionally, volatile byproducts are frequently created and removed from the reaction chamber by gas movement. To deposit materials in a variety of shapes, including monocrystalline, polycrystalline, amorphous, and epitaxial, microfabrication methods frequently use CVD. These materials include silicon, carbon fiber, carbon nanofibers, filaments, carbon nanotubes, silicon-germanium, tungsten, silicon carbide, silicon oxynitride, titanium nitride, and a variety of strong dielectrics. The CVD method is also used to produce diamond alternatives. It is a chemical process used to produce solid materials that are highly effective and pure. The results show the necessity of using CVD covering to boost output.

1.8.4. PVD (Physical Vapour Deposition)

Sputtering and evaporation, two physical procedures, are used in the PVD technique to install thin films on the cutting blades. More people are using PVD coatings, which are applied at temps between 400 and 600 °C. For the past ten years, they have been used successfully with carbide metal cutting tools. In finishing, interrupted cuts, applications needing sharp edges, and other applications, they offer a performance advantage. Depending on the intended use, different PVD methods are used, such as electron beam evaporation, sputtering, and arc evaporation. Improvements in these technologies, such as high-ionization magnetron sputtering and new cathodic-arc processes, have further improved the efficacy of PVD coated tools. PVD coated tools' ability to cut metal depends significantly on the substrate's makeup, the tool's geometry, the coating's microstructure, internal stresses, and adhesion to the substrate. Pre-PVD and post-PVD steps are both included in the PVD process chain. While post-PVD processes have an effect on the smoothness of the coating face and improved chip flow, pre-treatment processes like plasma etching and chemical etching have an impact on adhesion, grain growth, stress at the substrate surface, and coating structure. Cemented carbide inserts exhibit outstanding cutting performance, according to PVD coatings. The benefits that lower coating temps provide in terms of micro-toughness are the reason that PVD has increasingly replaced other coating deposition methods.

1.8.5. Advantages of CVD coated carbides

A broad range of applications, from finishing to roughing and low to high speed. Due to the material's exceptional toughness and crack resistance, stable machining can be achieved. Using different chip breakers, there is a chance to cut machining time while maintaining good chip control.

1.9. Types of Coating

1.9.1. Single Layer Coating

The initial coating was a single layer of TiC that was 10 to 12 micrometers thick and was applied using the chemical vapor deposition (CVD) method on a hard metal substrate. The carbon balance at the intersection of the coating and the hard metal substrate altered as some carbon was removed from the surface of the hard metal during the deposit process as part of the coating. Early coated indexable inserts were vulnerable to chipping of the cutting edge due to this reduction in the carbon balance. The next development was to apply a coating of TiN, which prevented any decarburizing of the hard metal substrate, but the coating, which is gold in color, did not adhere well to the hard metal base. Although though TiC has superior abrasion resistance, TiN is a better diffusion barrier than TiC.

1.9.2. Multi-Layer Coatings

Even though single-layer coatings have a wide variety of uses in many engineering fields, there are more and more processes for which the characteristics of a single material are insufficient. Utilizing a multilayer coating that blends the alluring qualities of several materials, each selected to solve a specific issue in the application, is one strategy for solving this issue. As many as eight levels may be present in multi-layer coverings with a total thickness of 10 micrometers or less. Thin inert coverings on top of wear-resistant layers can help prevent the corrosion of cutting instruments, as can the use of interfacial adhesive layers to encourage binding. The evidence is still accumulating that a multilayer structure created by many interspersing layers of two materials can result in improvements in performance over a mixed coating due to the creation of new interfaces, even if the two materials don't have specific functional requirements in the intended application.

1.9.3. Why TiN?

Currently, nitride-coated carbide tools make up the bulk of inserts used in different metal cutting operations. (TiN, CrN, etc.).In the world of hard coatings, mono-layer-deposited TiN retains the leading position. TiN covering is frequently used as the top layer. The golden colour of the TiN coating aids in wear detection by enabling the operator to differentiate between a used and a new cutting-edge corner as it increases wear resistance and decreases the sticking of the work material.

1.10. Tool wear

One of the most important issues resulting in the design of cutting operations is the prediction and control of wear. The statement "A tool is considered to be worn out when the replacement cost is lower than the cost of not replacing the tool" is a handy way to describe one. While absolute failure (ultimate failure) is described as the full removal of the cutting edge, a situation carried when tragic failure happens, tool failure is considered to occur when the tool no longer performs the required function. In order to minimize the huge expenses associated with comparable disastrous failures, tools in machining processes are therefore regarded to be worn out and are changed well before they are completely necessary. During interrupted cuts, the tool may experience repeated impact stresses, and the work piece chips may chemically react with the materials of the tool. A variety of wear mechanisms, such as crater wear and tear, flank wear or abrasive wear, built-up edge, notching, and nose wear, may reduce the useful life of a cutting tool. A significant contributor to flank wear is abrasion of the flank face by the hard components of the work piece, which is seen on the flank or clearance face of an essence cutting insert.

The rake face of metal cutting inserts and the hot metal chip that is being forced over the tool chemically interact to produce crater wear, which is visible on the rake face of cutting tools. It's not a novel idea to use coating materials to improve the performance of cutting instruments. Since its debut in 1969, carpeted hard metals have significantly increased production and had an immediate influence on the metal cutting industry. Cutting tools made of carbide are utilized more frequently than high-speed steels in the manufacturing sector today because of their much higher hardness. Carbides that are carpeted or uncoated are frequently employed in metalworking and provide a fashionable alternative for the majority of turning operations. Cemented carbides can be employed in extremely hot applications thanks to their heat endurance, and any PVD or CVD procedure can be used to deposit coatings on them. The crucial coating properties, such as wear resistance, abrasion resistance, and adhesion strength, are determined by the combination of substrate-coating properties. A hard surface resistant coating is ineffective. Well, unless a robust and firm substrate is added. As a result, the qualities of a hard coating that is applied to a soft substrate are inadequate. Vapor-deposited coatings that are both physically and chemically deposited present a significant alternative today for enhancing the cutting performance of the cutting materials. Tool materials must maintain their high temperature strength. Several ceramic materials, including TiC, Al2O3, and TiN, are strong at high temperatures, but their fracture toughness is inferior to that of common tool materials, such as high-speed steels and cemented tungsten carbides. By applying single- and multi-layer coatings to conventional tool materials, it is possible to combine the advantageous qualities of ceramics and conventional tool materials to improve the machining of hard and chemically reactive materials at high speeds. Metal machining is a difficult process. High stress and localized heat characterize the environment around cutting tools. During interrupted cuts, the tool may experience repeated impact stresses, and the work piece chips may chemically interact with the tool's materials. A number of wear processes, such as crater wear, hand wear and tear or abrasive wear and tear, constructed up edge, depth of cut notching, and nose wear, can reduce the usable life of a cutting tool. The abrasion of the flank confronted by the hard components of the work piece is the primary cause of flank wear, which is visible on the flank or clearance face of a metal cutting insert.

CHAPTER-2

LITERATURE REVIEW

To obtain the best parameters for the anticipated output utilizing the available sources, engineers must overcome a difficulty. For the intended result, choosing the machining settings is typically fairly challenging. The table provided by the machine-tool designer and the engineers' experience are actually what determines this. Hence, in order to satisfy both economy and superiority of the machined item, optimization becomes important. The preference selection index (PSI) is a multi-objective optimization technique that is used to rank and select alternatives based on a set of multiple criteria or objectives. The PSI method takes into account both the importance of each criterion and the trade-offs between them. To apply the PSI method, first, a set of criteria or objectives should be defined. Then, each criterion is assigned a weight or importance factor that reflects the relative importance of that criterion compared to the others. Next, each alternative is evaluated based on each criterion, and a score is assigned to it. The score represents how well the alternative performs in that criterion. After scoring all alternatives, the PSI method aggregates the scores into a single value for each alternative. The aggregation process uses the weights assigned to each criterion and takes into account the trade-offs between them. The PSI method then ranks the alternatives based on their aggregated scores. The Taguchi method describes how to reduce variation using offline or online quality control to improve quality. While online quality control aids in retaining compliance to the original or intended design, offline quality control aids in increasing the quality of processes. The primary goal of Taguchi's design is to make sure that the product works well in noisy environments; this contributes to the product's durability. The Taguchi method can be applied quickly and with little effort. To enhance the process quality in manufacturing sectors, Taguchi's approach is used in a variety of industries. Cutting force and surface roughness are two crucial machining process variables. Power machining calculations require cutting force. Dimensional accuracy, work-piece deformation, and chip formation are all influenced by cutting forces. According to client demand, industries always need components with a specific surface roughness.

This can be accomplished through the optimization procedure that we will outline. Here, machining professionals shared their thoughts on the findings produced. Many studies on turning operations and optimizations strategies have been conducted.

Trung [1] optimized turning process parameters using (PSI), (PSG) & Collaborative Unbiased Rank List Integration are three MCDM techniques that were employed (CURLI). Using Steel SB410 as a test substance and TiN is used to coat cutting instruments. Determined to attain the "minimal" surface roughness and "most" MRR at the equal time, it's far vital to pick the cutting pace, feed fee and depth of cut.

Hoang Anh et. *al.* [2] determined the maximum fabric removal price and the minimum surface roughness by way of combining the Taguchi technique with the PSI approach on 0A4 metal in which the cutting device is a face milling cutter produced from high pace steel (HSS).

Arti Saxena1 *et. al.* [3] used the H-13 (P8) material is turned and drilled with the cutting tools CNMG190616-M5-TM2501 and SD205A-1050-056-12R1-P, respectively. Taguchi L9 array analysis and additional ANOVA analysis are then used to improve the performance of the CNC machine by taking into account the input control factors cutting speed (CS), feed rate (FR), and depth of cut (DOC).

P. Sivaiah and D. Chakradhar [4] examined the use of TGRA to optimize multiple responses when turning 17-4 Precipitation Hardened Stainless Steel (PH SS) under the jetting of liquid nitrogen. The TGRA end result confirmed that the improved turning method can be accomplished at cutting velocity of 120.89 m/min, feed rate of 0.048 mm/rev, and intensity of cut of 0.4 mm.

Ali Kalyon *et. al.* [5] analyzed the amounts of influence that machining parameters had on FR and Ra (ANOVA), to simultaneously minimize FR and Ra (GRG) a grey relational grade was calculated. By the ANOVA results based on GRG, the feed rate was followed by the cutting depth, The feed rate, cutting depth, chrome ratio, cutting speed and that produced the best results were 12%, 0.1 mm, 100 m/min, and 0.05 mm/r, respectively.

Muhammad Jamil *et.al.* [6] applied the RSM-based GRA to discover the trade-off between four matrices under EMQL. For multi-goal optimization, the tribological behavior of cutting speed, feed, depth of cut, and EMQL flow rate on sustainable leading responses (MRR, tool life, surface roughness, and power consumption) was simulated and analyzed.

Ponugoti Umamaheswarrao ***et.al.*** **[7]** optimized the cutting parameters by utilizing the Technique for Order preference by means of Similarity to best answer (TOPSIS) on AISI 52100 metallic the usage of polycrystalline cubic boron nitride (PCBN) tools by using difficult turning machining method. The use of analysis of variance (ANOVA) is used to determine how process parameters affect results.

Umamaheswarrao P ***et.al.*** **[8]** conducted experiment on AISI 52100 steel by hard turning using multiple-objective optimization to produce the better surface standard, machinability force, investigations are carried out by Taguchi L9 orthogonal-array, with aid of the MINITAB14 software package, a parametric inquiry is done to determine the impact of in-put criteria on the response.

Vara Prasad ***et.al.*** **[9]** focused on the responses of removal rate of material & surfacee- roughness at various combinations of Speed and Feed's depth of cut. Machining is done for AA7075 work parts on the Oorthogonal array (L9) of Taguchi by utilizing the preference selection index approach.

Dr. G. Bhanodaya Reddy ***et.al.*** **[10]** investigated parameter optimization for turning process- of 7075 alloy of aluminium utilizing taguchi L-27 Orthogonal array, which used for DOE and S/N both to examine the effects of the selected parameters. The outcome shows that different cutting parameters have distinct effects on cutting-forces, roughness of surface, and two samples temperature when comparing them.

Maya Radune ***et.al.*** **[11]** focused on the primary High -Energy Ball Milling (HEBM) criteria of MillingTime (MT), Ball To powder Weight Ratio (BPWR), & Milling speed (MS) on the size of CaCO3 crystallite were examined using Taguchi's method. To display the efficiency of Taguchi optimization process, a confirmation test with a 90% confidence level was conducted. The examination of the signal-to-noise ratio was uutilized to establish best milling parameter combination.

Do Duc Trung *et.al.* [12] conducted the experiment on by using a CNC milling machine, a TiAlN cutting tool, SCM400 steel for the experimental material, and Caltex Aquatex 3180 oil as the coolant. The impact of in-put criterias on out-put criterias had identified by Pareto chart analysis of experimental findings. The input parameter values have been determined using the Moora method.

Nguyen Huu Quang *et.al.* [13] made an article that presents a multiple objectivable optimization of turning procedure examining with four in-put criteria's Nose Radius, Cutting speed, Feed rate, and depth of cut the Observational Matrix was developed using the taguchi method. The multiple objective optimization issue has been solved using Copra's technique. In the end, the ideal values of the minimal surface-roughness and the utmost MRR were found.

He Le Hoang Anh *et.al.* [14] studied the machinability of vertical milling machine to mill this sort of 060A4 steel using a multi-objective optimization approach. The Faced Milling-Cutter constructed of high-speed-steel (HSS) is cutting tool. The best merit of three in-put criterias (parameter) have calculated using the Taguchi technique and the PSI method in conjunction to concurrently meet the requirements of least Surface Roughness and the utmost material-emoval-rate (MRR).

Nguyen Huu-Phan *et.al.* [15] worked on the parameteric process of titanium-based PMEDM for machining die steels were optimized using Taguchi PSI. According to the trials and investigations, PSI, TOPSIS, and MOORA outperform GRA in multiple objectivable optimizations in PMEDM utilizing powder of titanium. Because of their relevance in determining spark energy, the material of electrode and concentration of powder may have a considerable impact on performance measurements.

Fulya Erdemir, Murat Tolga Ozkan [16] pre-owned the taguchi method to plan the investigation set, and 27 experimental sets were created instead of 729 experimental sets, saving time and money. Complete (Full) Factorial Analysis was done in ANSYS environment for applied method, and the method used in the analysis is verified and detailed in the article.

Ghosh *et. al.* [17] goal of this work is to use the Taguchi L9(34) Method to straight turn AISI 1018 .Here two vegetable-depended cutting-fluids and commercial-half synthetic cutting-fluid are employed and usefulness of reaction variables are studied for determining whether utilizing vegetable depended Cutting -fluid for legitimate machining improves performance of the response of machining parameters.

Dipayan Mukherjee *et. al.* [18] done this research, Taguchi grey relational investigation is utilized to maximize feedback qualities such as roughness of surface and removal-rate of material. The tTaguchi technique used here to undertake 18 experiment iterations upon a L-18 mixed combined orthogonal -array. Grey relationship grade derived from grey connection investigation is used to determine optimum parameter along with numerous work attributes.

Hilmi Pekşen & Ali Kalyon [19] evaluated the machinability of AISI 430 stainless steel based on the insert of cutting coating type, speed of cutting, and rate of feed. Experiments were carried out in a moist environment with a same 1.5 mm depth of cut through out. By extracting 801-900 mm3 chip volume from the working materials, VB and Ra were investigated. The taguchi-belonging GRA was used to identify the best processing settings.

Dušan Petković *et. al.* [20] described the use of a up to date MCDM technique, the psi-method, for tackling discrete-machining optimisation issues. The detailed computing technique of the psi-method is presented by addressing two case-studies in respect to material Machinability and the selection of the best cutting fluid for the particular machining application.

Ning Li *et. al.* [21] optimized the design of process criteria's, for turning Ti: 6Al:4V at- dry conditions including kind of inserts, rate of feed, and depth-of-cut. The Depth of cut has greatest impact, according to range analysis's findings.

Zahid Hussain [22] interchanged 2 stages straight cemented tungsten-carbide-cobalt mixed (wc-co) by taguchi coupled-grey relationship investigation, a in-sert rank (cstc—k20) tool was brought for the best turning-parameter in turning process. It is advised that metal cutting enterprises utilize these optimal ways to decrease material waste and production costs while machining EN31-535A99 SS.

Palanisamy *et. al.* [23] demonstrated that improved surface finish is obtained by combining greater machine-speed with slow feed, & the depth of machining have a large effect on surface-roughness. Precipitation in the hardened state, 17Cr-4Ni is used as a PH stainless steel. Different machining parameters were taken into consideration as responses, including Tangential-force, Surface-roughness, & Vibration ccomponents in 3-axes.

Satish Kumar *et. al.* [24] optimized the CNC turning parameters for cutting EN19 alloy steel. Examination of variance is utilized to find out how parameter can affect MRR and surface roughness (ANOVA). Optimization is done using the desirability technique.

Engin Nas *et.al.* [25] addressed a procedure which depends on the taguchi-method with grey relationship survey for enhancing the parameters of turning of hard DIN-1.2344 Hot-Work tool steels [54 hrc] along with various performances traits. In dry turning testing, both cryogenically treated and untreated uncoated carbide cutting tools were used.

Vaxevanidisa *et.al.* [26] examined effects of rotating speed, depth of cut and feed rate depth of cut on the machinability properties of a high-leaded brass alloy (CuZn39Pb3). It became determined to use an L18 mixed-stage Taguchi Orthogonal Array experimental layout / design.

Johnson Santhosh *et.al.* [27] generated the Face centered central composite design (CCD) technique used in the Coded and Actual Empirical model. In order to determine the perfect machining process parameters, this examine recommends combining artificial Neural network (ANN) with Genetic algorithm (GA) technique.

Muhammad Ali Khan *et.al.* *[*28] developed the best machining parameter by optimizing the formulated multi-objective function. To maximize the efficiency of the machining process, concurrent responses were optimized with the best-suitable values of the input parameters. According to the results of the analysis of variance, the best parameter is feed, observed by cutting condition.

Djordje Cica *et.al.* [29] presented the results of an experiment investigation and multi-objective to optimization of the machining parameters for turning Inconel 718 with the coated carbide tools under a high-pressure jet assistance. The experimental design made use of the Taguchi L27 orthogonal array, and the analytic hierarchy process turned into used to determine the weights of the responses.

Saran Keeratihattayakorn *et.al.* [30] developed a fast tool servo compensation technique to reduce the out-of-roundness when milling with a traditional CNC machine. A conventional CNC machine became used to fabricate and install the fast tool servo with piezoelectric actuator. A representative profile was created after analysis of the profiles of machined femoral heads.

Tugrul O zel *et.al* [31] investigated the impact of cutting-edge preparation geometry, workpiece surface hardness, and cutting circumstances on the cutting forces and surface roughness during finish hard turning of AISI H13 steel. They discovered that the geometry of the cutting edge and the hardness of the workpiece's surface, in addition to the cutting circumstances, had an impact on the cutting forces. Lower tangential and radial forces were produced as a result of the workpiece's decreased surface hardness and tiny edge radius.

Arsecularatne *et.al* [32] detailed an experimental examination on the use of PCBN tools to machine AISI D2 steel with a hardness of 62 HRC, a difficult-to-cut material. They discovered that flank wear played a major role in the majority of the evaluated PCBN tools reaching their end of life. The lowest speed tested (70 m/min) produced the greatest acceptable tool life and volume of material removal values, however the highest feed employed produced the highest volume of material removal and lower feeds produced the maximum tool life values.

Ibrahim [33] reported the findings of experimental work done using CVD multilayer coated cemented carbide tools to dry turn austenitic stainless steels (AISI 304 and AISI 316). TiC/TiCN/TiN and TiCN/TiC/Al2O3 coated cementide carbides were employed as the cutting tools. They discovered that the values of the machined surface roughness are considerably influenced by the cutting speed. The surface roughness values reduced as cutting speed increased until a minimal value was achieved, after which they began to rise.

Abhijeet *et.al* [34] have proposed that PCBN is the dominant tool material for hard turning applications due to its high hardness, high wear resistance, and high thermal stability. They have presented the result that the flank wear is mainly due to abrasive actions of the martensite present in the hardened AISI 4340 alloy. The crater wear of the CBN–TiN coated inserts is less than that of the PCBN inserts because of the lubricity of TiN capping layer on the cBN–TiN coating.

Rech [35] In the context of high-speed dry turning of steels, it was discovered that different coatings put on a carbide insert had demonstrated the sliding qualities of the TiN and (Ti, Al) N+MoS2 coatings, compared to uncoated tools. The secondary shear zone's thickness, temperature, and tool-chip contact area are all decreased by TiN and (Ti, Al) N+MoS2 coatings, which also minimize the heat flux transmitted to the cutting tool substrate.

Renato Franc *et.al* [36] evaluated the effectiveness of coated and uncoated carbide tools (ISO grade K10) when continuously turning AISI 8620 steel with a 3 _m thick monolayer of TiN (produced by PAPVD). Their findings show that when using coated cutting tools for machining, there are two separate crater wear rates present, whereas an uncoated insert showed a higher and single wear rate.

Che Haron *et.al* [37] examined the tool life and wear patterns under different machining conditions. The wear progression for both types of carbide tools encountered three phases of wear rate, namely initial, gradual, and abrupt stages of wear mechanism. Coated carbide (KC 9125) and uncoated carbide (K 313) were used in turning tool steel AISI D2 bar with a hardness of 25 HRC. Low feed rate of 0.05 mm/rev resulted in slow wear rate and consistent flank wear. In general, coated tools outperformed bare tools in performance. Using coated tools, an excellent surface finish and increased tool life were obtained.

Chattopadhyay *et.al* [38] investigated the wetting properties of aluminum towards various cutting tool materials using mono- or multi-layer coated carbide tools with top coatings of TiC, TiN, Al2O3, and diamond. Uncoated carbide tools (94%WC+6%Co). noticed that aluminum had a propensity to wet inserts made of uncoated carbide (94% WC+6%Co). However, when the surface was cobalt-enriched, wetting was more evident. Pure nonwetting qualities for aluminum could not be demonstrated by coatings like TiC, TiN, or Al2O3. Aluminum turning tests revealed that substantial material had accumulated on the uncoated (94%WC+6%Co) tool.

Abhay Bhatt *et.al* [39] showed the findings of an experimental study on the wear mechanisms of uncoated tungsten carbide (WC) and coated tools (single-layer (TiAlN) PVD and triple layer (TiCN/Al2O3/TiN) CVD) in Inconel718 oblique finish turning. The deterioration and eventual failure of the WC tools were found to be primarily controlled by abrasive and adhesive wear. The triple layer CVD coated tools displayed the highest wear resistance at high cutting speeds and low feeds, while the uncoated tools outperformed the single and multi-layer coated tools in the low range of cutting speeds and intermediate feeds.

Kyung-Hee Park *et.al* [40] used sophisticated microscope and image processing techniques, including wavelet transform, to analyze the flank wear on the multi-layer (TiCN/Al2O3/TiCN) coated carbide inserts while turning AISI 1045 steel. They obtained the flank wear profiles and examined the surface roughness and groove sizes on the coating layers. The abrasion caused by the cementite phase in the work material was discovered to be the main wear process. They came to the conclusion that, due to its high wear resistance against abrasion, the coating's hardness is the most crucial prerequisite to resist flank wear.

CHAPTER-3

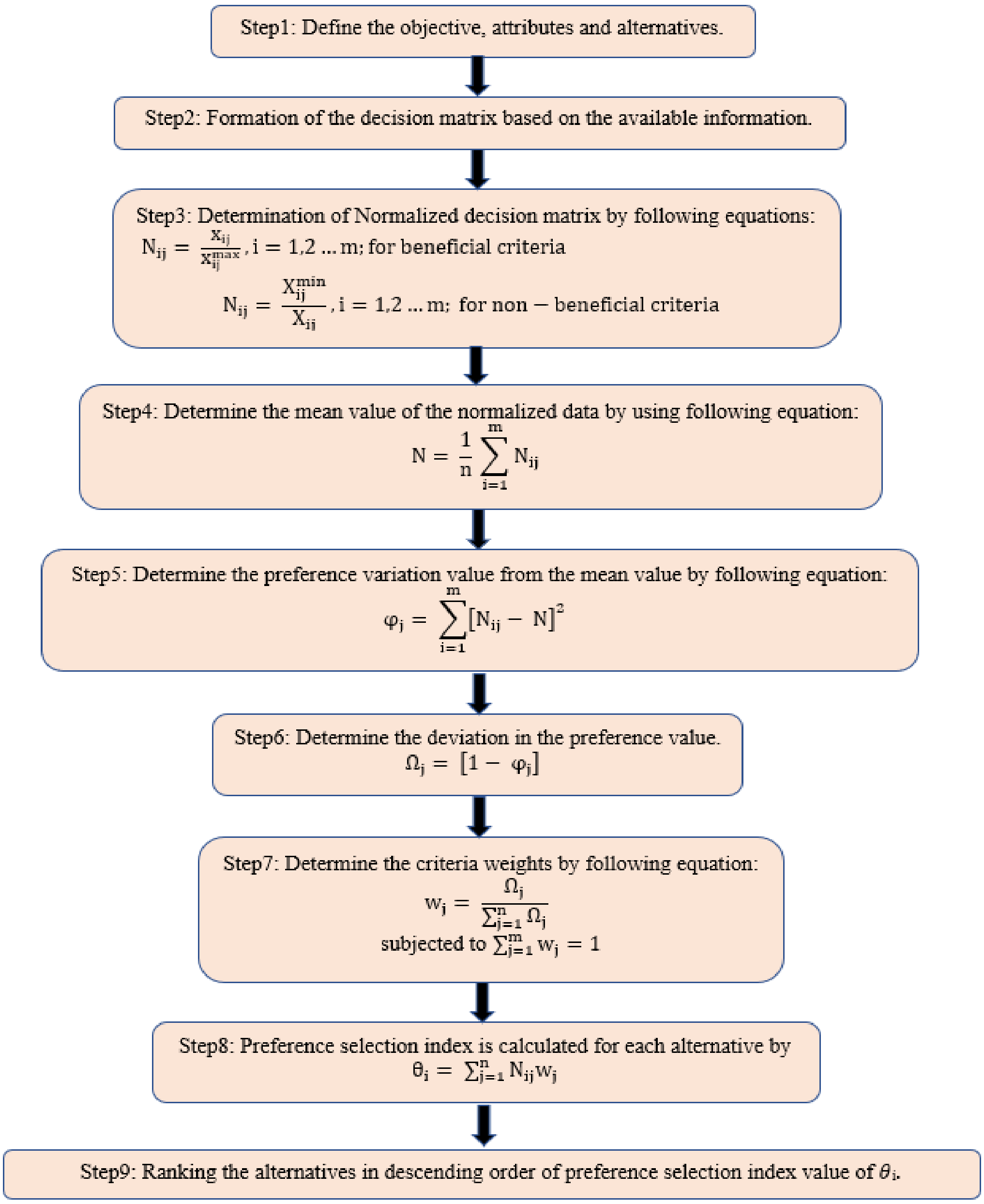
METHODOLOGY

3.1. Preference Selection Method

The preference selection index (PSI) is a multi-objective optimization technique that is used to rank and select alternatives based on a set of multiple criteria or objectives. The PSI method takes into account both the importance of each criterion and the trade-offs between them. To apply the PSI method, first, a set of criteria or objectives should be defined. Then, each criterion is assigned a weight or importance factor that reflects the relative importance of that criterion compared to the others. Next, each alternative is evaluated based on each criterion, and a score is assigned to it.

The score represents how well the alternative performs in that criterion. After scoring all alternatives, the PSI method aggregates the scores into a single value for each alternative. The aggregation process uses the weights assigned to each criterion and takes into account the trade-offs between them. The PSI method then ranks the alternatives based on their aggregated scores. One advantage of the PSI method is that it provides a systematic approach to integrate multiple criteria and objectives, even when they are conflicting or incommensurable. Furthermore, it allows decision-makers to explicitly consider their preferences and priorities when selecting among alternatives. However, the PSI method also requires careful consideration of the criteria and their weights, which can be subjective and dependent on the decision context.

During the system design phase, the engineer uses science and engineering knowledge to create a fundamental working prototype design, which includes the stages of product design and process design. Materials, components, possible product parameter values, and other decisions are made during the product creation step. When it comes to the process design step, decisions are made regarding manufacturing machinery choices, study of processing sequences, and potential values for process parameters, among other things. System design may not be at its best in terms of quality and expense because it is an early functional design. The goal of parameter design is to determine the product parameter values that fall within the optimum process parameter values while also optimizing the settings of the process parameter values to improve performance qualities. Additionally, it is anticipated that the values of the optimum process parameters derived from the parameter design will be immune to changes in the environment's parameters and other sources of noise. As a result, the PSI method's crucial stage for attaining high quality without raising costs is parameter design.



Fundamentally, Fisher's traditional parameter design is difficult to use and is overly complicated. Particularly when the number of process factors rises, numerous tests must be conducted. The Taguchi method utilizes a unique design of orthogonal arrays to complete this job and investigate the entire parameter space with a minimal number of experiments. The difference between the trial value and the intended value is then determined using a loss function. To assess the performance characteristic deviating from the intended value, Taguchi suggests using the loss function. The loss function's value is further converted into the signal-to-noise (S/N) ratio g. In the study of the S/N ratio, there are typically three performance trait categories: the lower-the-better, the higher-the-better, and the nominal-the-better. Based on the S/N analysis, the S/N ratio is calculated for each stage of the process factors. The higher S/N ratio equates to the superior performance characteristic, regardless of the division of the performance characteristic. As a result, the level with the greatest S/N ratio g is the one where the process settings are optimal. To determine which process factors are statistically important, a statistical analysis of variance (ANOVA) is additionally carried out. The ideal arrangement of the process factors can be anticipated using S/N and ANOVA analyses. The best process parameters discovered through parameter design are then validated through a proof trial. To achieve the best machining performance in turning, the Taguchi technique of cutting parameter design is used in this work.

$$\text{Nominal is the best: } S/N_T = 10\log\left(\frac{\bar{y}}{s_y^2}\right) \tag{1}$$

$$\text{Larger-is-the better(maximize): } S/N_L = -10\log\left(\frac{1}{n}\sum_{i=1}^{n}\frac{1}{y_i^2}\right) \tag{2}$$

$$\text{Smaller-is-the better(minimize): } S/N_S = -10\log\left(\frac{1}{n}\sum_{i=1}^{n}y_i^2\right) \tag{3}$$

Where, n is the number of samples, s2 y is y's variance, and y is the observed data. y is the average of the data that was witnessed. You'll see that the decibel scale is used to describe the S/N rates. S/NL is used if the goal is to optimize the system when the response is as big as possible, S/NS if the goal is to optimize the system when the response is as small as possible, and S/NT if the goal is to minimize variability around a particular target. The ideal factor values maximize the necessary S/N ratio. This study sought to shift operations with the least amount of surface irregularity (Ra). Better or enhanced surface roughness is indicated by smaller Ra numbers. As a result, in this research, a smaller-the-better quality trait was used.

The following stages are involved in using the Taguchi method's parameter design to optimize a process with numerous performance characteristics:

- Specify the process factors to be assessed along with the success characteristics. Establish the number of stages for each process parameter as well as any potential connections between them.
- Choose the suitable orthogonal array and give the orthogonal array the process parameters.
- Run the tests using the orthogonal array's configuration.
- Determine the S/N ratio and the overall loss function.
- Use the S/N ratio and ANOVA to analyze the trial findings.
- Decide on the ideal process parameter settings.

Use the confirmation trial to corroborate the ideal process settings. In order to achieve the best turning machining performance, the Preference Selection Index techniques were used in this study to create the cutting parameters.

3.2. Analysis of Variance (ANOVA)

The ANOVA is used to determine which process parameters have a substantial impact on the performance characteristics. To do this, the contributions from each of the process parameters and the error are divided into the variability of the S/N ratios, which is calculated as the sum of the squared deviations from the overall mean of the S/N ratio. First, the total squared deviations SST from the overall mean of the S/N ratios can be computed 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 "i" is the mean S/N ratio for the ith trial 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 overall 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 "sj" is the total S/N ratio for both parameter "p" and level "j." The squares of the error factors SSe are equal to

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

DT = m 1, where m is the number of tested degrees of freedom, and m is the overall degrees of freedom element Dp = t 1. The parameter under evaluation has a variance of VP = SSP/DP. The F-value is then merely the ratio of the mean square deviation to the mean square error (FP = VP/Ve) for each design parameter. The formula for computing the SP's adjusted sum of squares is: $\hat{S}_P = SS_P - D_P Ve$

Calculating the percentage input q is as follows: P = SP /S*S*

To determine which process variables significantly affect the performance characteristic, statisticians use an instrument called the F-test after Fisher. It is necessary to compute the mean of the squared differences SSm caused by each process parameter before running the F test. The total of the squared deviations SSd divided by the quantity of degrees of freedom connected to the process parameter yields the mean of the squared deviations SSm. The F-value is then just a ratio of the mean squared variance SSm to the mean squared error SSe for each process parameter. Typically, the higher the F-value, the more the change in the process parameter has an impact on the performance characteristic.

CHAPTER-4

EXPERIMENTAL DETAILS

The experimental steps involved in the present work are clearly explained in this chapter. This includes selection of work material, selection of process parameters with their and selection levels and of appropriate orthogonal array etc.

4.1. Selection of Work Material

The Alloy 410 (UNS S41000), a 12% Chromium Martensitic Stainless Steel with a Wide Variety of Mechanical Qualities, was used in the current experiment. The alloy possesses great strength and hardness as well as outstanding corrosion resistance. 410 is ductile and can be created when annealed. When annealed and subjected to heat treatment, it keeps its magnetic characteristics. It is extensively used in cutlery, petrochemical processing equipment, gate valves, ore processing, , press plates and sugar processing. The mechanical characteristics and chemical characteristics of the work material are shown in tables 4.1 and 4.2, respectively. In current work, Experiment was planned by taking Tool Type, Speed, Feed rate, DOP as variable factors showing in Table 4.3, a suitable L18 design considered, and the experiment were performed as per the chart given in. The CNC Turret Lathe used for the experiment and the finished samples were shown in figure 4.1 & 4.2.

Figure 4.1. CNC Turret Lathe

Figure 4.2. Machined Components Samples

Table 4.1: Chemical Composition of SS410

Material	Composition%	Material	Composition%
Chromium	11.5 min- 13.5 max	Phosphorus	0.04
Nickel	0.75	Sulphur	0.03
Carbon	0.08 min- 0.15 max	Silicon	1.0
Manganese	1.0	Iron	Balance

Table 4.2: Mechanical Properties of SS410

Yield Strength 0.2% Offset		Ultimate Tensile Strength		Elongation in %	Hardness (Max)
Psi	**(Mpa)**	**Psi**	**(MPa)**	34	96 Rb
42,000	290	74,000	510		

4.2. Selection of the Process Parameters and Their Levels

In an unconventional process, selecting the optimal combination of process parameters and defining the range of process parameters is a critical stage. Slight changes in process parameters will have a negative impact on the surface roughness and accuracy of the machined components. In general, there are two kinds of process parameters.

- Fixed parameters
- Controlled parameters

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

Table 4.3: Process Parameters and their Levels

	Level-1	**Level-2**	**Level-3**
Tool type	Non-Coated	Coated	
Speed, RPM	1000	1250	1500
Feed, mm/Rev	0.1	0.15	0.2
DoC, mm	0.5	1	1.5

4.3. Selection of Orthogonal Array (OA)

Taguchi has developed a design called orthogonal array it is used to study the entire design space with a smaller number of experiments. For the three parameters with mixed levels Taguchi standard L18 has been chosen and it is given in the table 4.4

Table 4.4: Input Parameters & L18 OA

S.No.	Tool Type	Speed, RPM	Feed, mm/rev	DoC, mm
1	Non-Coated	1000	0.1	0.5
2	Non-Coated	1000	0.15	1
3	Non-Coated	1000	0.2	1.5
4	Non-Coated	1250	0.1	0.5
5	Non-Coated	1250	0.15	1
6	Non-Coated	1250	0.2	1.5
7	Non-Coated	1500	0.1	1
8	Non-Coated	1500	0.15	1.5
9	Non-Coated	1500	0.2	0.5
10	Coated	1000	0.1	1.5
11	Coated	1000	0.15	0.5
12	Coated	1000	0.2	1
13	Coated	1250	0.1	1
14	Coated	1250	0.15	1.5
15	Coated	1250	0.2	0.5
16	Coated	1500	0.1	1.5
17	Coated	1500	0.15	0.5
18	Coated	1500	0.2	1

4.4 Selection of Tools

The tools selected for the study are tungsten carbide non-coated tool and tungsten carbide Coated tool as shown in figures 4.2 and 4.3. The Coating is done using MT-CVD.

Figure 4.3. Non-Coated tool

Figure 4.4. Coated tool

The experiments were conducted on CNC turret lathe it is shown in the figure 4.2. The work pieces are first trued for 0.5 mm to remove the unevenness and the components after machining were shown in the figure 4.5. After machining the finished components were tested for their roughness with SJ-210 tester shown in the figure 4.5.

Figure 4.5. SJ-210 Roughness Tester

CHAPTER-5

RESULTS AND DISCUSSION

In this chapter the experimental results of Surface Roughness (Ra) and Material Removal Rate (MRR) are analyzed using Taguchi and Anova methods. The focus of the work is to identify the optimal combination of process parameters that concurrently maximizes the material removal rate and minimizes the surface roughness.

5.1. Experimental Results

The output responses of Material removal rate, roughness and dimensional deviation measured were dissipated in Table 5.1. By following the proposed methodology steps the normalized and weighted normalized values calculated and given in the table 5.2 & 5.4 respectively.

Table 5.1: Measured Output Responses.

S.No.	MRR	R_a	R_t	DD
1	0.0500	0.231	1.973	0.1413
2	0.1500	0.487	3.524	0.0688
3	0.3000	0.635	4.521	0.0675
4	0.0625	0.275	2.276	0.0438
5	0.1875	0.847	5.717	0.0100
6	0.3750	0.614	4.142	0.1238
7	0.1500	0.372	3.928	0.0425
8	0.3375	0.406	3.140	0.0638
9	0.1500	1.266	5.734	0.1600
10	0.1500	0.214	3.463	0.0638
11	0.0750	0.319	2.282	0.0413
12	0.2000	0.651	3.833	0.0613
13	0.1250	0.217	1.635	0.0200

14	0.2813	0.325	2.921	0.1763
15	0.1250	0.412	3.125	0.0025
16	0.2250	0.341	3.836	0.1063
17	0.1125	0.309	2.229	0.0320
18	0.3000	0.668	3.483	0.0750

Table 5.2: Normalized values

S. No	**MRR**	**R_a**	**R_t**	**DD**
1	0.133	0.928	0.829	0.018
2	0.400	0.440	0.464	0.036
3	0.800	0.337	0.362	0.037
4	0.167	0.778	0.718	0.057
5	0.500	0.253	0.286	0.250
6	1.000	0.349	0.395	0.020
7	0.400	0.576	0.416	0.059
8	0.900	0.528	0.521	0.039
9	0.400	0.169	0.285	0.016
10	0.400	1.000	0.472	0.039
11	0.200	0.672	0.716	0.061
12	0.533	0.329	0.427	0.041
13	0.333	0.986	1.000	0.125
14	0.750	0.658	0.560	0.014
15	0.333	0.520	0.523	1.000
16	0.600	0.628	0.426	0.024
17	0.300	0.693	0.734	0.078
18	0.800	0.321	0.469	0.033
Avg	**8.950**	**10.1641**	**9.603**	**1.947**
N	**0.497**	**0.565**	**0.533**	**0.108**

Table 5.3: Weights of the responses

	MRR	R_a	R_t	DD	Total
ϕj	1.1346	1.0722	0.6345	0.8943	3.7356
Ωj	-0.1346	-0.0722	0.3655	0.1057	0.2644
Wj	**-0.5090**	**-0.2729**	**1.3822**	**0.3997**	1.0000

Table 5.4: Weighted Normalized values

S.No.	MRR	R_a	R_t	DD	θ_i	S/N of θ_i
1	-0.0677	-0.2534	1.1454	0.0071	0.8314	-1.6053
2	-0.2036	-0.1200	0.6413	0.0145	0.3322	-9.5725
3	-0.4072	-0.0920	0.4999	0.0148	0.0155	-36.1929
4	-0.0848	-0.2124	0.9929	0.0228	0.7186	-2.8707
5	-0.2545	-0.0689	0.3953	0.0999	0.1718	-15.3011
6	-0.5090	-0.0952	0.5456	0.0081	-0.0505	-25.9320
7	-0.2036	-0.1572	0.5753	0.0235	0.2380	-12.4670
8	-0.4581	-0.1440	0.7197	0.0157	0.1333	-17.5056
9	-0.2036	-0.0461	0.3941	0.0062	0.1506	-16.4413
10	-0.2036	-0.2729	0.6526	0.0157	0.1918	-14.3449
11	-0.1018	-0.1834	0.9903	0.0242	0.7294	-2.7410
12	-0.2715	-0.0898	0.5896	0.0163	0.2447	-12.2288
13	-0.1697	-0.2691	1.3822	0.0500	0.9934	-0.0578
14	-0.3818	-0.1797	0.7737	0.0057	0.2179	-13.2349
15	-0.1697	-0.1419	0.7229	0.3997	0.8113	-1.8166
16	-0.3054	-0.1713	0.5891	0.0094	0.1219	-18.2820
17	-0.1527	-0.1890	1.0139	0.0312	0.7034	-3.0561
18	-0.4072	-0.0875	0.6488	0.0133	0.1675	-15.5214

5.2 Preference Selection Index Output

Table 5.5: Response Table for Signal to Noise Ratios Larger is Better

Level	Tool Type	Speed	Feed	Doc
1	-9.031	-12.781	-8.271	-4.755
2	-15.321	-9.869	-10.235	-10.858
3		-13.879	-18.022	-20.915
Delta	6.289	4.010	9.751	16.160
Rank	3	4	2	1

It determined that we should give importance first to Depth of Cut then Feed then Tool Type and at last Speed this is the order we have to give importance while doing the machining on SS410 material at these considered limits for the parameters.

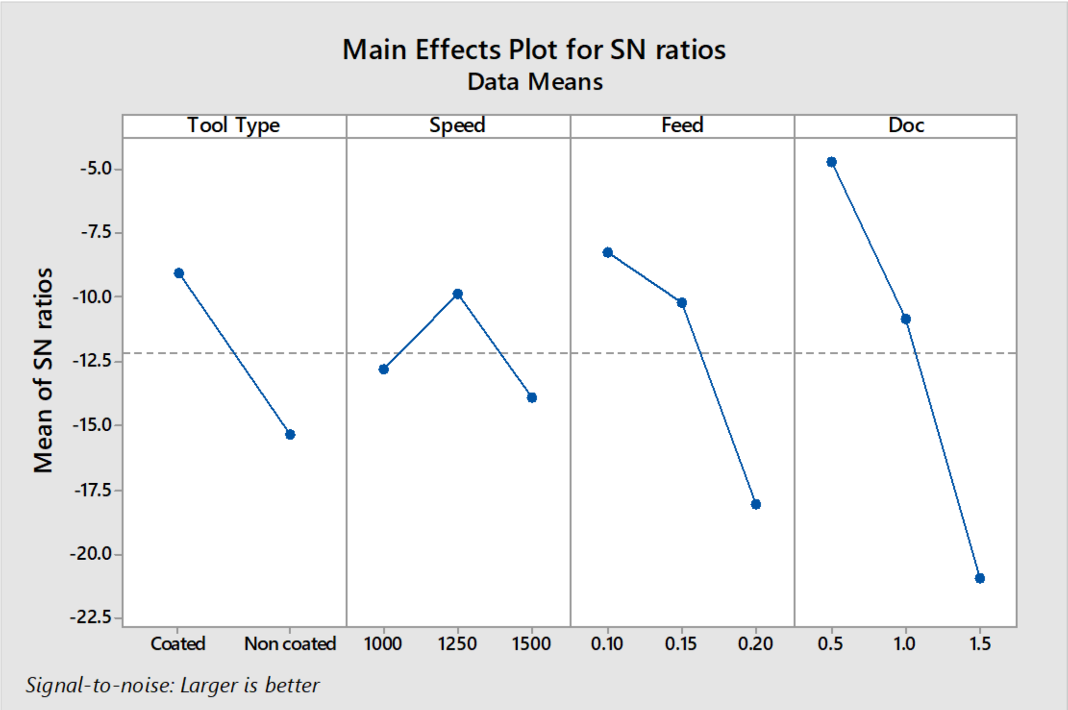


Figure 5.1: Main Effects Plot for SN ratios

5.3 PSI and ANOVA Analysis for R_a:

The analysis was carried out using MINITAB-17 software. The effect of process parameters on responses were calculated and plotted. PSI results for the responses given in table 5.4, where the ranks specify the relative importance of each factor. The main effect plot was drawn to study the variation effects of parameters on the responses with their changes in levels. The plots were shown in figures 5.2. ANOVA results of the responses were given in table 5.4. From the results it is observed that depth of cut and feed are the most significant factors for the responses respectively.

Table 5.6: Analysis of Variance for θ_i.

Source	DF	Adj SS	Adj MS	F	P
Model	13	1.57975	0.121520	3.47	0.119
Linear	4	1.10709	0.276774	7.91	0.035
Speed	1	0.03606	0.036063	1.03	0.367
Feed	1	0.26602	0.266024	7.61	0.051
Doc	1	0.50829	0.508292	14.53	0.019
Tool Type	1	0.10410	0.104104	2.98	0.160
Square	3	0.11531	0.038437	1.10	0.447
Speed*Speed	1	0.09981	0.099812	2.85	0.166
Feed*Feed	1	0.01822	0.018225	0.52	0.510
Doc*Doc	1	0.00017	0.000171	0.00	0.948
2-Way Interaction	6	0.17905	0.029842	0.85	0.590
Speed*Feed	1	0.01326	0.013263	0.38	0.571
Speed*Doc	1	0.01011	0.010111	0.29	0.619
Speed*Tool Type	1	0.00997	0.009967	0.29	0.622
Feed*Doc	1	0.00363	0.003629	0.10	0.763
Feed*Tool Type	1	0.00368	0.003679	0.11	0.762
Doc*Tool Type	1	0.10425	0.104251	2.98	0.159
Error	4	0.13989	0.034973		
Total	17	1.71964			

For the weighted Normalized Preference selection values are obtained Taguchi analysis and ANOVA were employed to analyze the ratios of depicted in Table 8&9 respectively, main effect plot and residual plot drawn also were shown in figures 3&4 respectively. From the result it is noticed that depth of cut has highest influence over the composite index significant interaction effects between Speed* Speed and DOC* Tool type were also well noticed. Residual plots showed that the modals prepared were best fit and accurate.

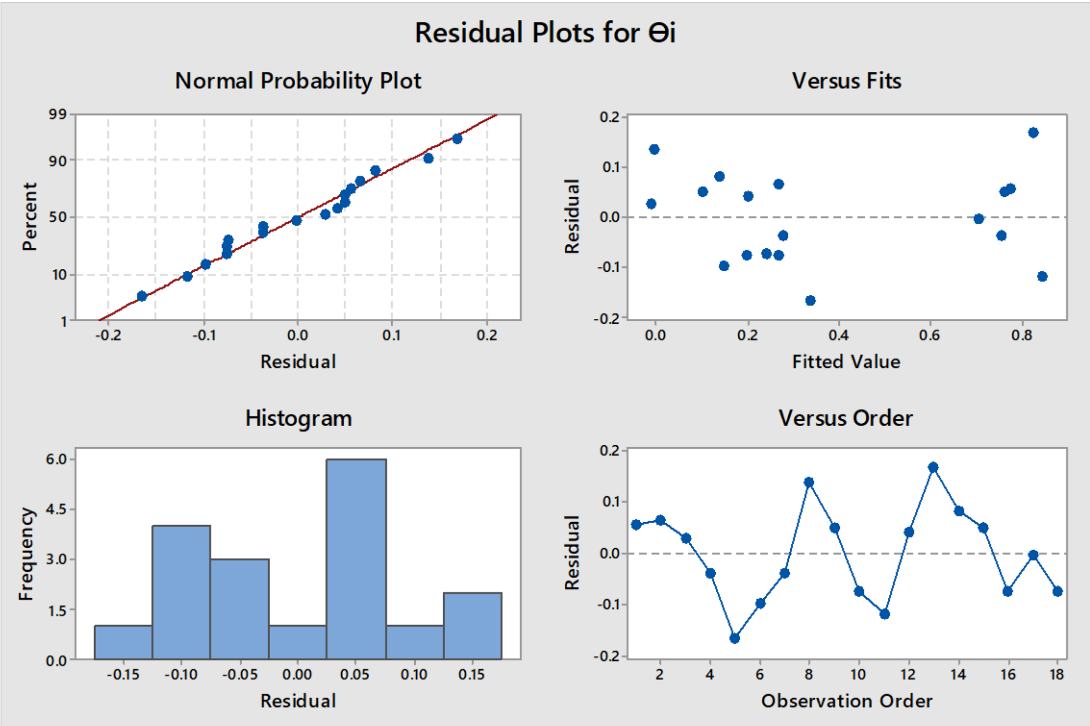


Figure 5.2: Residual Plots for θ_i.

CHAPTER-6

CONCLUSIONS & FUTURE SCOPE OF WORK

6.1 Conclusion:

The work piece SS410 has been machined using Turning process with Single point tungsten carbide cutting tool. The analysis of signal-to-noise ratio and ANOVA has been used to determine the best PSI values. For the design of experiments, the Taguchi approach and the PSI method have been used.

In this study, the suitable cutting process parameters for material removal rate and surface roughness for the workpiece SS410 have been measured.

The following conclusions can be drawn from Taguchi and ANOVA analysis.

1) DOC is found to be the most important parameter altogether.
2) Interaction effects of speed* speed and DOC * Tool type are found to be significant.
3) Residual plots showed that the models prepared are more significant and accurate as they are following normal distributions and constant variance.
4) The proposed method of Preference Selection Index proves significant applications in solving many Industrial problems with less efforts and computational simplicity.

6.2 Future scope

In the present work, Optimization of Composite Quality Attributes in Turning of SS410 Using PSI Method has been done by using Taguchi & ANOVA.

For further extension of the work, we can conduct the experiments by the following methods.

1. We can conduct the experiment by changing the cutting tool and its coating material.
2. We can conduct the experiment by changing the workpiece material.
3. We can conduct the experiment by using different optimization techniques like Grey Relational Analysis, TOPSIS, artificial Neural network (ANN) with Genetic algorithm (GA).
4. We can conduct the experiment by considering the attributes like speed, feed, DOC, tool angle, cutting fluid etc.

CHAPTER-7

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