STUDY ON INFLUENCE OF HSS & HSS-COBALT DRILLS OVER PERFORMANCE CHARACTERISTICS OF EN36 GRADE MATERIAL

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

BACHELOR OF TECHNOLOGY
IN
MECHANICAL ENGINEERING

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CERTIFICATE

This is to certify that the project report entitled **"Study on Influence of HSS & HSS-COBALT Drills over Performance characteristics of EN36 Grade Material"** being submitted **by Bylapudi Anirudh (319126520070), Gorle Vamsi (319126520080), Bendi Nihant (319126520066), Madalana Shiva Sai (319126520091), Moka Abhishikth (319126520095)**. to the Department of Mechanical Engineering, ANITS is a record of the bonafide work carried out by them under the esteemed guidance **Mrs. K.S. Lalitha Soujanya**, 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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ACKNOWLEDGEMENTS

We express immensely our deep sense of gratitude to Mrs. K.S. LALITHA SOUJANYA, Assistant Professor, Department of Mechanical Engineering, Anil Neerukonda Institute of Technology & Sciences, Sangivalasa, Bheemunipatnam (mandal), Visakhapatnam District for their valuable guidance and encouragement at every stage of the work made it a successful fulfilment.

We were very thankful to our **Prof. K.SRI RAMA KRISHNA,** Principal, ANITS and **Prof. B. NAGA RAJU**, Head of the Department, Mechanical Engineering, Anil Neerukonda Institute of Technology & Sciences for their valuable suggestions and also for encouraging us.

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

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ABSTRACT

The Present work is aimed to find the effect of drilling process parameters on objectives of Material removal rate and surface roughness. Several experiments were performed on EN 36GRADE MATERIAL with non-coated and coated HSS twisted drills. The optimization was done Using Taguchi's Signal-to-Noise ratios and Utility Methodology. The optimal combination of process parameters of MRR and Ra is obtained at Tool type: (HSS,HSS-cobalt), Point angle(90,118&135degress), Speed(900,1200&1500RPM),Feed(90,240& 450mm/min).From ANOVA analysis feed has been found as the most influence factor for multi response in the simmlar waya significant effect of interaction between field & drill type has been observed or noticed as the residual following the normal probability at constant variants, the model prepared for compare utility is more accurate &adequate.

Keywords:

Drilling, ANOVA, EN36 Grade Material, MRR, Surface Roughness, Signal-to-Noise Ratio,Utility Methodology, Taguchi Analysis, HSS & HSS-Cobalt drill Bits

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CHAPTER-1
INTRODUCTION

1.1 Introduction

One of the trickiest machining procedures is drilling. The primary feature that sets it apart from other machining processes is the simultaneous cutting and extrusion of metal at the chisel edge in the drill's center. Metal is first extruded beneath the chisel edge by the feeding motion's high-thrust force. Then it tends to Shear under the action of a negative rake angle tool.

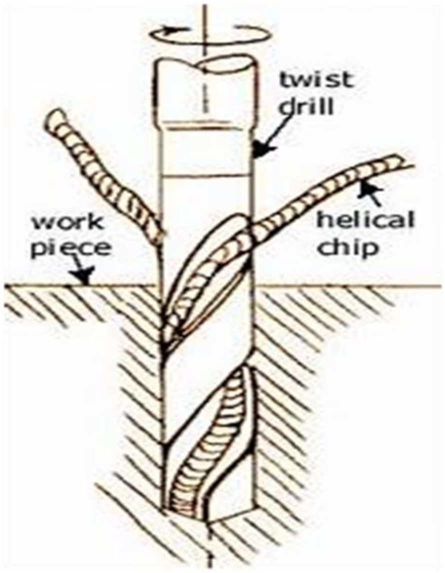

Figure 1.1 Drilling Operation

The cutting motion along the drill's lips is similar to that of other machining operations. The cutting action varies at different radii on the cutting edges due to the varied rake angle and inclination. The constraint of the entire chip on the chip flow at any single location along the lip complicates matters. Nonetheless, the metal-removing motion is genuine cutting, and the difficulties of changeable shape and constraint exist. However, because it accounts for such a minor fraction of the whole drilling activity, it is not a distinctive feature of the process.

The process of drilling requires specific machine settings that have a significant impact on the outcome. In drilling, the depth of cut is closely tied to the drill radius, which is the primary determinant of the hole's diameter. The un-deformed chip width in drilling corresponds to the drill lip's length, which varies based on the point angle and drill size. Maintaining a constant un-deformed chip width is crucial for producing high-quality holes. The feed dimension specified for drilling is typically the feed per revolution of the spindle, but a more fundamental quantity is the feed per lip, which is half the feed per revolution for a two-flute drill. Lastly, the un-deformed chip thickness differs from the feed per lip and is influenced by the point angle.

While the cutting speed fluctuates across the cutting edge when drilling, the spindle speed is constant throughout the process. Usually, the drill's outer diameter is used to calculate the cutting speed. At any position along the lip, the cutting speed increases proportionately with radius from zero at the chisel edge's center. One key aspect of drilling is the difference in cutting speed along the cutting edge. Drilling is more related to turning than milling because once the drill makes contact with the workpiece, it stays in constant contact with it until it breaks through the material's bottom or is removed from the hole.

1.2 Drill Nomenclature

The twist drill is the most significant kind of drill. The key terminology is provided below.

Drill: A drill is a hole-making end-cutting tool. It features one or more cutting edges as well as flutes that let liquids in and chips out. A shank, body, and point make up a drill.

Shank: The drill's holding and driving mechanism is known as the shank. It might have a straight or tapered shape.

Tang: The drill holder's driving slot on the machine's spindle is accessed via the tang, a flattened section of the shank at the end.

Body: Drill's body, which runs from the shank to the point, houses the flutes. The drill's body is partially ground away when being sharpened.

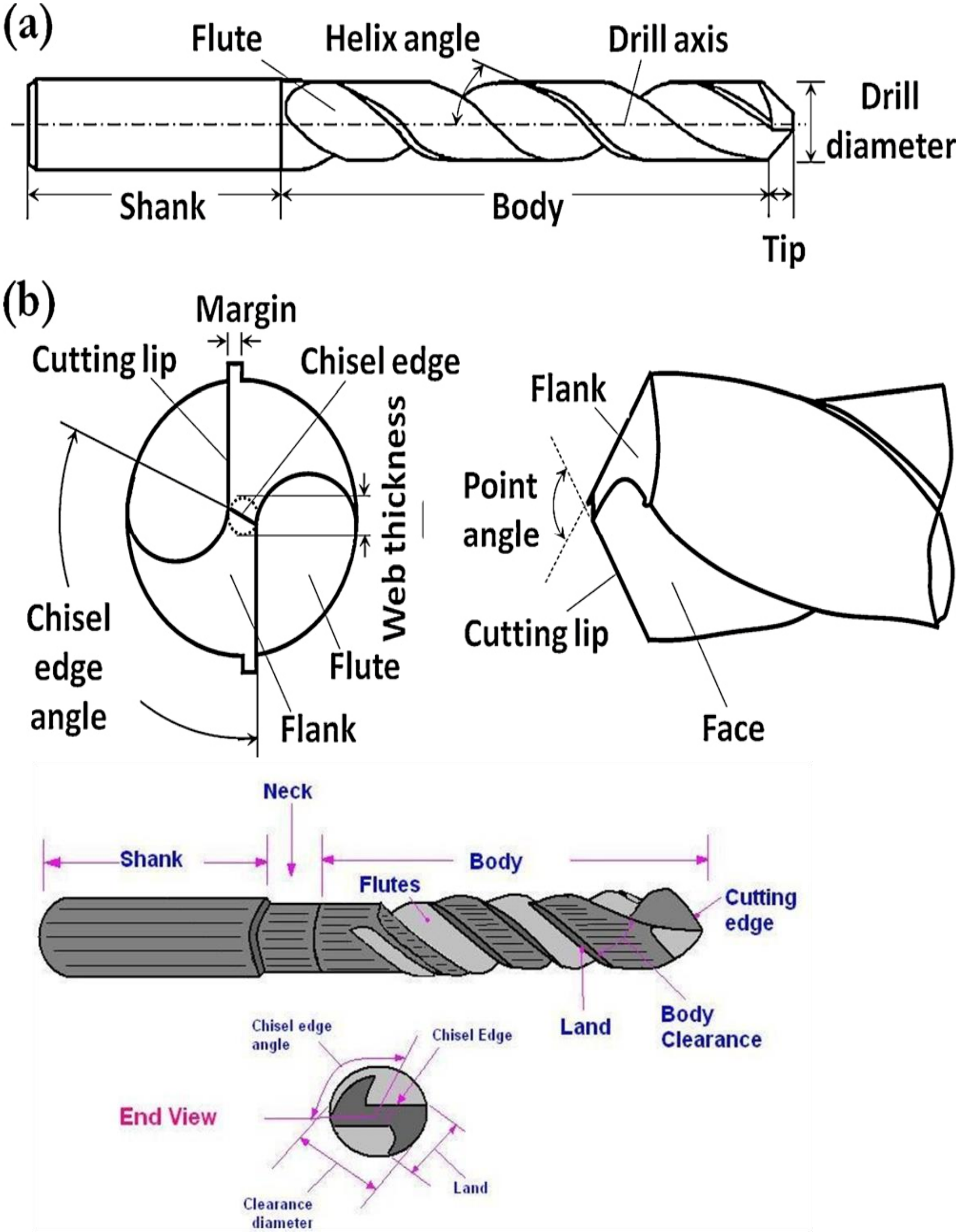

Figure 1.2 Twist Drill and parts

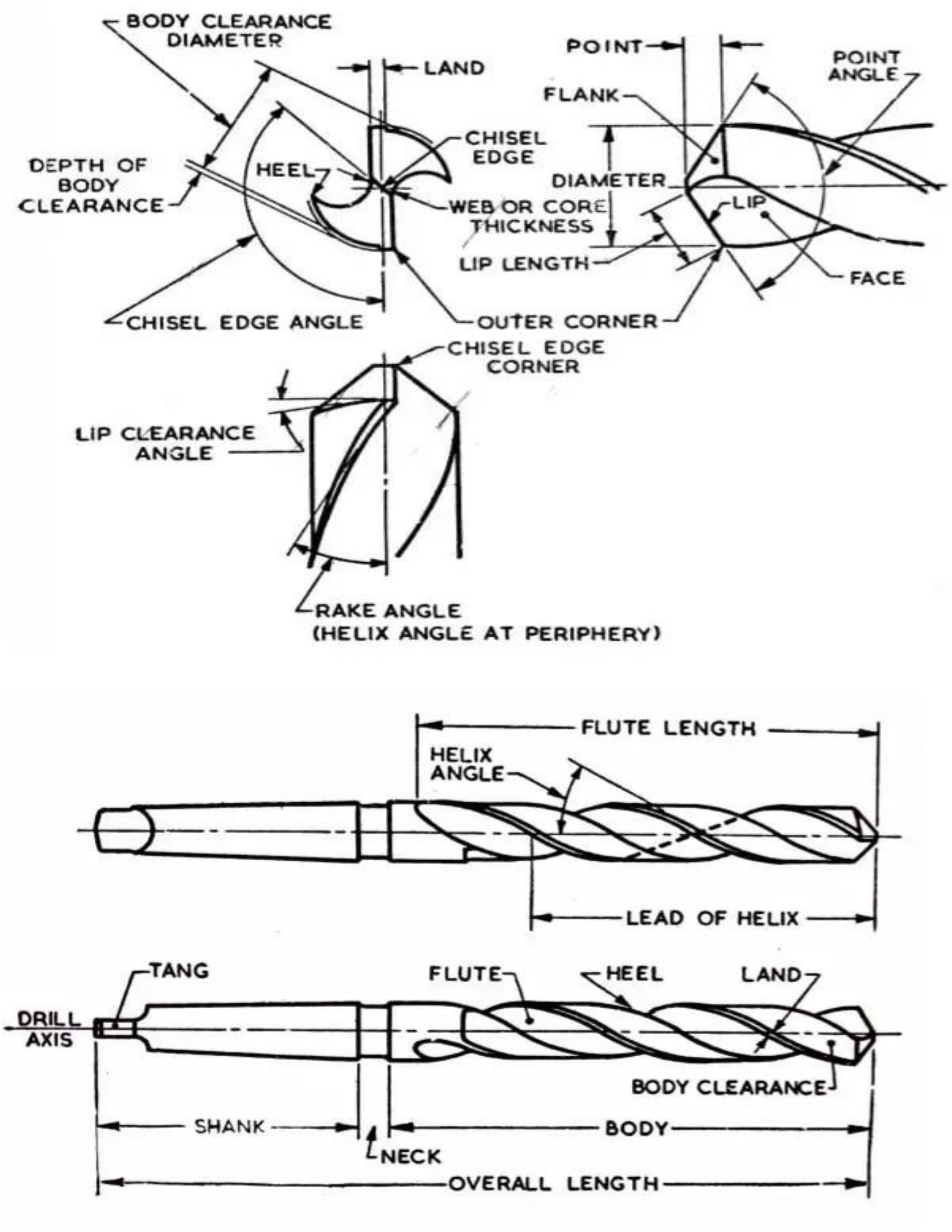

Figure 1.3 Nomenclature of Twist Drill

Point: The drill's cutting end is known as the point.

Flutes: Flutes are grooves cut or produced into the drill's body to allow chips and fluids to reach the tip and the surface of the work piece, respectively. Although they are occasionally used with straight flutes, helical flutes are more common.

Land: Following the cutting of the flutes, the land is the remaining outside of the drill body. To create clearance, the terrain has been somewhat reshaped away from the drill's outer diameter.

Margin: The margin is a brief area of land that has not been cleared or chopped away. It keeps the entire drill diameter intact.

Web: The middle area of the drill body that connects the lands is known as the web.

Chisel edge: The edge that has been ground along the tool point's web is referred to as the chisel edge. It ties together the cutting lips.

Lips: The drill's main cutting edges are the lips. They reach all the way out to the edge of the drill, from the chisel point.

Axis: The drill's axis is the tool's centerline. It is parallel to the diameter and passes through the web.

Neck: Between the body and the shank of some drills is a relieved area. It is referred to as the drill neck. In addition to the terminology used to describe the many components of the drill, there are several terminologies that describe the drill's dimensions, including key drill angles. These terms include:

Length: When the drill size is stated, the axial length of a drill is also listed along with its outer diameter. In addition, the lengths of the flute, the shank, and the neck are frequently employed.

Body diameter clearance: The body diameter clearance is the height of the step from the margin to the land.

Web thickness: The smallest dimension throughout the web is the web thickness. Unless otherwise stated, it is measured at the point. Going up the body away from the point, web thickness will frequently grow, and it might need to be ground down during sharpening to lower the size of the chisel edge.

Helix angle: The helix angle is the angle formed by the drill axis and the leading edge of the land. For varied operational needs, drills with different helix angles are offered.

Point angle: The point angle is the included angle formed by the drill lips. For various work piece materials, it varies.

Lip relief angle: The lip relief angle corresponds to the typical relief angles found on other tools. It is gauged from the edge.

Chisel edge angle: Seen from the end of the drill, the chisel edge angle is the angle between the lip and the chisel edge.

1.3 Classes of Drills

Drills are classified into numerous sorts based on the type of operation. Work piece materials can also have an impact on the type of drill used, however this usually affects the point geometry rather than the overall type of drill best suited for the work. The most crucial class is the twist drill. Within the general category of twist drills, there are a variety of drill types designed for specific applications.

High helix drills: the high helix angle of this drill makes cutting more effective but weakens the drill body. This drill's high helix angle increases cutting effectiveness but weakens the drill body. It is employed to cut weaker materials, such as softer metals.

Low helix drills: When drilling brass and comparable materials, a lower helix angle is sometimes advantageous to prevent the tool from "going forward" or "grabbing.

Heavy-duty drills: Drills that experience high stresses can be strengthened using techniques like increasing web thickness.

Figure 1.4 Types of Drills

Figure 1.5 Drills Based on Helix Angle

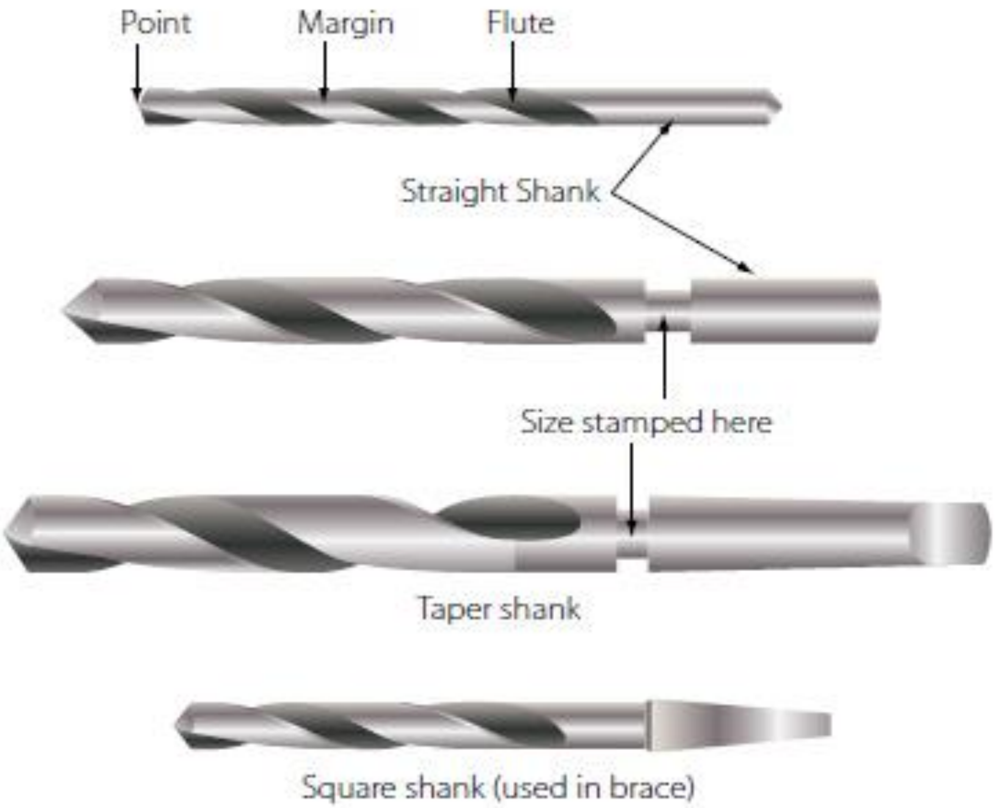

Figure 1.6 Drills Based on Shank Type

Left hand drills: designed to rotate anticlockwise are known as left hand drills. They are a version of the common twist drill. They are frequently used in numerous drill heads with spindles that may revolve in various directions to simplify head design and offer more drilling process versatility.

Straight flute drills: Drills that are straight like a flute are an extreme example of low helix drills. They are employed to drill sheet metal and brass.

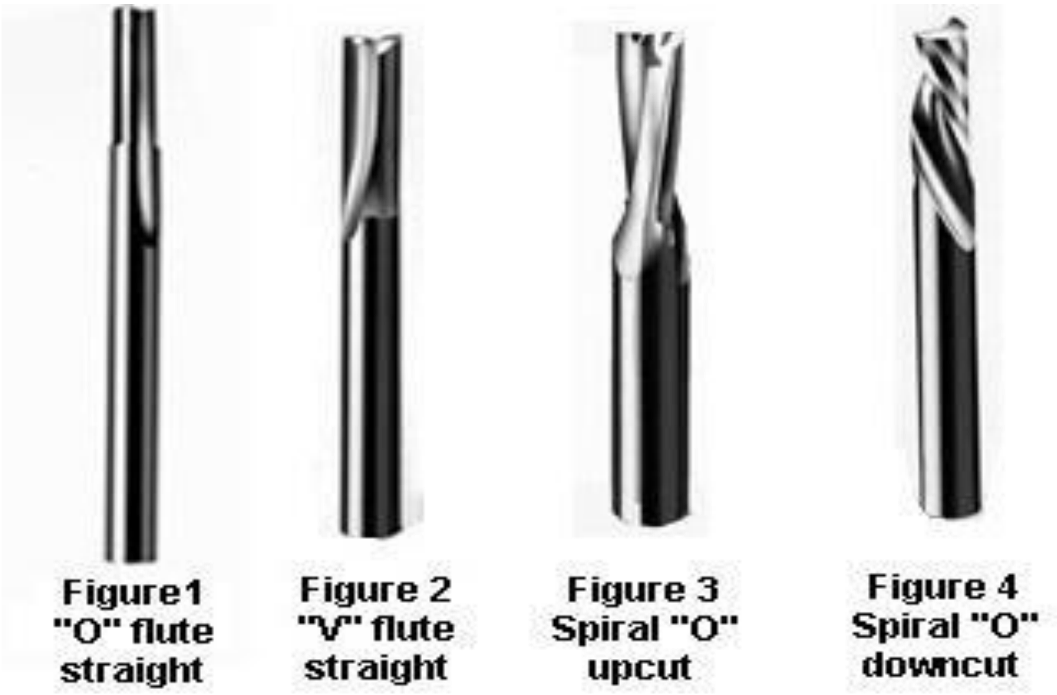

Figure1 "O" flute straight

Figure 2 "V" flute straight

Figure 3 Spiral "O" upcut

Figure 4 Spiral "O" downcut

Figure 1.7 Drills Based on Flutes

Crankshaft drills: It has been demonstrated that drills designed expressly for crankshaft operations are efficient for drilling large holes in tough materials**.** Its helix angle is a little higher than usual, and they feature a hefty web.

Extension drills: Drills with an extended, tempered shank are called extension drills, because they can drill through surfaces that are often unreachable.

Extra-length drills: A longer body drill may be necessary for deep holes if the ordinary long drill is insufficient.

Step drill: To create a hole with stepped diameters, two or more diameters may be machined on a twist drill.

Sub land drill: Step drill's equivalent is the sub land drill, often known as a multi-cut drill. In contrast to the step drill, which employs one land, it has independent lands that run the entire length of the body for each diameter. A sub land drill resembles two drills that have been twisted together.

Solid carbide drills: Solid carbide rods may be ground to standard drill geometry for drilling small holes in light alloys and nonmetallic materials. Due to the fact that carbide is highly brittle, gentle cuts must be made without shock.

Carbide-Tipped drills: To increase the durability of the edges at greater speeds, carbide tips can be used on twist drills. Drills with carbide tips are frequently used for masonry and other hard, abrasive non-metallic materials**.**

Oil hole drills: To force oil under pressure to the tool tip, small holes through the lands or small tubes in slots machined in the lands can be employed. When drilling large holes in hard materials, these drills are extremely helpful.

Flat drills: Flat bars may be ground at the end with a typical drill tip. As a result, there is no helix but very vast chip gaps. Their primary use is for railway track drilling.

Three and four-fluted drills: There are Drills with three or four flutes, but they differ from normal twist drills in that they lack a chisel edge. They are employed to enlarge already drilled or punched holes. These drills are employed because they perform the same task with greater productivity, accuracy, and surface polish than a normal drill would.

Drill and countersink: To machine "center holes" on bars that will be twisted or ground between centers, a combined drill and countersink is a handy tool. This tool's tip resembles the end of a typical drill. On the body, the countersink begins a short way back.

Figure 1.8 Straight,2Flute &3 flute Drills

Figure 1.9 Countersink Drills

1.4Drilling Operations

Drilling has a number of related operations. With the exception of centering and spot facing, most of the activities in the list below come after drilling. Drilling is required to create a hole before one of the other procedures may be used to change it. Here are some examples of these operations.

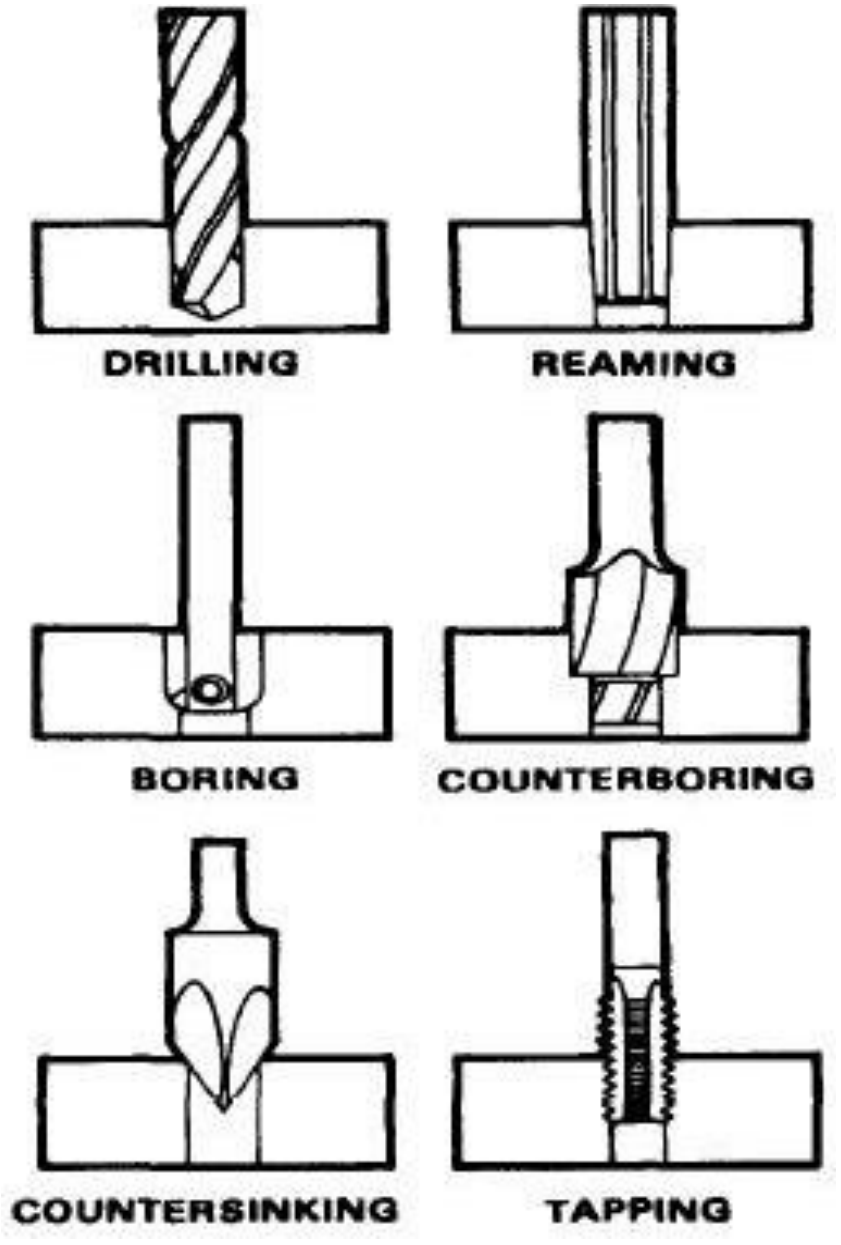

Figure 1.10 Drilling Operations

Reaming: A reamer is used to increase the size of a hole that has already been drilled, to offer a better degree of tolerance, and to improve the hole's surface finish.

Tapping: A tap is used to create internal threads in a hole that has already been bored.

Counter boring: To fit a bolt head below the surface of the object, counter boring creates a bigger step in the hole.

Countersinking: Countersinking and counter boring are similar, but countersinking has an angular step that enables flat-head screws to be seated below the surface.

Centering: To precisely locate a hole that needs to be drilled later, center drilling is employed.

Spot facing: Spot facing is used to give a part's surface a flat, machined appearance.

1.4.1Operating Conditions:

Due to the diverse range of conditions in which drills are used, it is challenging to provide fixed guidelines for speeds and feeds Nevertheless, suggestions for suitable speeds and feeds for drilling various materials are provided by drill manufacturers and reference books.

Drilling speed: Cutting speed is the amount of time it takes for a point to travel around the perimeter of a drill. Surface feet per minute is the unit of measurement (SFPM). One of the most crucial elements that affects a drill's life is cutting speed. The drill could chip or break if the cutting speed is too slow. The cutting lips quickly become dull when cutting too much at once. The following seven factors affect cutting speeds:

- The nature of the drilling material. (The cutting speed is slower the harder the material is.)
- The cutting tool's diameter and composition. (Material can be machined more quickly the tougher the cutting tool material is. The drill must rotate more slowly the larger it is.)
- The types and applications of cutting fluids enable faster cutting.

- The drill press's stiffness.
- The drill's stiffness. (The drill should be kept to a minimum.)
- The rigour of the working arrangement
- A hole's quality before drilling it.

Drilling Feed: After deciding on the cutting speed for a specific workpiece material and condition, the proper feed rate needs to be determined. In order to increase production while preserving chip control, drilling feed rates are chosen. IPR, which measures the drill's movement in inches per revolution, is the unit of measurement for feed in drilling operations. As the result of the drill's RPM and IPR, the feed can alternatively be stated as the distance covered by the drill in a minute, or IPM (inches per minute). IPM is calculated using the formula IPM = IPR x RPM.

When selecting the appropriate drilling speed (SFPM) and feed (IPR) for different materials to be machined, the process typically begins by referring to manufacturer-provided application tables or consulting reference books for recommendations.

1.5Cutting Tool Material Selection

The standard material for Rota broach cutting tools is M2 High Speed Steel (HSS). M2 is the most affordable tool material and offers the widest range of applications. It is normally suggested for cutting materials up to 275 BHN and can be used on both ferrous and non-ferrous materials. Harder materials can be worked with M2, but tool life is significantly reduced. Cobalt has been added to High-Speed Steel (HSS) drill bits, increasing the material's red hardness above that of regular HSS. These drill bits' increased hardness enables them to drill through treated stainless steel, cast iron, or titanium, as well as other materials with a Rockwell hardness of 38C or above. In addition, they have better abrasion resistance than traditional HSS and can be used at faster cutting speeds.

Figure 1.11 HSS Drill Bits

CHAPTER-2
LITERATURE REVIEW
2.1 Literature Review

Many studies have examined the impact of various cutting parameters on the surface finish in drilling, including cutting speed, feed rate, drill tool diameter, cutting fluid, point angle, and depth cut. Some of the literature related to thid has been discussed below:

Hüseyin gokce , Mehtap yavuz , İbrahim ciftc[1]In this investigation, the ideal drilling conditions for employing HSS drill bits to drill commercially accessible molybdenum will be determined. In trials, the impacts of cutting settings were investigated for surface roughness, drill bit wear, hole diameter deviation, cylindricity error, and drill bit temperature.. The findings demonstrated that drilling at speeds more than 40 m/min caused rapid drill bit failure and significant surface roughness, while higher cutting and feed rates raised drill bit temperature.

Zlatko botak, katarina pisacic, marko horvat, damir mađeric [2] In particular, this study looks at coated drill bits used for dry machining and how drill point geometry influences drill bit longevity and surface quality during drilling. Using consistent processing conditions and concentrating on chip removal and surface quality in Hardox 500, the study compares high-speed steel drill bits and hard metal drill bits with and without coatings. The research compares the costs and efficacy of making, sharpening, and using drill bits, and then uses data on drill point damage to determine which drill bit is the most cost-effective for processing holes.

Sarmad Ali Khana, Sumbul Shamaila , Saqib Anwar[3] The drill's ability to drill AISI 304 SS at various cutting speeds was tested using three surface-treated high-speed steel drills (M2, M42, and M35) and one drill with an AlCrN coating. The M2-ST drill performed best, drilling 48 holes at a maximum speed of 11 m/min while only drilling 15 holes with the M42-ST drill. With M35-GR and M35-AlCrN drills, catastrophic fracture was seen. The best hole quality was likewise achieved by M2-ST drills, which had the least amount of diametric error and surface roughness. The smaller volume proportion of primary carbides in M2-ST drills, according to the study, accounts for their higher performance.

Sarla Rubi Charles, Udaya Prakash Jayavelu, Rajkumar Chinnaraj and Sachin Salunkhe [4]This paper addresses The difficulties of machining abrasive LM6 alloys are discussed in this work, along with an assessment of the effects of drilling reactions to process variables such thrust force, surface roughness, and burr height. The study made use of stir-cast LM6 aluminum alloy and conducted L9 orthogonal array experiments in a vertical machining center equipped with a dynamometer to measure thrust forces. A Surface Roughness Tester and a Vision Measuring System, respectively, were used to measure the burr height and surface roughness. Within the investigated para, the presented model successfully predicts drilling reactions for LM6 alloy.

Santosh, Manjunatha L H , Lokesha M , B S Ajaykumar”[5]In this study, the benefits of cryogenic treatment for improving tool steel's resistance to wear are emphasized. Together with other cryogenic therapy and optimisation techniques, the Taguchi approach is investigated. The study examines how cryogenic treatment affects a single point cutting tool and recommends using regression models and fuzzy logic-based methodologies to optimise process parameters for a better surface finish and longer tool life.

Dr. Ravi Shankar Raman,Mr. Nitin Kukreja, Ms. Nidhi Singh [6] In order to increase quality and efficiency, this study addresses the application of optimisation techniques to milling and drilling operations. Surface roughness significant control factors were found using the ANOVA approach. Response surface methods and DOE approaches are often used in machining research projects. The Taguchi technique is examined for surface roughness in this review study. Important machining parameters for optimisation include cutting speed, feed rate, tool diameter and structure, cutting depth, and work piece material.

Milton Luiz Polli, Marlon Josee Cardoso [7] the difficulties of deep drilling are discussed, and the effectiveness of minimal quantity lubrication (MQL) as an environmentally friendly substitute for wet machining is assessed. The study establishes the optimal ratio of cutting speed, feed-rate, and tool shape for deep drilling SAE 4144 M steel to decrease chip size and workpiece temperature. According to the results, MQL can prolong tool life but may also result in more surface defects than pressurised oil lubrication.

Abera E. Bekele , Hirpa G. Lemu and Moera G. Jiru [8]In this study, the drilling techniques utilised to assemble interior pieces are examined in relation to their utilisation as natural-fiber reinforced composites. Unidirectional and weaved enset/sisal hybrid polyester composites are made by hand layup
techniques, and they are subsequently CNC drilled. The study looks into how delamination variables and surface roughness are affected by drilling speed, feed rate, and drill bit diameter. 3D optical surface profiles are used to examine the drilling holes' quality.

R. Ramesh Babu, R. Karthick, P. Sabarinathan, R. Shyam Sundar, C. Pradeep [9]In this work, the Taguchi technique is used to optimise the drilling parameters for minimum surface roughness, hole diameter, cylindricity, and machining time. The studies were carried out on SS304 using twist drills made of M42, CRYO-treated HSS, and HSS. The experiment was conducted on the L9 orthogonal array, and MINITAB17 was used to analyse the results.

K. Siva Prasad , G. Chaitanya[10] Abrasive water jet machining (AWJM) is being looked into as a revolutionary machining technology to improve the surface quality of fiber-reinforced polymer composites. The effects of process factors such as hydraulic pressure, stand-off distance, abrasive flow rate, fibre orientation, material thickness, and abrasive mesh size are investigated using the Taguchi L27 orthogonal array. After analysing the experimental findings with ANOVA, it is found that the abrasive mesh size has the greatest impact on surface roughness.

K. Siva Prasad , G. Chaitanya[11] Composite materials' anisotropy and inhomogeneity make drilling holes un them difficult. This study intended to reduce delamination during drilling of GFRP composites by optimising cutting settings. The most important variables influencing delamination were identified using Taguchi's S/N ratio analysis and an ANOVA analysis. According to the findings, material thickness, followed by feed rate and fibre orientation, had the biggest impact on peel-up delamination, whereas material thickness, followed by feed rate, had the biggest impact on push-down delamination. A regression-based model was created to accurately predict delamination.

S. Jebarose Juliyana, J. Udaya Prakash[12] The goal of this work was to determine the ideal drilling parameters for an unique metal matrix composite (MMC) composed using the Taguchi technique and the LM5 aluminium alloy reinforced with zirconia. Drilling studies employing a CNC machine's L27 orthogonal array were conducted in order to ascertain the impacts of input factors on thrust force, including feed rate, spindle speed, drill material, and % of reinforcement. ANOVA and Taguchi's signal-to-noise ratio analysis were used to examine the data, and the results revealed that spindle speed and feed rate were the most crucial variables for reducing thrust force.

C. Manickam , N. Parthipan[13] The primary focus of this research is the enhancement of surface roughness and material removal rate during drilling of AISI SS317L material. The study investigates the impact of drill speed, feed rate, and tool selection on surface finish, torque, thrust force, and rate of material removal. The output parameters are enhanced using Minitab-17, a statistical tool. AISI SS317L, a material with high hardness and good corrosion resistance, is used in a variety of industrial applications.

Janak Suthar a, S.N. Teli b, Amar Murumkar [14] The Taguchi method is used in this study to examine how drill bit diameter, feed rate, and cutting speed affect hole diameter and surface roughness. Low cutting speed, high feed rate, and tiny drill bit diameter are shown to be the ideal values for smallest hole diameter and surface roughness. It has been demonstrated that the Taguchi approach works well for drilling process optimisation and performance enhancement.

J.Pradeep Kumar , P.Packiaraj[15] In this investigation, the impacts of drilling parameters (cutting speed, feed, drill tool diameter) on surface roughness, tool wear, material removal rate, and hole diameter error when using an HSS spiral drill for drilling OHNS material are examined. The Taguchi technique, S/N ratio, ANOVA, and regression analysis are used to investigate the impact of various variables on the quality of drilled holes. The study makes use of an L18 orthogonal array and a DECKEL MAHO-DMC 835V machining centre. Using linear regression equations, MINITAB 13 is used to analyse the data and create correlations.

Arti Saxena , YM Dubey , Manish Kumar and Abneesh Saxena [16] By examining input variables including cutting speed, feed rate, and depth of cut, the Taguchi method is used in this work to optimise the metal removal rate in turning and drilling processes. For H-13 (P8) material, the study applies cutting tools CNMG190616-M5-TM2501 and SD205A-1050-056-12R1-P and uses Taguchi L9 array, ANOVA, and regression analysis to achieve optimal performance in SBCNC 60 lathe machine..

Ulaş Çaydaş, [17] Dry drilling of AISI 304 austenitic stainless steel was carried out using aş aydaş, K20 solid carbide, and TiN-coated HSS tools. Experimental research was done to determine the effects of spindle speed, feed rate, drill point angle, and hole count on surface roughness, tool flank wear, exit burr height, and hole enlargement. The technique known as the design of experiments (DOE), which enables us to carry out a very limited number of experiments, has been used to identify the structure of this analysis. The experimental data were collected via a L9 orthogonal array. The experimental findings showed that the drilling performances previously mentioned exhibited a propensity to improve in response to the cutting settings. The K20 carbide and HSS tools came in second and third place, respectively, with the TiN coated HSS drill demonstrating the highest performance with a longer tool life, better hole quality, and reduced surface roughness.

CHAPTER -3

DESIGN OF EXPERIMENTS

3.1 Design of Experiments (DOE) Overview

In industry, Designed experiments can be employed in the business world to methodically study the process or product variables that affect product quality. Direct improvement initiatives increase a product's manufacturability, dependability, quality, and field performance once the process conditions and product components that affect product quality have been identified. Gaining the most information possible from each experiment is crucial because there are only so many resources available. As comparison to random or unplanned experiments, well-designed experiments frequently result in a lot more information and require fewer runs. The significant impacts are determined through a well-designed experiment. If there is a relationship between two input variables

Instead of doing a "one factor at a time" experiment, they should be considered during design. When the magnitude of one input variable is affected by the level of another input variable, there is an interaction.

Planning, screening (sometimes called process characterisation), optimisation, and verification are the common four stages of designed experiments.

3.1.1Planning

Planning carefully might help you prevent issues that might arise while carrying out your experimental plan. The capacity to finish the experiment, for instance, may depend on the availability of staff, equipment, financing, and system mechanics. The preparation needed prior to starting an experiment varies on the issue. The following steps must be followed:

- **Define the issue**. Creating a proper problem statement aids in the investigation of the appropriate variables.

- **Establish the goal.** A well-defined purpose will guarantee that the experiment answers the relevant questions and produces useful data. Define the experiment's aims at this point.

- **Create an experimental strategy that will yield useful data.** Examine pertinent background material, such as theoretical concepts and observational or past experimentation expertise.

- **Ascertain that the process and measurement systems are under control**. Both the process and the measurements should ideally be under statistical control, as assessed by a working statistical process control (SPC) system. Minitab includes a plethora of options for evaluating process control and analysing your measurement system.

3.1.2Screening

There are various potentially significant factors in many process development and manufacturing applications. By identifying the important variables that determine product quality, screening decreases the number of variables. This reduction allows process improvement efforts to be focused on the most essential factors. Screening recommends the "best" ideal settings for these variables.

The following screening procedures are frequently used:

- Plackett-Burman designs have limited resolution but are effective in some screening experiments and robustness testing.
- In industry, two-level complete and fractional factorial designs are often utilised.
- For modest screening investigations, general complete factorial designs (designs with more than two levels) may be effective.

3.1.3 Optimization

After finding the critical variables through screening, the "best" or optimal values for these experimental elements must be determined. The optimal factor values are determined by the process objective.

General complete factorial designs (designs with more than two levels), response surface designs, mixture designs, and Taguchi designs are among the optimisation approaches accessible in Minitab.

- Factorial Designs Overview explains how to create and analyse general complete factorial designs.
- An Outline of Reaction Surface Designs presents methods for creating and assessing central composite and Box-Behnken designs.
- Combination Designs Methods for constructing and assessing simplex centroid, simplex lattice, and extreme vertices designs are described in this overview. Mixture designs are a subset of response surface designs in which the proportions of the components (factors) are more significant than their size.
- Response Optimization explains how to optimise numerous answers. Minitab offers numerical optimisation, an interactive graph, and an overlay contour plot to assist in determining the "optimal" settings for optimising numerous replies at the same time.
- Taguchi Designs Overview explains how to analyse Taguchi designs. Taguchi designs are sometimes referred to as orthogonal array designs, robust designs, and inner-outer array designs. These designs are utilized to create goods that are resistant to the circumstances that will be encountered in their intended working environment.

3.1.4. Verification

Verification entails repeating the experiment under the projected "optimal" processing settings to check the optimisation outcomes.

3.1.5. Advantages and Disadvantages of DOE

DOE surpassed its predecessor, one-factor-at-a-time (OFAT), as the most extensively utilised modelling approach. DOE has the benefit of displaying the connection between parameters and replies. In other words, DOE demonstrates the interaction of factors, allowing us to focus on adjusting critical parameters to produce the best results. DOE can also help us with the most optimal parameter setup to get the greatest possible output characteristics. Aside from that, the created mathematical model may be utilised as a prediction model, predicting the probable output response depending on the input values. Another important reason DOE is utilised is that it saves time and money on experiments. DOE works in such a way that the number of experiments or runs is chosen before the actual experimenting begins. We save time and money by not having to repeat unneeded experiment runs. Often, errors arise throughout experiments. Some of them may be predicted, while others are just out of control. DOE enables us to deal with these problems while proceeding with the analysis. DOE is extremely good in predicting linear behaviour. When it comes to nonlinear behaviour, however, DOE does not necessarily produce the greatest results.

3.1.6 Hierarchy

Minitab allows you to choose how model hierarchy is enforced throughout a stepwise approach. If you select a non-hierarchical model in the Model dialogue box, the Hierarchy button is hidden.

A model that contains the interaction term A*B*C, for example, is hierarchical if it includes the following terms: A, B, C, A*B, A*C, and B*C.

Non-hierarchical models are possible. Lower order words can generally be removed if they are inconsequential, unless subject area knowledge advises that they be included. Models with too many terms may be inaccurate and impair the capacity to predict the values of incoming data.

Consider the following suggestions:

1. First, fit a hierarchical model. Insignificant phrases can be removed afterwards.
2. Fit a hierarchical model to yield an equation in uncoded (or natural) units if you normalise your continuous predictors.
3. If your model includes categorical variables, the findings will be easier to understand if the category terms are at least hierarchical.
4. At the very least, category concepts are hierarchical.

3.2 Utility Methodology

Utility should be defined as the usefulness of a product or process in relation to consumer expectations. The performance of every machining process is determined by a variety of output characteristics. As a result, a composite measure is required to assess its overall performance, which must account for the relative contribution of all quality criteria. A composite index of this type measures the total utility (U) of a product/process. It provides a scientific framework for assessing alternative traits created by individuals, businesses, and organisations. The satisfaction that each quality brings to the decision maker is referred to as utility. Hence, utility theory argues that each decision is made with the utility maximising principle in mind. According to which, the best option is the one that gives the decision maker the most satisfaction.

According to the utility theory, if X_i is the measure of effectiveness of an attribute i and there are n attributes evaluating the outcome space, then the overall utility function can be expressed as

$$U(X_1, X_2, \dots \dots \dots, X_n) = f\big(U_1(X_1),\ U_2(X_2) \dots \dots \dots, U_n(X_n)\big)$$

Here, $U_i(X_i)$ is the utility of the i^{th} attribute.

If the qualities are independent, the overall utility function is provided as the sum of individual utilities.

$$U(X_1, X_2 \dots \dots \dots X_n) = \sum_{i=1}^{n} U_i(X_i)$$

After weighting the qualities, the total utility function may be represented as

$$U(X_1, X_2 \dots \dots \dots X_n) = \sum_{i=1}^{n} W_i U_i(X_i)$$

On a logarithmic scale, the preference number may be stated as follows:

$$P_i = A * \log\left(\frac{X_i}{X_i'}\right) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \text{Eq.(1)}$$

In this case, Xi is the value of any quality characteristic or attribute i, X_i' is simply an acceptable value of any quality characteristic or attribute i and A is a constant.

The value of A may be calculated by assuming that if Xi = X* (where X* is the ideal value), then $P_i = 9$.

$$A = \frac{9}{\log \frac{X^*}{X_i'}}$$

The overall utility can be expressed as

$$U = \sum_{i=1}^{n} W_i P_i \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \text{Eq. (2)}$$

subjected to $\sum_{i=1}^{n} W_i = 1$

The computed overall utility index is now treated as a single objective function for optimization. The best option is the one with the highest total utility value.

3.3.Taguchi Method

Dr. Genichi Taguchi, a Japanese engineer, invented the Taguchi Method. It is a statistical technique that may be used to standardise the fractional factorial design. He created the orthogonal array (OA) to standardise and optimise the levels of process parameters. Taguchi was a firm believer in offline quality control. To generate sturdy design, which are less subject to the \suncontrollable external elements, is the major purpose of the Taguchi Method. Taguchi pioneered the Taguchi loss function and signal-to-noise (S/N) ratio. The S/N ratio is classified into three categories:

1. Smaller is better,
2. Bigger is better,
3. Nominal is the best kind.

Taguchi created a system for using planned experiments, as well as a practitioner's manual. This technique has transported experimental design out of the exclusive domain of statisticians and into the realm of manufacturing. His insights have also simplified practitioner work by pushing for the use of fewer experimental designs and offering a deeper grasp of the variable nature and economic ramifications of quality engineering in the manufacturing environment. Taguchi outlines his technique, which involves employing experimental design to create products/processes that are resistant to external circumstances; creating and developing products/processes that are resistant to component variation; and limiting variance around a target value. Taguchi's philosophy is widely applicable. He advocated that engineering optimisation of a process or product be done in three steps: system design, parameter design, and tolerance design. The engineer uses scientific and engineering expertise to create a basic functioning prototype design, which includes the product design and process design stages. The product design stage includes the selection of materials, components, preliminary product parameter values, and so on.

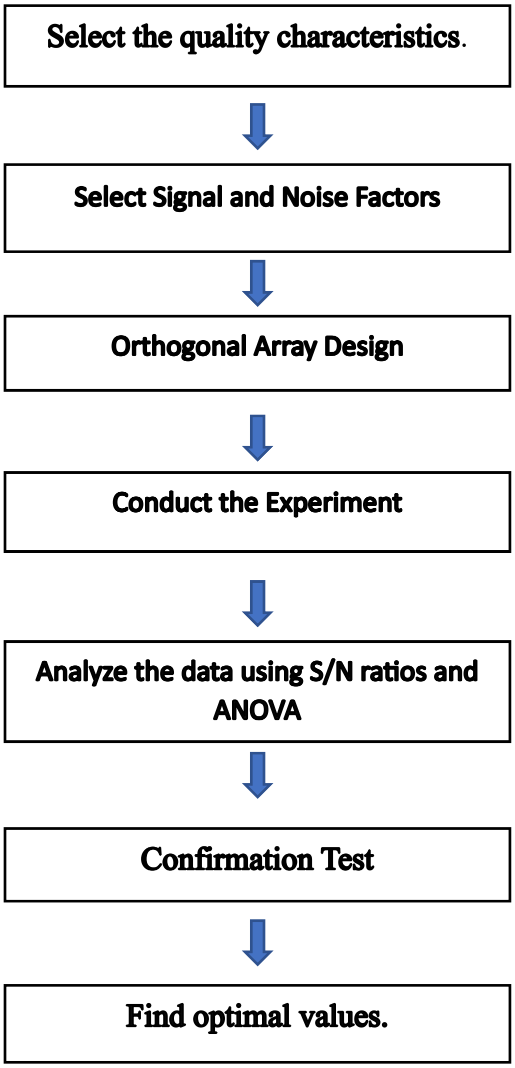

Figure.3.1 Taguchi Method

The process design stage includes the study of processing sequences, the selection of production equipment, the estimation of process parameter values, and so on. Because system design is the first functional design, It may be far from ideal in terms of both quality and expense. The goal of parameter design is to improve the process parameter value settings for increasing performance characteristics and to find the product parameter values under the ideal process parameter values. Furthermore, the optimal process parameter values derived from the parameter design are supposed to be immune to variations in ambient conditions and other noise components. As a result, parameter design is a critical stage in the Taguchi approach for obtaining high quality without raising costs. Essentially, Fisher's classical parameter design is complicated and difficult to utilize. When the number of process parameters rises, a great number of experiments must be performed. The Taguchi technique solves this problem by using a particular design of orthogonal arrays to explore the full parameter space with a minimum number of tests. The difference between the experimental and intended values is then calculated using a loss function. Taguchi suggests using the loss function to quantify performance characteristics that deviate from the target value. The loss function value is then converted into a signal-to-noise (S/N) ratio g. In the examination of the S/N ratio, there are three kinds of performance characteristics: lower-the-better, higher-the-better, and nominal-the-better. Based on the S/N analysis, the S/N ratio for each level of process parameters is derived. Regardless of the performance characteristic category, the higher the S/N ratio, the better the performance characteristic. As a result, the level of process parameters with the largest S/N ratio g is the ideal level. A statistical analysis of variance (ANOVA) is also carried out to determine whether process parameters are statistically significant. The ideal combination of process parameters may be determined using the S/N and ANOVA analysis. Lastly, a confirmation experiment is performed to validate the best process parameters determined via parameter design. The Taguchi approach of cutting parameter design is used in this study to achieve optimal machining performance in turning.

$$\text{Smaller-the-better (STB)} = -10 * log\,(1/n * \Sigma(yi\hat{}2))$$

$$\text{Larger-the-better (LTB)} = -10 * log\,(1/n * \Sigma(1/yi\hat{}2))$$

$$\text{Nominal-the-best (NTB)} = -10 * log\,(1/n * \Sigma(1/(yi - t)\hat{}2))$$

where y is the observed data's average, s2 y is its variance, n is the number of observations, and y is the observed data. Take note that these S/N ratios are indicated in decibels. We would choose S/NT if the goal is to limit variability around a certain target, S/NL if the system is designed to have the largest possible reaction, and S/NS if the system is optimised to have the smallest possible response. The ideal factor values are those that optimise the proper S/N ratio. The purpose of this study was to achieve the lowest possible surface roughness (Ra) in a turning operation. Ra values that are lower reflect better or improved surface roughness. As a result, in this study, a smaller-the-better quality feature was established and presented. The following phases are involved in using the Taguchi method's parameter design to optimise a process with numerous performance characteristics:

- Determine the performance criteria and process parameters to be assessed. Identify the number of levels for the process parameters and any potential interactions between them.
- Choosing the right orthogonal array and assigning process parameters to it.
- Do the tests based on the orthogonal array configuration.
- Determine the total loss function as well as the S/N ratio.
- Use the S/N ratio and ANOVA to analyse the experimental data.
- •Choose the best levels of process parameters.
- Confirm the best process parameters using a confirmation experiment.

3.4. Analysis of Variance (ANOVA) Using MINITAB

R.A. Fisher, an English statistician, invented ANOVA (1890-1962). Despite its origins in agricultural data, this technology has been used to a wide range of different disciplines for data analysis. Despite its widespread use, some practitioners fail to grasp the importance of double-checking the validity of many essential assumptions before using an ANOVA on their data. It is hoped that this article will give some useful instructions for conducting basic analysis with such a software programme.

ANOVA is a set of statistical models used to study variations in group means and their related procedures (such as "variation" across and between groups), in which the observed variance in a certain variable is partitioned into components attributed to different sources of variation. ANOVA, in its most basic form, gives a statistical test to determine whether or not the means of numerous groups are all equal, and so generalises the t-test to more than two groups. Doing numerous two-sample t- tests increases the likelihood of making a type I mistake. As a result, ANOVAs are useful for comparing (testing) the statistical significance of three or more means (groups or variables).

ANOVA is a type of statistical hypothesis testing that is widely employed in the analysis of experimental data. A statistical hypothesis test is a way for making data-driven judgements. A statistically significant test result (derived from the null hypothesis and the sample) is one that is regarded unlikely to have occurred by chance, provided the null hypothesis is true. The rejection of the null hypothesis is justified by a statistically significant finding (where a probability (p-value) is less than a threshold (significance level). ANOVA nomenclature is mostly derived from statistical design of studies. In order to determine an effect, the investigator modifies variables and measures responses. To verify the validity of the results, factors are assigned to experimental units using a mix of randomization and blocking. Blinding maintains the weighing's objectivity. The variety in responses is due in part to the impact and in part to random error. ANOVA is a synthesis of numerous theories that may be utilised for a variety of reasons. As a result, it is difficult to define in a succinct or accurate manner.

3.4.1. Characteristics of ANOVA

ANOVA is used to analyse comparison studies in which the sole variation in outcomes is of relevance. A ratio of two variances determines the statistical significance of the experiment. This ratio is altered by a variety of experimental observational changes: Adding a constant to all observations has no influence on their significance. A constant multiplied by all observations has no effect on their significance. As a result, ANOVA statistical significance results are independent of constant bias, scaling errors, and the units used to describe observations. To facilitate data input during the mechanical computation period, it was typical to reduce a constant from all observations (when equal to deleting leading digits).

Classical ANOVA for balanced data accomplishes three tasks at once:

1. An ANOVA is an arrangement of additive data decomposition used in exploratory data analysis, and its sums of squares represent the variance of each component of the decomposition

2. Mean squares comparisons, in conjunction with F-tests... enable testing of a nested succession of models.

3. A linear model fit with coefficient estimates and standard errors is closely connected to ANOVA.

4. In summary, ANOVA is a statistical tool that may be used to generate and confirm an explanation for observed data in a variety of ways.

Additionally:

It is computationally elegant and generally resistant to assumptions violations.

5. ANOVA statistically gives industrial strength (multiple sample comparison).

6 It has been adapted to the analysis of variety of experimental designs.

CHAPTER –4
EXPERIMENTATION DETAILS

EXPERIMENTAL DETAILS

This chapter describes the work piece (chemical and mechanical properties), drill bits, CNC drilling machine specifications, cutting process parameters and their levels, orthogonal array (L18) design, and setup conditions in measuring surface roughness values for machined components, among other things

4.1. Work Material and Drills

The drills in this work are formed on a plate of EN36 GRADE MATERIAL with a thickness of 30mm using HSS twisted drills (10mm), as indicated in figure 4.1. EN 36 is a versatile steel grade that may be used for a wide range of applications requiring high strength, hardness, and wear resistance. This substance is commonly used for

1 Manufacturing of gears and shafts that require high strength and toughness.
2. Components in heavy-duty machinery and equipment, such as axles, Spindles, crankshafts.
3. High-performance fasteners, such as bolts, studs, and screws, that require high strength and wear resistance.
4. Connecting rods in automotive and racing engines.
5. Drill collars used in oil and gas drilling.

Figure 4.1 EN 36 Grade Material

Figure 4.2 HSS Twist Drill Bits

Figure 4.3 HSS-Cobalt Drill Bits

4.2. Chemical Composition and Mechanical Properties of EN 36 Grade Material

4.2.1 The Chemical Composition of EN36 Grade Material is as follows:

Carbon (c): 0.35%-0.45%

Silicon (Si): 0.10%-0.35%

Manganese (Mn): 0.50%-0.80%

Phosphorus(p): 0.035%

Sulphur(s): 0.040%

Chromium (Cr): 0.80%-1.20%

Nickel (Ni): 025%-0.50%

Molybdenum (Mo):15%-0.25%

4.2.2. The mechanical properties of EN 36 steel depend on the heat treatment and processing. methods used. The following are typical values for EN 36 steel that has been normalized and hardened:

Tensile strength: 900 - 1200 MPa

Yield strength: 600 - 800 MPa

Elongation: 10 - 15%

Reduction in area: 40 - 50%

Hardness: 250 - 300 HB

4.3.CNC Machine Specifications used for Drilling.

In the present work the experiments were conducted on CNC drilling machine and the specifications of the machine were tabulated in table

Table 4.1 CNC Machine Specification

Manufacturer	Kitamura
Model	Mycentre 2/585
Type	Vertical Machining Centre with 4 axis
Auto Tool Changer	24 position
X-Axis	585mm
Y-Axis	430mm
Z-Axis	460mm

Fig 4.4 CNC Machine

4.4. Selection of Process Variables

A total of three process variables are selected for the experimental procedure.

The deciding process variables are

1.Tool Type

2. Point Angle

3. speed

4. feed

- Feed is the rate at which the material is removed from the work piece.
- Spindle speed, or the rate at which the spindle turns the tool.

4.4.1 Selection of levels

Since it is a three-level design by observing the parameters taken in a various project the levels of the factors are designed as follows

Table 4.2 Process Parameters and Their Levels

LEVEL	1	2	3
Drill Type	HSS	HSS-Cobalt	
Point Angle, degree	90	118	135
Feed, mm/min	90	240	450
Speed, RPM	90	1200	1500

4.4.2. L18 Orthogonal Array:

Table 4.3 L18 Orthogonal Array

S.NO	Drill Type	Point Angle (Degree)	Feed (Mm/min)	Speed (RPM)
1	HSS	90	90	900
2	HSS	90	240	1200
3	HSS	90	450	1500
4	HSS	118	90	900
5	HSS	118	240	1200
6	HSS	118	450	1500
7	HSS	135	90	900
8	HSS	135	240	1200
9	HSS	135	450	1500
10	HSS-Cobalt	90	90	900
11	HSS-Cobalt	90	240	1200
12	HSS-Cobalt	90	450	1500
13	HSS-Cobalt	118	90	900
14	HSS-Cobalt	118	240	1200
15	HSS-Cobalt	118	450	1500
16	HSS-Cobalt	135	90	900
17	HSS-Cobalt	135	240	1200
18	HSS-Cobalt	135	450	1500

4.5.CNC Machine Program

```
O0000
G21
G0 G17 G40 G49 G80
G90 G0 G90 G54 G0
G90 X-30. Y15.
S900 M3
G43 H2 Z50. M8
Z1.
G1Z-4. F40.
 G0 Z1.
 Z-3.
G1 Z-9.
G0 Z1.
Z-8.
G1 Z-14.
 G0 Z1.
Z-13.
 G1 Z-19.
 G0 Z1.
Z-18.
G1 Z-20.
G0 Z50.
Y-15. Z1.
G1 Z-4.
G0 Z1.
 Z-3.
 G1 Z-9.
```

```
 G0 Z1
Z-8.
G1 Z-14.
G0 Z1.
Z-13.
G1 Z-19.
 G0 Z1.
 Z-18.
 G1 Z-20
G0 Z50.
 Y-15.
 Z1.
 G1 Z-4.
G0 Z1.
 Z-3.
 G1 Z-9.
G0 Z1.
 Z-8.
G1 Z-14.
G0 Z1.
Z-13.
G1 Z-19.
G0 Z1.
Z-18.
 G1 Z-20.
G0 Z50.
 X-29.853 Y-.591
Z1.
```

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 G1 Z-4.
G0 Z1.
 Z-3
G1 Z-9.
 G0 Z1.
 Z-8.
 G1 Z-14.
G0 Z1.
 Z-13.
 G1 Z-19.
 G0 Z1.
Z-18.
G1 Z-20.
G0 Z50.
M5
G91 G28 Z0. M9.
G28 Y0.
```

Fig 4.5 Material after drilling

Fig 4.6 Surface Roughness Tester (Profilometer)

Fig 4.7 Surface Roughness Tester measure

CHAPTER -5
RESULTS AND DISCUSSIONS

Results and Discussions

The experimental findings and optimisation of those employing the Taguchi Method and Response Surface Methodology. The measured Material Removal Rate and Surface Roughness values are listed in the table. MINITAB-17 software was used to evaluate the obtained results.

Table 5.1 Experimental Results

S.No.	Drill Type	Point Angle (Degrees)	Feed (mm/rev)	Speed (RPM)	MRR $(\frac{cm3}{min})$	Ra (μm)
1	HSS	90	90	900	7.063	2.44
2	HSS	90	240	1200	18.880	1.89
3	HSS	90	450	1500	35.062	2.57
4	HSS	118	90	900	7.063	1.67
5	HSS	118	240	1200	18.880	1.57
6	HSS	118	450	1500	35.062	2.99
7	HSS	135	90	1200	9.440	2.90
8	HSS	135	240	1500	23.657	1.55
9	HSS	135	450	900	21.113	2.13
10	HSS-Cobalt	90	90	1500	11.757	1.79
11	HSS-Cobalt	90	240	900	14.126	2.60
12	HSS-Cobalt	90	450	1200	28.456	0.85
13	HSS-Cobalt	118	90	1200	9.440	2.91
14	HSS-Cobalt	118	240	1500	23.657	1.96
15	HSS-Cobalt	118	450	900	21.113	1.15
16	HSS-Cobalt	135	90	1500	11.757	1.33
17	HSS-Cobalt	135	240	900	14.126	1.78
18	HSS-Cobalt	135	450	1200	28.456	2.12

Table 5.2 individual utility values of responses table

S.No.	PMRR	PRa	Ui	S/N of Ui
1	0.000	1.4545	0.7272	-2.7667
2	5.5229	3.2822	4.4025	12.8740
3	9.0001	1.0831	5.0416	14.0513
4	0.0000	4.1677	2.0838	6.3771
5	5.5229	4.6095	5.0662	14.0936
6	9.0001	0.0000	4.5000	13.0643
7	1.6294	0.2187	0.9240	-0.6862
8	6.7898	4.7012	5.7455	15.1866
9	6.1508	2.4268	4.2888	12.6467
10	2.8626	3.6711	3.2668	10.2826
11	3.8934	1.0001	2.4467	7.7717
12	7.8275	9.0000	8.4137	18.4998
13	1.6294	0.1941	0.9117	-0.8027
14	6.7898	3.0219	4.9059	13.8143
15	6.1508	6.8371	6.4939	16.2502
16	2.8626	5.7965	4.3296	12.7289
17	3.8934	3.7112	3.8023	11.6010
18	7.8275	2.4604	5.1440	14.2259

PMRR $=12.9339 * \log (Xi/7.063)$

PRa $= -16.4759 * \log (\frac{Xi}{2.99})$

5.1. Taguchi Analysis

Taguchi MRR and Ra results were discussed here, and response tables for MRR and Ra were provided in tables.... and....., respectively. The major effect plots for both answers were constructed and displayed in figures..and...., respectively, based on signal-to-noise ratio values. The plots revealed the best combinations of process parameters for the replies.

MRR vs. Tool Type, PA, S, and f

Table 5.3 Response Table for Signal to Noise Ratios of MRR &Ra

Response Table for Signal to Noise Ratios

Level	Drill Type	Point Angle	feed	speed
1	9.427	10.119	4.189	8.647
2	11.597	10.466	12.557	9.701
3		10.950	14.790	13.188
Delta	2.170	0.832	10.601	4.541
Rank	3	4	1	2

Larger is better

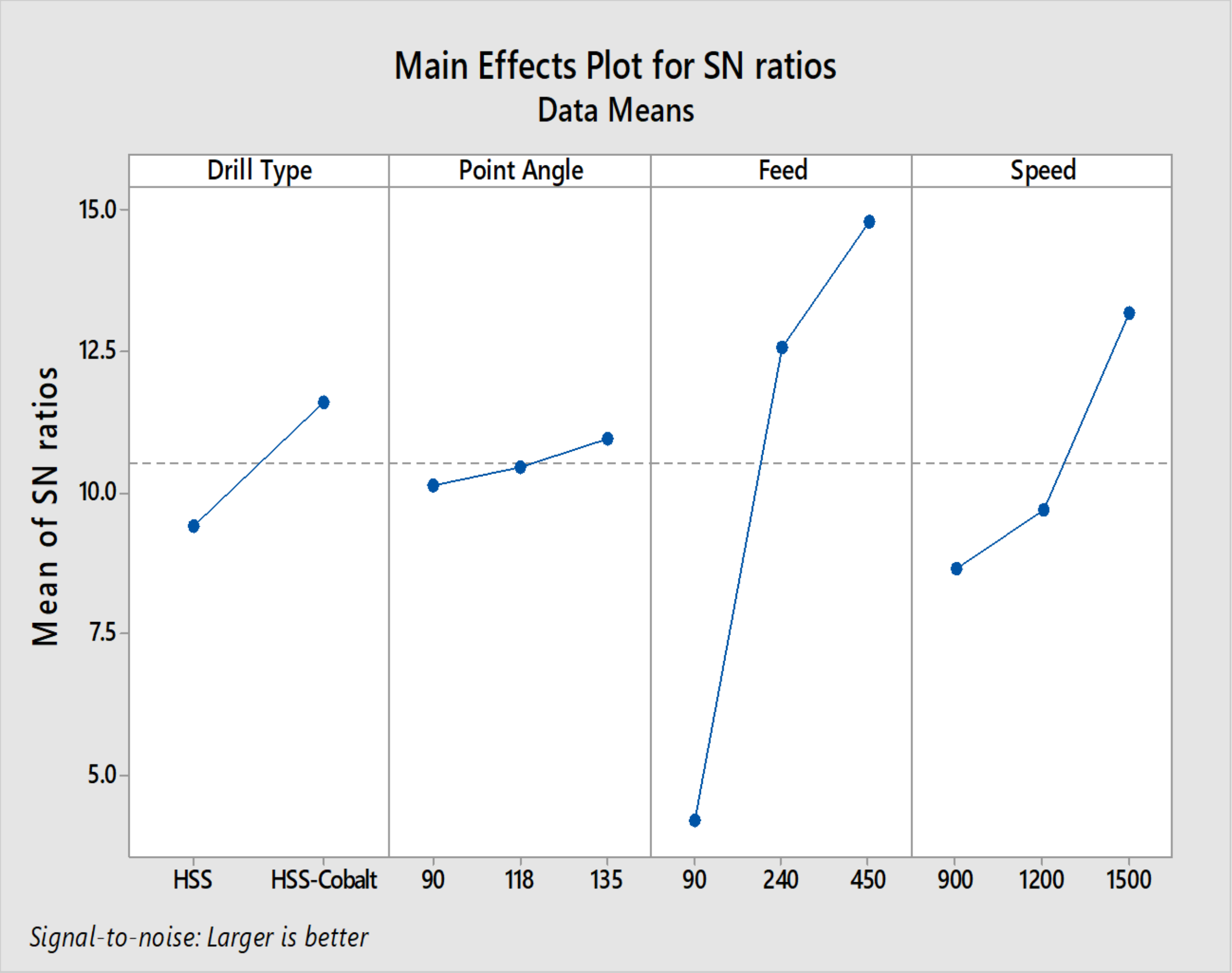

Figure 5.1. Main Effect Plot for SN ratio

Table 5.4 Response Surface Regression: Ui versus Point Angle, Feed, Speed, Drill Type

Source	DF	Adj SS	AdjMS	F	P
Model	13	61.5255	4.7327	2.22	0.230
Linear	4	41.7542	10.4385	4.89	0.077
Point Angle	1	1.0591	1.0591	0.50	0.520
Feed	1	29.5008	29.5008	13.83	0.021
Speed	1	4.9281	4.9281	2.31	0.203
Drill Type	1	0.0903	0.0903	0.04	0.847
Square	3	4.9096	1.6365	0.77	0.569
Point angle*Point angle	1	0.2147	0.2147	0.10	0.767
Feed*feed	1	3.8261	3.8261	1.79	0.252
Speed*speed	1	0.9230	0.9230	0.43	0.547
2-way interactions	6	13.2242	2.2040	1.03	0.511
Point angle*feed	1	3.6151	3.6151	1.69	0.263
Point angle*speed	1	0.0305	0.0305	0.01	0.911
Point angle*Drill type	1	0.0719	0.0719	0.03	0.863
Feed*speed	1	4.1831	4.1831	1.96	0.234
Feed*Drill type	1	4.8078	4.8078	2.25	0.208
Speed*drill type	1	0.9402	0.9402	0.44	0.543
Error	4	8.5346	2.1336		
Total	17	70.0601			

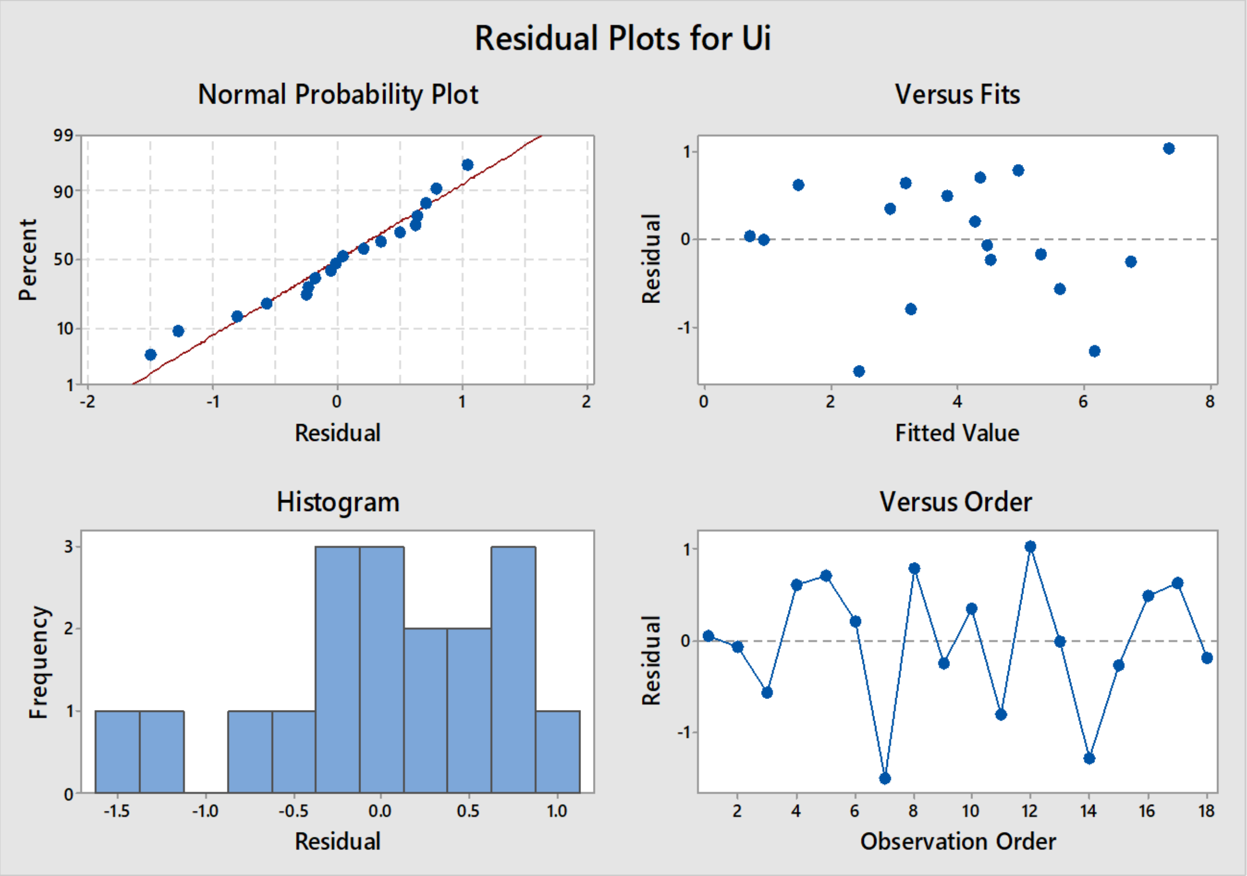

Fig 5.2. Residual plots for Ui

CHAPTER -6
CONCLUSIONS & FUTURE SCOPE

6.1 Conclusions

Performance comparison: The study found that HSS-Cobalt drills had improved performance compared to HSS drills in terms of material removal rate, and surface roughness when machining EN36 grade material.

Optimal conditions: The study identified the optimal conditions for using HSS and HSS-Cobalt drills in machining EN36 grade material, taking into account factors such as Drill Type , cutting speed, feed rate, and point angle.

From ANOVA Analysis feed has been found as the most influence factor for multi response in the similar way a significant effect of interaction between field& drill type has been observed or noticed

As the residual following the normal probability at constant variants, the model prepare for compare utility is more accurate & adequate.

6.2Future scope

Investigation of the effects of different cutting parameters: The study can be extended to investigate the effects of different cutting parameters, such as cutting speed, feed rate, and depth of cut, on the performance characteristics of EN36 grade material. This can provide valuable insights into the optimal cutting conditions for HSS and HSS-Cobalt drills.

Analysis of wear mechanisms: The wear mechanisms of HSS and HSS-Cobalt drills can be studied in detail to understand the factors that influence tool life and performance. This can help in the development of new tool materials and coatings that can enhance the performance of these drills.

Comparison with other drill materials: The study can be expanded to include a comparison of the performance characteristics of HSS and HSS-Cobalt drills with other drill materials, such as carbide and diamond drills. This can help in selecting the most appropriate drill material for a given machining application.

Application in other materials: The study can be extended to investigate the performance of HSS and HSS-Cobalt drills on other materials, such as stainless steel, titanium alloys, and composite materials. This can help in expanding the scope of the study and identifying new applications for these drills.

Development of predictive models: Based on the experimental data, predictive models can be developed to predict the performance characteristics of HSS and HSS-Cobalt drills under different cutting conditions. These models can be used to optimize the machining process and reduce the need for costly trial-and-error experiments.

CHAPTER-7
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