INVESTIGATION ON EFFECT OF TURNING PROCESS PARAMETERS OF MACHINING ON SS304 USING TAGUCHI BASED GREY RELATIONAL GRADE METHOD

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

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in
Mechanical Engineering

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CERTIFICATE

This is to certify that the Project Report entitled "Investigation on Effect of Turning Process Parameters of Machining on SS304 Using Taguchi Based Grey Relational Grade Method" being submitted by **B. Venkatesh (319126520124), B. Krupa Sagar (320126520L16), L. Roopam Sai (319126520149), V. Adithya (319126520166), S. Sanjay Babu (319126520159)** to the Department of Mechanical Engineering, ANITS is a record of the bonafide work carried out by them under the esteemed guidance of **Dr. B. Naga Raju.** The results embodied in the report have not been submitted to any other University or Institute for the award of any degree or diploma.

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ABSTRACT

One of the machining techniques used to reduce the diameter of a cylindrical work piece is turning. Surface Finish (S.F.) and Material Removal Rate (MRR) are two output characteristics that affect how well a machining process performs. Additionally, the Surface Finish and Material Removal Rate of machined components are primarily influenced by many process variables like Speed, Feed, Cut Depth, and Cutting Fluid type.

The current project focuses on SS304 stainless steel alloy machining. By taking into account several machining characteristics, it is possible to forecast the responses, such as MRR, Surface roughness, and tool tip temperature, using Castrol oil. Utilise GRA techniques to further verify the results by determining the ideal setting for each input parameter.

Castrol oil was used in an attempt during the turning of stainless steel 304 while adjusting the feed rate, speed, and depth of cut. Nine trials were conducted based on Taguchi Design of trials (DOE) for varying speed, feed, and depth of cut. Surface Finish (SF), Material Removal Rate (MRR), and cutting tool tip temperatures are assessed as output machining qualities. Grey Relation Analysis (GRA) and individual optimality are used to optimise the output parameters. Analyses are done to determine the ideal set of process variables. Based on the findings, it can be said that cutting speed, cutting fluid feed, and depth of cut have the biggest effects on MRR and Surface Roughness.

Keywords: *Turning, optimization, grey relational grade method, DOE, Regression analysis, SS304, Castrol oil, Dynamometer for force analysis, Infrared gun.*

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NOMENCLATURE

DOE	Design of experiments
GRA	Grey relational analysis
MRR	Material removal rate
R_a	Arithmetic average roughness values
R_t	Total height of roughness profile
R_z	Mean roughness depth
F_x	Radial force
F_y	Feed force
F_z	Tangential force
°C	Degree centigrade
µm	Microns

CHAPTER I
INTRODUCTION

1.1 Introduction to Lathe Machine

One of the most useful and popular machine tools in the world, the lathe machine, also known as the "Mother of all Machines," removes unwanted material from a rotating work piece in the form of chips using a tool that is traversed across the work and can be fed deeply into the work. A revolving work piece and a fixed cutting tool are the basis of how a lathe operates. The work piece is held in a chuck or faceplate that revolves between two hard, powerful supports known as centres. Lathe uses a tool that is transverse across the work and can be fed deeply into the work to remove unwanted material from a rotating work piece in the form of chips.

1.1.1 Types of lathes

1.1.1.1 Speed lathe: Of all the several kinds of lathes, its construction and use are the simplest. It lacks a feed box, lead screw, and typical carriage types. A hand control feeds the tool into the job while it is mounted on the movable slide. Where cutting force is little, such as in wood working, spinning, centering, polishing, etc., the speed lathe finds use. The headstock spindle of this lathe spins at an extremely fast speed, hence its given name.

1.1.1.2 Engine Lathe: The engine lathe has all the fundamental components, such as a bed, headstock, and tailstock, just like the speed lathe. Its headstock, however, is built considerably more solidly and has an additional mechanism for operating the lathe spindle at various speeds. In contrast to the speed lathe, the engine lathe uses a carriage, feed rod, and lead screw to feed the cutting tool both transversely and longitudinally with respect to the lathe axis. We can see an engine lathe in the Figure 1.1.

1.1.1.3 Bench Lathe: This is a little lathe that is often bench-mounted. It performs nearly all the functions of an engine lathe or speed lathe and has almost all of its components.

This is utilised for precise, tiny tasks.

1.1.1.4 Tool Room Lathe: Although this lathe is much more precisely constructed, it has many characteristics with engine lathes. Its spindle speeds range widely, from a very low speed to a very high speed of up to 2500 rpm. This lathe is mostly used for accurate machining tasks that need precision work on tools, dies, and gauges.

1.1.1.5 Capstan and Turret Lathe: These lathes were created as a result of the technological evolution of the engine lathe and are extensively utilised for jobs requiring large manufacturing. The distinctive characteristic of this kind of lathe is that the engine lathe's tailstock is replaced by a hexagonal turret, on whose face several tools may be mounted and fed into the work in the appropriate order. Due to this setup, several operations of various sorts can be performed on a task without resetting work or tools, and numerous identical components can be created in the shortest amount of time.

1.1.1.6 Special Purpose Lathes: These lathes are made for specialised tasks and jobs that can't be easily done on a regular lathe. The wheel lathe is designed for using on railway car and locomotive wheels to polish the journals and turn the tread. Extra-large diameter items are swung using the gap bed lathe, which has a removable segment of the bed near the headstock. Rotors for jet engines are machined on a T-lathe. This lathe's bed is T-shaped. A replicating lathe is used to transfer the outline of a flat or rounded template to the work piece.

1.1.1.7 Automatic Lathes: These lathes are made in such a way that the entire production process for a task, including all job management and working movements, is automated. These lathes are fully automatic, heavy duty, high speed, mass production lathes.

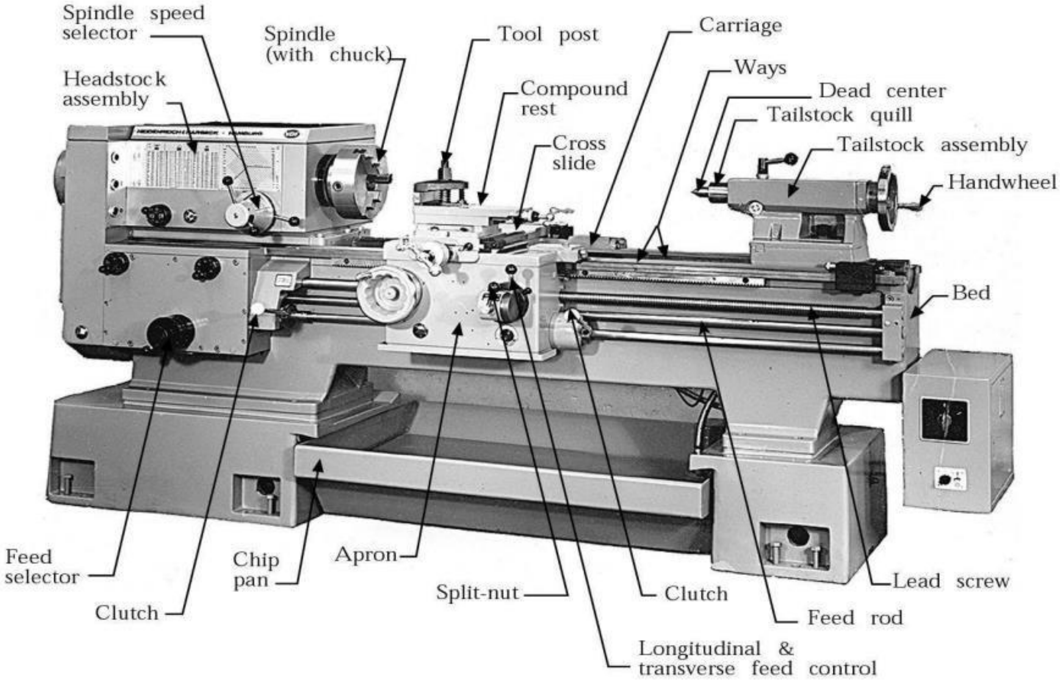

Figure 1.1: Lathe Machine

1.1.2 Lathe constructional features

1.1.2.1 Bed and Ways: The bed is the basis of the lathe's parts, and its essential characteristic is the ways, which are produced on the bed's upper surface and run the length of the bed, keeping the tailstock and carriage, which glide on them, in alignment with the headstock.

1.1.2.2 Headstock: The headstock contains the spindle and the device that drives it. The spindle cone pulley is moved along a drive belt by a motor-driven cone pulley in the belt-driven variant. Both direct spindle rotation and rotation via rear gears are possibilities. When the headstock is set up for direct drive, a bull gear pin connecting the pulley to the spindle is concealed by a cover to the right of the spindle pulley. This connection causes the spindle and spindle pulley to rotate at the same speed. The headstock contains the spindle and the device that drives it. The spindle cone pulley is moved along a drive belt by a motor-driven cone pulley in the belt-driven variant. Both direct spindle rotation and rotation via rear gears are possibilities. When the headstock is set up for direct drive, a bull gear pin connecting the pulley to the spindle is concealed by a cover to the right of the spindle pulley. This connection causes the spindle and spindle pulley to rotate at the same speed.

1.1.2.3 Tailstock: The tailstock's main function is to maintain dead centre while supporting one end of the work being machined. However, drill chucks, reamers, and tapered shank drills can also be held in the tailstock. It may be moved along the ways that run the length of the bed, and by tightening the tailstock clamping nut, it can be clamped in the desired position. Diverse lengths of work can be turned using this movement. To reduce a taper, the clamping screws at the bottom of the tailstock can be loosened, allowing the tailstock to be moved laterally (front to back). Carefully clean the tapered shank and wipe out the tapered hole of the tailstock spindle before inserting a dead centre, drill, or reamer. Make sure the drills or reamers are securely held in the spindle's tapered hole so they won't spin. They will score the tapered hole and reduce its precision if you let them circle.

1.1.2.4 Carriage: The cross-feed slide and the compound rest are supported by the carriage, which is mobile. The cutting tool is carried by the compound rest in the tool post. The carriage moves along the bed by sliding along the outside ways. For clamping work during boring or milling operations, the carriage has T-slots or tapped holes. In boring and milling processes, the carriage feeds the work to the cutting tool, which is spun by the headstock spindle, by carriage movement. By tightening the carriage clamp screw, you can lock the carriage in any position on the bed. However, you only do this while performing tasks like facing or separating off, which do not require longitudinal feed. The carriage clamp is often left in the unlocked position. Before activating the carriage's automatic feed, always move the carriage by hand to make sure it is clear.

1.1.2.5 Apron: The mechanism that governs how the carriage and cross slide move is located in the apron, which is fastened to the front of the carriage.

1.1.2.6 Feed Rod: The longitudinal feed and cross feed mechanisms are propelled by the apron with the help of the feed rod. Through a series of gears, the spindle drives the feed rod. By utilising change gears, it is possible to alter the relationship between feed rod speed and spindle speed to provide a range of rates. Through friction clutches, the revolving feed rod drives gears in the apron, which in turn drive the longitudinal feed and cross feed mechanisms. Some lathes employ a spline in the lead screw instead of a separate feed rod for the same purpose.

1.1.2.7 Lead Screw: Thread cutting is done with the lead screw. It has precisely cut Acme threads throughout its length that, when half nuts are clamped over it, engage the threads of the half nuts in the apron. Through a gear train, the spindle drives the lead screw. As a result, the spindle's rotation and the lead screw's rotation are directly related. When the half nuts are tightened, the spindle's rotation immediately affects how the carriage moves longitudinally. As a result, for each spindle revolution, the cutting tool is moved a specific distance along the job.

1.1.2.8 Cross feed Slide: The cross-feed slide rotates on the carriage at a right angle to the lathe's axis and is mounted to the top of the carriage in a dovetail. The slide can be precisely adjusted towards or away from the work using a cross feed screw.

1.1.2.9 Compound Rest: A rigidly adjustable attachment for the cutting tool is provided by the compound rest installed on the compound slide. The following are the main components of the compound rest assembly:

1. The compound rest swivel, which is adjustable in angle and can be secured in place. Around a 90° arc on either side of its centre position, it is graduated. for simpler adjustment to the chosen angle. The angle on bevel gears, valve discs, and lathe centres are just a few examples of short, steep tapers that are machined using this feature.
2. On a dovetailed slide's swivel part is affixed the compound rest, also known as the top slide. The compound rest feed screw moves it. The angular setting of the swivel part determines the angle at which the tool can be fed to the work in this configuration. For precise adjustment in determining the depth of cut, graduated collars on the cross feed and compound rest feed screws read in thousandths of an inch.

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1.1.3 Accessories and attachments

The tools and equipment used in standard lathe machining operations are called accessories. Special fixtures known as attachments can be installed on a lathe to increase its capabilities and enable milling, grinding, and taper cutting. The following paragraphs provide descriptions of some of the most popular accessories and attachments.

Tool Post: The tool post's sole function is to give the tool a stable support. It is fixed in the compound rest's T-slot. The tool post's slot is filled with a forged tool or tool holder. You may securely hold the entire unit in place and position the tool by tightening a set screw.

Tool holders: Take note of the angles at which the tool bits are positioned in each holder. These angles need to be taken into account in relation to the angles that are ground on the tools and the angle at which the tool holder is positioned in relation to the work axis. The tool holders used for threading and knurling are two varieties that are slightly different from the standard tool holders. The formed cutter on the threading tool holder only has to be sharpened on the upper surface of the cutter. As the surface is removed by grinding, the cutter may be adjusted to the proper position and held in place by the setscrew because the thread form is precisely fashioned along a sizable arc of the tool.
Two knurled rollers are held in a holder for knurling tools, and when they rotate, they leave their patterns on the work. The goal of the knurling tool is to give circular metal objects, such knobs, a roughened surface to provide a stronger grip when handling. There are numerous layouts for the knurled rollers.

1.1.4 Lathe operations

1.1.4.1 Turning – The most frequent machining operation on a lathe is turning. A cutting tool removes material from the outside diameter of a spinning work piece during the turning process. Turning's primary goal is to reduce the work piece's diameter to the appropriate size and it produces straight, conical, curved, and grooved work pieces

1.1.4.2 Facing – Machining a work piece's end perpendicular to the rotating axis is known as facing. By removing a tiny layer of material, the tool moves along the workpiece's radius to generate the appropriate component length and a smooth face surface during the facing process.

1.1.4.3 Boring – In boring, internal material is removed from a workpiece to produce or enlarge holes using a non-rotating cutting tool, such as a drill. The competence of a qualified specialist is necessary since boring must produce exact results with tight tolerances. The operation is carried out using a lathe, boring mill, or standard milling machine.

1.1.4.4 Drilling - A drill bit is spun to create a circular cross-sectional hole in solid materials during the drilling process. The drill bit is often a multi-pointed, rotating cutting tool. While rotating at speeds ranging from hundreds to thousands of revolutions per minute, the bit is forced against the work piece. By pressing the cutting edge against the work piece, this prevents chips from the hole during drilling from falling into it.

1.1.4.5 Cutting off – The goal of parting, or cut-off, operations is to effectively and securely divide one piece of the work piece from another. To do this, a straight cut is made to a depth equal to the radius of the work piece or bar being cut. The idea is the same, but the cut is shallower, in grooving operations.

1.1.4.6 Threading – On the workpiece, thread cutting on the lathe results in a helical ridge with a consistent section. This is accomplished by making a series of cuts with a threading toolbit that matches the desired thread form.

1.1.4.7 Knurling – The procedure is used to create indentations on a piece of work. Compared to the original smooth metal surface, knurling provides hands or fingers with a greater grip on the knurled object. Sometimes the knurled pattern is not the more typical criss-cross pattern but a succession of straight ridges or a helix of "straight" ridges. Figure 1.2 shows some of the lathe operations.

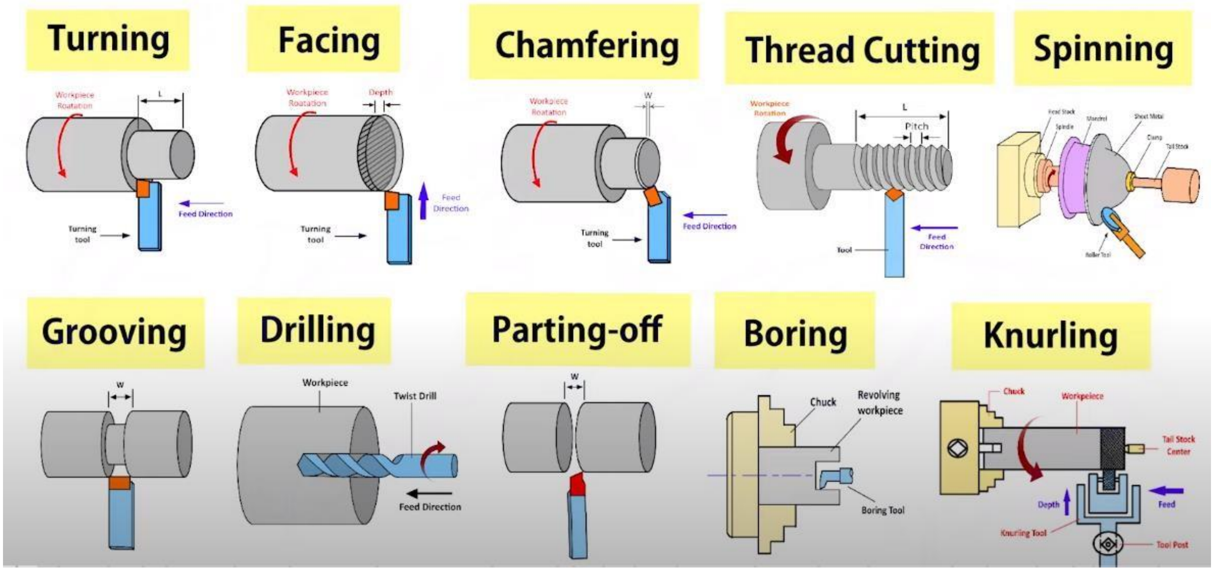

Figure 1.2: Types of Lathe Operations

1.2 Cutting Tools

Cutting is carried out by cutting tools. Heat is the end product of all the power utilised to cut metal. A thin metal ridge can be seen right above the cutting edge of a tool that has made several deep cuts. This piece of metal, which is considerably harder than the metal being cut and is nearly soldered to the edge of the tool, demonstrates the intense heat and pressure that was created. Coolants assist in absorbing heat generated by the tool's cutting edge during high-speed production work. The cutting tool's point should be exposed to a constant stream of cutting compound so that it spreads out and covers the work.. Cutting tools and cutter bits can be made from a variety of materials. It is essential to have the appropriate lathe tool ground with a keen, well-supported cutting edge for the specific type of metal being machined in order to accurately and effectively manufacture metal. Cutting tool materials include, among others:

- Cutting tools made of carbon steel are less expensive and effective on specific types of metal.
- The most common kind of lathe tools are cutting tools made of high-speed steel. Compared to carbon steel cutter bits, they can endure faster cutting rates..
- Compared to high-speed ones, satellite cutting tools can endure higher cutting rates. A nonmagnetic alloy called satellite is more durable than standard high speed steel..

- For manufacturing activities where the highest cutting speeds are demanded, carbide cutting tools are created. Titanium carbide, tantalum carbide, and tungsten carbide are the most commonly utilised ones.

By grinding its sides and edges at different angles, the cutting end of the cutting tool is modified to meet its cutting requirements. The angles are categorised as tool angles or working angles since the cutting tool is essentially inclined in the tool holder. The inclination of a tool's face towards or away from the base is known as top back rake. The rake angle is positive if the object is inclined away from the base. The rake angle is negative if the slope slopes away from the base. For optimal strength at the cutting edge and to transfer heat away from the cutting edge, the cutting angle should be as large as feasible. Side rake angle is the angle between the face of a tool and a line parallel to the base. The cutting tool will not cut without side rake, and this angle relieves excessive strain on the feed mechanism also varies with the material being machined. On the other hand, more force is needed to press the cutting edge into the work the greater the cutting angle.

- The front clearance angle lies between the flank and the cutting edge's line perpendicular to the base plane. The diameter of the work that needs to be rotated influences front clearance somewhat.
- The angle between a tool's side and a line drawn from the face edge and perpendicular to the base plane is known as the side clearance. The section of the tool bit immediately beneath the cutting edge can clear the work while taking a chip when it is spinning because of the clearance angle.
- The side relief angle is defined as the angle formed by a line drawn across the side-cutting edge perpendicular to the base and the piece of the side flank immediately below it. It is considered normal side relief since it is typically measured in a plane perpendicular to the side flank.

1.2.1 Cutting tool nomenclature

It is well knowledge that tool material and geometry have an impact on the cutting process' efficiency. The development of turning operations has substantially improved tool design and material processes. The full nomenclature of a single point tool's numerous components is depicted in Figure. They are: shank, face, flank, heel, nose, base rake angle, side rake angle, side clearance angle, end cutting edge, broad cutting angle, and lip angle. These components specify how the tool is shaped. Figure 1.3 shows the cutting tool nomenclature.

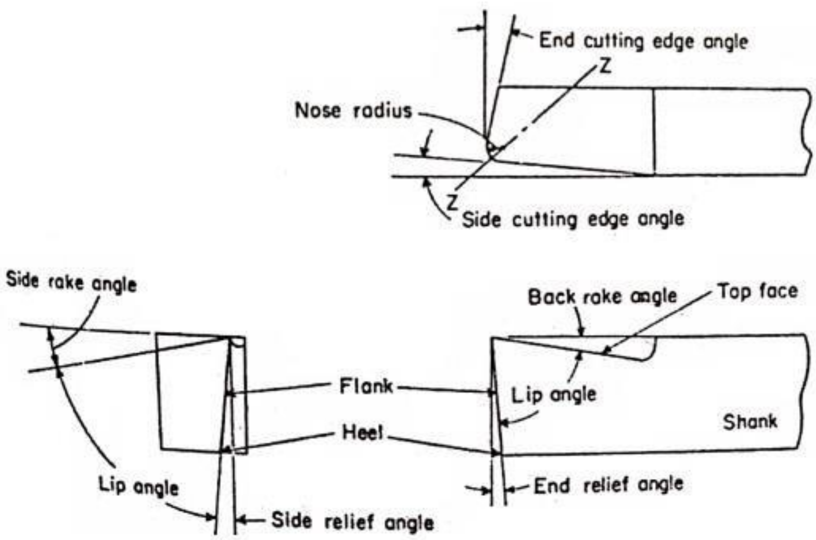

Figure 1.3: Cutting Tool Nomenclature

1.2.2 Insert tool & identification

Indexable inserts and tool holders make up a significant percentage of contemporary cutting equipment. The American National Standard ANSI B212.12-1991 contains the dimensions of the inserts and tool holders. Indexable inserts are made using a number of tools, such as single-point cutting tools with a cutting edge on one end, the majority of contemporary face milling cutters, side milling or slotting cutters, boring tools, and a wide range of specialised equipment. This kind of tooling aims to offer an insert with many cutting edges. The insert is indexed in the tool holder when an edge begins to wear until all of the cutting edges have deteriorated, at which point it is discarded. The insert is not meant to be reground because the hardened materials frequently coat the inserts. The benefits include the ability to quickly swap out a tool's cutting blades without removing the tool holder from the machine, the elimination of tool grinding expenses, and a lower cost for the insert than for a comparable brazed carbide tool. The insert size and form must be carefully selected depending on the source material and cutting method.

The majority of insert tool manufacturers use either the International Organisation of Standards (ISO) standards or the American National Standards Institutes (ANSI) indexable insert identification system to fully characterise an insert in order to choose a tool size and shape. In this section, the ANSI system is described. There are up to ten positions in the ANSI standard identifier. Because of its rigidity and hardness, the carbide insert has gained widespread acceptance since it was first developed. Applying coatings increased the number of wear-resistant inserts, enabling the creation of much harder materials.

1.3 Castrol as Cutting Fluid

Cutting fluid as Castrol reduces heat production and friction between the cutting tool and the work piece. Because of this, machining operations require less cutting force. A lower cutting force results in less total power usage during the machining operation. During machining operations, tool-chip friction occurs naturally. Your machining components experience higher wear and tear due to excessive friction. High-quality soluble cutting fluids from Castrol absorb the heat generated during cutting to enable accurate machining. Our carefully prepared cutting fluids lessen heat generation and the coefficient of friction. The cost of Castrol's soluble cutting oil is reasonable, and it has superior cooling and lubricating qualities.

1.4 Types of Cutting Fluids

A cutting fluid is a type of coolant and lubricant designed specifically for metalworking processes such as machining and stamping. Cutting fluids come in a variety of forms, including oils, oil-water emulsions, pastes, gels, aerosols (mists), and air or other gases.

1.4.1 Straight oil

Petroleum or mineral oils are the primary types of straight oils, so named because they do not contain any water. They might contain additives intended to enhance particular features. For the simplest jobs, such light-duty machining of ferrous and nonferrous metals, additives are typically not needed.

1.4.2 Soluble oil

In numerous industrial settings, soluble oil is used as a lubricant and coolant for machinery and metalworking. Users have referred to it by a variety of names, including cutting oils, suds, cutting fluid, cutting compound, coolant, and lubricants.

1.4.3 Mineral Oil

It does not carry electricity and serves to replace air and water, mineral oil is utilized in a range of industrial and mechanical capacities as a non-conductive coolant or thermal fluid in electric components.

1.4.4 Synthetic Liquids

These are synthetic coolants because there is no mineral oil in them. The liquid becomes clear when diluted and is a true solution with no droplet formation. Zero foaming is one of the key advantages of synthetic coolants. It helps in tool and surface finish.

1.4.5 Semi-Synthetic Fluids

Both oil and a synthetic substance (polymer) are present in this kind of coolant. Oil content in semi-synthetic coolants can range from 5% to 35%. Semi-synthetics have a lower oil content than soluble oils, which allows heat to disperse much more quickly and increases tool life and finish.

1.4.6 Solid and Paste Lubricants

Solid lubricants are less harmful, environmentally benign, and quickly biodegradable. Due to their great thermal stability and low coefficient of friction, they are developing into desirable alternatives to petroleum-based oils. Solid lubricants need to be non-toxic, simple to use, affordable, and durable at high temperatures.

1.5 Process Parameters

Given the application of a single point cutting tool, turning operations are among the easiest cutting processes to study. The work piece rotates at an angular speed equal to the spindle speed (n), which is expressed in rev/min (rpm) units, in this illustration of a turning process with its key parameters. Meters per minute (m/min) is a unit of measurement for cutting speed (V).

The tool progress in the axial direction (Z axis) each revolution is defined by the feed (f), which is measured in mm/rev or in/rev. The feed rate (f), which is measured in mm/min or in/min, represents the linear tool speed along the same direction.The distance the cutting tool is fed into the work piece in the radial direction (X axis) is measured by the depth of cut (t). This variable, expressed in mm or in.

The lead angle quantifies how the cutting edge of the tool is positioned in relation to the radial direction (X axis). The procedure is referred to as orthogonal cutting when this angle is zero. The procedure is known as oblique cutting for any other angle.

1.6 Turning Process Parameters

The input process parameters affecting the response of turning process are:

•Cutting speed

•Feed

•Depth of cut

• Cutting fluid

1.6.1 Speed:

The spindle and the work piece are always referred to as the speed. The definition of rotational speed is expressed in revolutions per minute (rpm). However, the surface speed, or the rate at which the work piece material moves past the cutting tool, is crucial for a certain turning process. The circle of the work piece before the cut is made multiplied by the rotation speed. It solely applies to the work piece and is measured in metres per minute (m/min). Even though the rotation speed is constant, the cutting speed varies depending on the diameter of the work piece.

$$V = \pi DN/1000 \text{ rpm}$$

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

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

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

1.6.2 Feed:

The cutting tool is always referred to as the feed, and it describes how quickly the tool moves along its cutting path. On the majority of power-fed lathes, the feed rate is measured in millimetres (of tool advance) per revolution (of the spindle), or mm/rev.

Fm= f x N (mm/min)

Here, Fm is the feed in mm per minute,

f - Feed in mm/min and

N - Spindle speed in r.p.m

1.6.3 Depth of cut:

The depth of cut is self-explanatory. The thickness of the layer being removed (in a single pass) from the work piece, or the distance from the work's uncut surface to the cut surface, is measured in millimetres. However, because this layer is removed from both sides of the work piece, the diameter of the work piece is reduced by two times the depth of cut.

DOC =D-d/2

DOC - Depth of cut in mm

D - Initial diameter of the work piece

d - Final diameter of the work piece

1.7 Response Variables

The Material Removal Rate (MRR) and Surface Roughness (SR) of the machined work piece can be used to assess the performance of the turning process. These two machining characteristics must be calculated for the input parameters chosen. The process parameters should be selected carefully in order to achieve maximum MRR and minimum surface roughness. The turning process response factors are examined more below.

1.7.1 Material removal rate (MRR)

The work piece's material removal rate (MRR) is the amount of material removed per minute. Turning's MRR and cutting speed capabilities have grown dramatically over the years. They are impacted by the machine's age and type, as well as the features and characteristics of the work item being cut. The MRR and cutting speed are also affected by the machine settings selected by the operator and programmer.

Material removal rate has been calculated by the following formula:

MRR = v*f*d

V = cutting speed (m/min)

F = feed (mm/min)

D = depth of cut (mm)

1.7.2 Surface roughness

Since surface irregularities may serve as initiation locations for cracks or corrosion, roughness is frequently a reliable indicator of how well a mechanical component will operate. It is a measure of the texture of a surface. The vertical variations of a real surface from its ideal form are used to measure it. Large deviations indicate a rough surface. The surface is smooth if it is small. R_a stands for the Surface Roughness.

- Roughness Average, R_a, is the arithmetic average of the absolute values of the profile heights over the evaluation length.
- Maximum Height of the Profile, R_t the vertical distance between the highest and lowest points of the profile within the evaluation length.
- Average Maximum Height of the Profile, R_z is the average of the successive values of R_t is calculated over the evaluation length.

1.8 Surface roughness tester

Considering that a surface roughness measuring tool is necessary since the individual roughness imperfections are too small to be seen with the unaided eye. Surface roughness tester is displayed in the Figure 1.4 (a) and (b). The irregularities which are inherent in the production process.For instance, a cutting tool or grit Roughness is measured by how far an actual surface deviates from its ideal form in the direction of the normal vector. The surface is characterised as rough if these variations are considerable and smooth if they are minimal. Roughness gauges, which are often referred to as surface roughness testers, have a stylus with a tiny, smooth contact point that can be used to trace the surface of a work piece to measure minute abnormalities. It has probes that can measure surface roughness, and surface measurements like R_a, R_t, and R_z are shown on the LCD screen.

(a) **(b)**

Figure 1.4 Surface Roughness Tester

1.9 Lathe tool dynamometer

In machining or metal cutting operation the device used for determination of cutting force is known as lathe tool dynamometer . A lathe tool dynamometer is shown in the Figure 1.5.

The forces measured are:

F_t = the feed force or thrudt force acting in horizontal plane parallel to the axis of work.

F_r = radial force acting ,also acting in the horizontal plane but along a radius of work piece

F_c= the cuting force acting in vertical plane and is tangential to the work surface also called as axial force

A tool dynamometer for lathes has been created that can assess fixed cutting forces using the level of strain gauges.The sensor's design enables direct fixing of the cutting tool to the sensor and rigid mounting of the sensor on the tool post.The sensing system measures the deflection in strain gauges and these signals are modified into another quantity and computed in the form of forces on the display system. It have sufficient sensitivity to enable measurement of cutting force with sufficient accuracy

Figure 1.5 Lathe Tool Dynamometer

1.10 Infrared Temperature Gun

As shown in Fig. 1.6, temperature guns include electronic sensors that allow them to gather the amount of heat energy from a specific object whose temperature would otherwise be challenging to detect. These weapons frequently emit infrared beams, so all you have to do to measure an object's temperature without touching it is aim at it. As long as the device is operational, the sensors have the potential to gather precise temperature data. To use these temperature guns successfully, you must, however, be familiar with some fundamentals. The temperature gun first gathers data on the heat energy emitted from a certain object using beams. Therefore, the gun does not indicate whether the heat is generated by the target or the surroundings. This means that in order to obtain the accurate temperature reading, you must make sure that the gun is pointed directly at the object whose temperature you want to measure. In order to avoid reading other heat waves that can affect the accuracy of your reading, you need to get as close as you can. You must aim straight at the object whose temperature you want to measure because the gun only reads the heat energy on the region where it is pointed.

1.6 Temperature gun

1.11 Mini Tab

A statistics package is called Minitab. Researchers Barbara F. Ryan, Thomas A. Ryan, Jr., and Brian L. Joiner created it at Pennsylvania State University in 1972. Minitab started off as a simplified version of NIST's OMNITAB statistical analysis programme. It can be applied to statistical research as well as statistics education. Statistical analysis computer applications have the advantage of being accurate, reliable, and generally faster than computing statistics and generating graphs by hand. Once you are familiar with certain basic concepts, using Minitab is not too difficult. A privately held firm with its headquarters in State College, Pennsylvania, Minitab Inc. distributes Minitab. It also has subsidiaries in Coventry, England (Minitab Ltd.), Paris, France (Minitab SARL), and Sydney, Australia (Minitab Pty).

To implement six sigma, CMMI, and other statistics-based process improvement techniques today, Minitab is frequently utilised. The software, called Minitab 14, is offered in 7 languages: English, French, German, Japanese, Korean, Simplified Chinese, and Spanish. Minitab is a programme for statistical analysis. It can be applied to statistical research as well as statistics education. Computer programmes for statistical analysis have the advantage of being more precise, dependable, and generally quicker than manual methods for generating statistics and creating graphs. Once you are familiar with certain basic concepts, using Minitab is not too difficult. Two additional products from Minitab Inc., which go well with Minitab 14: Quality Companion 3 is an integrated tool for managing Six Sigma and Lean Manufacturing projects that enables the combination of Minitab data with management and governance tools and documents.

Quality Trainer is an eLearning package that teaches statistical tools and concepts in the context of quality improvement and integrates with Minitab 14 to simultaneously develop the user's statistical knowledge and ability to use the Minitab software. Projects and worksheets are the two major types of files in Minitab. Think of a spreadsheet as a file that contains data variables. Worksheets are data-based files. Worksheets, graphs, and commands make up projects. Graphs, worksheets, and commands will all be saved each time you save a Minitab project. Nevertheless, each component can be saved 16 separately and used in different documents or Minitab projects. Projects and their components can also be printed.

1.11.1 Two windows in mini tab

1. Session Window: The section where you can enter commands and see the statistical outcomes of your data analysis.

2.Worksheet Window: A table of rows and columns that is used to enter and edit the data. Although it resembles a spreadsheet, this area does not update its columns when entries are modified.

Other windows include:

- Graph Window: Each graph that is generated has its own window when you do so.
- Report Window: Its report manager aids in the organisation of your findings in a report.
- Additional Windows: Project Manager and History are additional windows. .

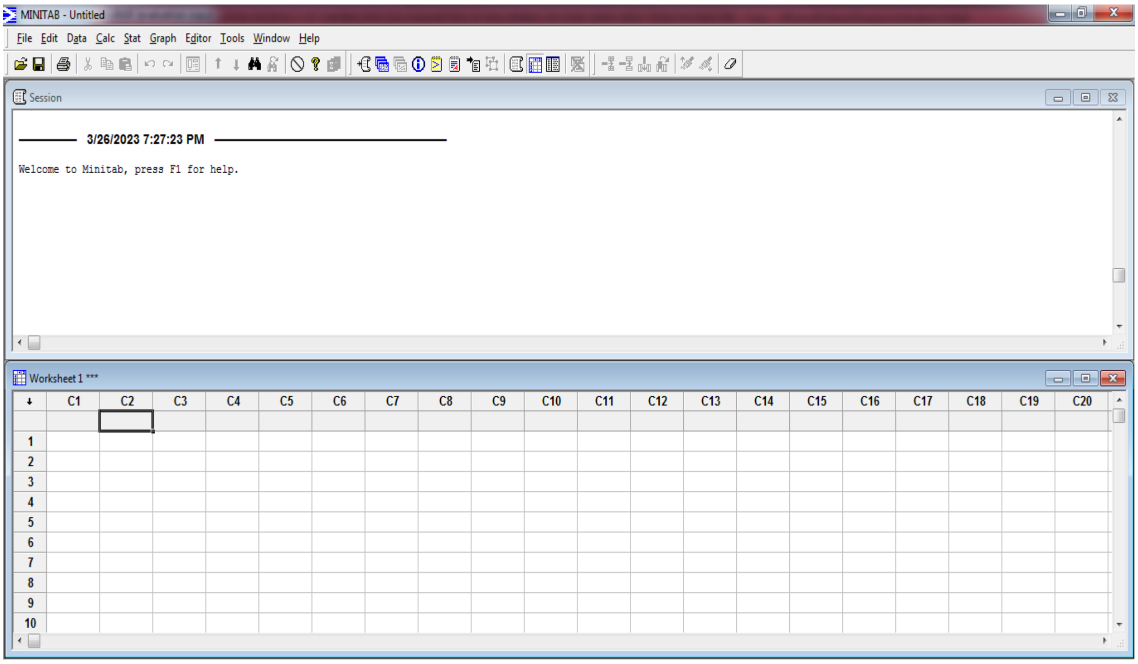

Fig 1.8 Mini Tab Interface

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1.11.2 Grey relational analysis with Taguchi method

Multi-response optimisation problems have been solved using the taguchi approach using Grey relational analysis to solve this issue.

Identification of responses (MRR, Ra, Rq, and Rz) and input parameters (Speed, feed, and depth of cut) and cutting forces (fx, fy, fz) are the first steps in Grey relational analysis.

• Identify the various input process parameter levels (3).

• Determining the process parameters and choosing a suitable orthogonal array (L9).

• Conduct the tests in accordance with the L9 orthogonal array.

• Averaging out responses.

• Determining the Grey Relational Coefficient (GRC) and Grey Relational Generation.

• The Grey Relational Grade (GRG) calculation.

• Examine the related grade in grey.

• Choosing the best possible set of process variables

1.11.3 Significance of signal to nose ratio

The resilience of a product design is directly tied to the signal-to-noise notion. Strong signal is delivered through a robust design or product. It carries out the anticipated task and can tolerate internal and external deviations (noise). Signal and noise are the desired and unwanted components, respectively, of the signal to noise ratio. For the purpose of optimising Static Problems, three Signal-to-Noise ratios are of common relevance. The signal to noise ratio formulas are created so that an experimenter can always use the greatest factor level setting to enhance an experiment's quality. As a result, a formula for determining the Signal-to-Noise ratio has been developed.

The better options are (i) smaller-the better, and (ii) larger-the better.

Smaller the better

Drinking water quality depends on impurities. The better the water is, the fewer pollutants customers discover in it. Vibrations are essential to a car's quality; the less vibration clients experience when driving, the better; the more appealing the cars, the better: The Signal-to-Noise ratio for smaller the better is:

$$Z_{ij} = \frac{\max(Y_{ij,} i = 1,2 \ldots\ldots\ldots n) - Y_{ij}}{\max(Y_{ij,} i = 1,2, \ldots\ldots n) - \min(Y_{ij,} i = 1,2 \ldots\ldots n)} ; \text{Smaller the better} - \text{Eq}(1)$$

Where, Y_{ij} is the response

Larger the better

Customers will want to get the most minutes possible for every dollar they spend on phone bills if the number of minutes per dollar they receive from their cellular phone service provider is a crucial component of quality. The Signal-to-Noise ratio for the bigger-the-better is:

$$Z_{ij} = \frac{Y_{ij} - \min(Y_{ij,} i = 1,2 \ldots\ldots\ldots n)}{\max(Y_{ij,} i = 1,2, \ldots\ldots n) - \min(Y_{ij,} i = 1,2 \ldots\ldots n)} ; \text{Larger the better} - \text{Eq}(2)$$

CHAPTER II

LITERATURE REVIEW

Venkata Rao and Kalyankar [1]is adopted multi-pass turning operations is to produce products with low cost and high quality, with a lower number of cuts. Parameter optimization plays an important role in achieving this goal. Process parameter optimization in a multi-pass turning operation usually involves the optimal selection of cutting speed, feed rate, depth of cut and number of passes. In this work, the parameter optimization of a multi-pass turning operation is carried out using a recently developed advanced optimiza-tion algorithm, named, the teaching–learning-based optimization.

Manjunatha and Umesh [2] aims to get the optimal turning parameters like Speed, Feed & Depth of cut to optimize the value of output parameters like Feed force, Tangential Force & surface roughness by machining of stainless steel with an coated carbide tool insert. Taguchi Technique is used in their study.

Suleiman Abdulkareem [3] investigated the influence of the three most important machining parameters of depth of cut, feed rate and spindle speed on surface roughness during turning of AISI 1045. Box Behnken experimental design method as well as analysis of variance (ANOVA) was used to analyze the influence of machining parameters on surface roughness height Ra. From the experiments they concluded that the feed rate is found to be the most important parameter effecting Ra, followed by cutting speed while spindle speed has the least effect. They also found that machining with high cutting speed and spindle speed has positive effect on Ra against feed rate.

Rahul Davis[4] has observed that the parameter designs yielded the optimum condition of the controlled parameters, as well as a predictive equation was used. A confirmation tests was then performed which indicated that the selected parameters and predictive equation were accurate to within the limits of the measurement instrument. Therefore, the above results can be recommended to get the lowest surface roughness for further studies

Lin et al. [5] adopted an abdicative network to construct a prediction model for surface roughness and cutting force. Once the process parameters: cutting speed, feed rate and depth of cut were given; the surface roughness and cutting force could be predicted by this network. Regression analysis was also adopted as second prediction model for surface roughness and cutting force. Comparison was made on the results of both models indicating that adductive network was found more accurate than that by regression analysis.

Kirby et al. [6] developed the prediction model for surface roughness in turning operation. The regression model was developed by a single cutting parameter and vibrations along three axes were chosen for in-process surface roughness prediction system. By using multiple regression and Analysis of Variance (ANOVA) a strong linear relationship among the parameters (feed rate and vibration measured in three axes) and the response (surface roughness) was found. The authors demonstrated that spindle speed and depth of cut might not necessarily have to be fixed for an effective surface roughness prediction model

Thamizhmanii et al. [7] applied Taguchi method for finding out the optimal value of surface roughness under optimum cutting condition in turning. The experiment was designed by using Taguchi method and experiments were conducted and results thereof were analyzed with the help of ANOVA (Analysis of Variance) method. The causes of poor surface finish as detected were machine tool vibrations, tool chattering whose effects were ignored for analyses. The authors concluded that the results obtained by this method would be useful to other researches for similar type of study on tool vibrations, cutting forces etc. The work concluded that depth of cut was the only significant factor which contributed to the surface roughness

Neeraj Saraswat [8] had adopted the Taguchi method for the design of experiments and results have been by minimizing S/N ratio. Optimization of the surface roughness was done using Taguchi method and Predictive equation was obtained. A confirmation test was then performed which depicted that the selected parameters and predictive equation were accurate to within the limits of the measurement instrument.

Neeraj Saraswat [9] adopted the Taguchi design approach for the design of experiments and results have been by minimizing S/N ratio. Optimization of the surface roughness was done using Taguchi method and Predictive equation was obtained. A confirmation test was then performed which depicted that the selected parameters and predictive equation were accurate to within the limits of the measurement instrument.

Ramanujam, et al.[10] work presents on optimization of input parameters by using Dry Turning on Inconel 718.This study is carried out by using Taguchi’s L9 Orthogonal array. Finally concluded that feed and depth of cut was found to be significant parameters for his experimentation

Anand Shivade, et al. 11], " Optimization of Machining Parameters for Turning using Taguchi Approach ". Modern manufacturers, seeking to remain competitive in the market, rely on their Manufacturing engineers and production personnel to quickly and effectively set up manufacturing processes for new products. This paper presents the single response optimization of turning parameters for Turning on EN8 Steel. Experiments are designed and conducted based on Taguchi's L9 Orthogonal array design. This paper discusses an investigation into the use of Taguchi parameter Design optimize the Surface Roughness and Tool tip temperature in turning operations using single point carbide Cutting Tool. The Analysis of Variance (ANOVA) is employed to analyze the influence of Process Parameters during Turning. The useful results have been obtained by this research for other similar type of studies and can be helpful for further research works on the Tool life.

D. Philip Selvaraj et al. [12] have studied the Taguchi optimization method was functional to find the most favourable process parameters, which minimizes the surface roughness for the duration of the dry turning of AISI 304 Austenitic Stainless Steel. The Taguchi orthogonal array, the signal to noise S/N ratio and the investigation of variance ANOVA were used for the optimization of cutting parameters. The ANOVA results shows that feed rate, cutting speed and depth of cut affects the surface irregularity by 51.84%, 41.99% and 1.66% respectively. A verification experiment was also conducted and confirmed the success of the Taguchi optimization process

Syung Lan [13] present the optimization of cutting parameter –speed, feed, depth of cut and nose radius in order to improve surface finish and MRR orthogonal array has been adopted for planning of trial and multi objective optimization by using grey relation analysis. It was observing that superior cutting speed, feed, depth of cut and minimum nose radius gives better surface finish and higher MRR. The result achieved by proposed multipurpose optimization technique, show that surface roughness and MRR increases about 27.80 %and 21.45 % respectively.

Nikhil Rathod et al. [14] Investigations on hard turning using SS304 sheet metal component grey based Taguchi and regression methodology Using a Grey-based Taguchi technique, the process parameters were optimized. Regression analysis has also been used to build prediction models for tool life and production time, and their suitability has been assessed.

Sakthivelu et al. [15] The experiment was conducted based on L9 orthogonal array. The parameters chosen for the experiment were rotational speed, axial load and traverse speed. The response values were hardness and maximum displacement in order to improve the wear, corrosion and bonding strength. The results were analyzed using Taguchi method to find the optimum machining parameters and to identify the effect of machining parameter

2.1 Scope of the Work from Literature Review:

- According to the above literature, it is clear that different researchers took into account different machining parameters to determine the impact on MRR, surface roughness, and tool tip temperature, with the majority of the work being done on various types of steels and other materials in the presence of different lubricants. The authors have noted several gaps in the literature about the use of castrol oil in turning process tests.
- As a result, the authors of this study used SS304 as their base material and used the input variables of speed, feed, and depth of cut to predict the responses of MRR, Surface roughness, and tool tip temperature. The authors also used GRA approaches to determine the best possible combination of input parameters to validate the results they had already achieved.

CHAPTER III
PROBLEM STATEMENT

One of the machining techniques used to reduce the diameter of a cylindrical work piece is turning. Surface Finish (S.F.) and Material Removal Rate (MRR) are two output characteristics that affect how well a machining process performs. Additionally, the Surface Finish and Material Removal Rate of machined components are primarily influenced by many process variables like Speed, Feed, Cut Depth, and Cutting Fluid type. The current project focuses on SS304 stainless steel alloy machining. By taking into account different machining characteristics, it is possible to forecast the responses, such as MRR, Surface roughness, and tool tip temperature, while using Castrol oil. Utilise GRA techniques to further verify the results by determining the ideal setting for each input parameter.

It is most frequently used in the chemical, petrochemical, food processing, dairy equipment, pharmaceutical, hospital, and heat exchanger industries. It also has outstanding corrosion resistance and forming qualities.

Castrol oil was used in an attempt during the turning of stainless steel 304 while adjusting the feed rate, speed, and depth of cut. Nine trials were conducted based on Taguchi Design of trials (DOE) for varying speed, feed, and depth of cut. Surface Finish (SF), Material Removal Rate (MRR), and cutting tool tip temperatures are assessed as output machining qualities. Grey Relation Analysis (GRA) and individual optimality are used to optimise the output parameters. Analyses are done to determine the ideal set of process variables. Based on the findings, it can be said that cutting speed, cutting fluid feed, and depth of cut have the biggest effects on MRR and Surface Roughness.

CHAPTER IV
EXPERIMENTATION

4.1 Selection of Work Material

Stainless Steel 304: The material used for this study is stainless steel type 304, which has strong corrosion resistance and can be used in a variety of applications. As a result, this was employed in the majority of industrial settings for the production of automotive interior components. In order to determine an appropriate parametric combination, experimental study and evaluation were conducted in light of the present study's objectives.

Table 4.1: Chemical composition of SS 304

Element	C	Mn	P	S	Si	Cr	Ni	N2	Iron
%	0.08	2	0.045	0.03	0.75	18.18	8.48	0.1	Bal

The work piece dimensions are Length 90mm and Diameter is 30mm and selected cemented carbide tool for the operation

4.1.1 Applications of SS304

Because it is utilised in the food processing sector and is non-reactive with the majority of organic acids, 304 steel is frequently referred to as "food-grade" stainless steel. Because of their superior weldability, machinability, and workability, these stainless steels are ideal for applications that call for a level of complexity and corrosion resistance..

As a result, 304 has found many uses, such as:

- Kitchen equipment (sinks, cutlery, splash backs)
- Tubing of various types
- Food equipment (brewers, pasteurizers, mixers, etc.)
- Pharmaceutical processing equipment
- Hypodermic needles
- Pots and pans
- Among its other uses is as dyeing apparatus.

Table 4.2: Mechanical and Thermal properties of Material

Mechanical properties	
Density(g/cc)	**8**
Poison's ratio	**0-29**
Elastic Modulus (Gpa)	**193-200**
Ultimate Tensile Strength (Mpa)	**1260-1390**
Ultimate Tensile Strength (Mpa)	**1041-1160**
Elongation at break (%)	**70**
Hardness (HRC) BRINELL	**123**
Thermal Properties	
Melting Point(°C)	**1400-1455**
Thermal Conductivity(W/m.K)	**16.2**
Specific Heat(J/Kg.K)	**435**

4.2 Equipment Used

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

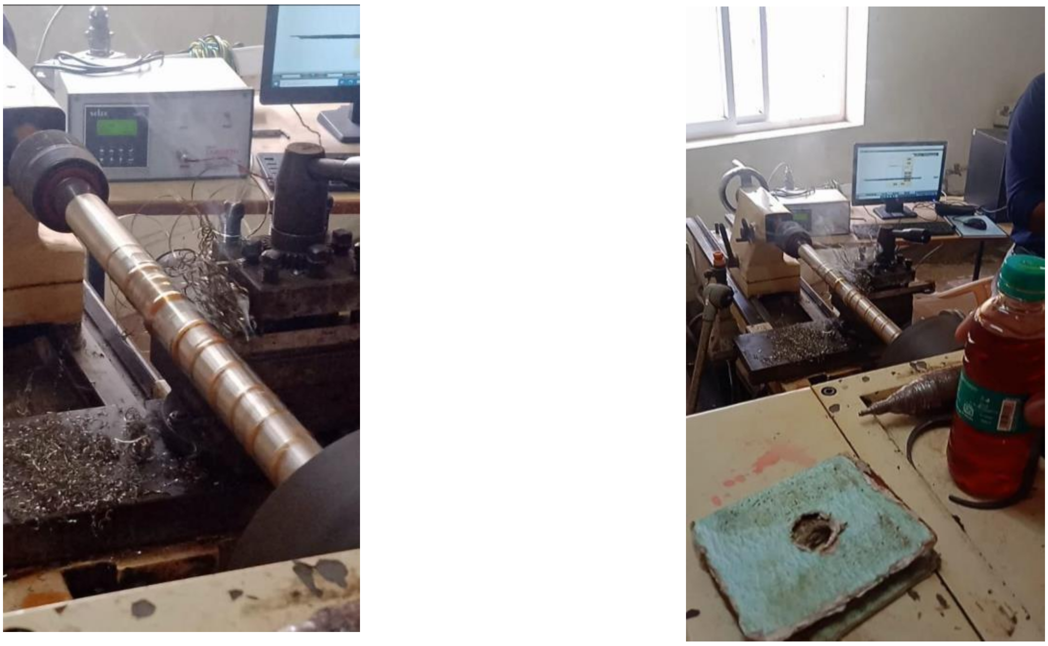
The following equipment were used namely

- LATHE (engine lathe)
- Castrol
- Dynamometer
- Surface Roughness tester
- Cemented Carbide tool insert
- Infrared gun

4.3 Experimental Analysis:

Experimentation on engine lathe as illustrated in the Figure 4.1 and 4.2 were carried out under Castrol oil. In the present study, SS304 is regarded as the work piece material to explore the influence of process parameters such as speed, feed, Depth of cut on material removal rate, surface roughness and tool tip temperature. Nine experiments, varying the speed, feed, and depth of cut, were conducted.

Figure 4.1 Engine lathe machine



(a) **(b)**

Figure 4.2 Machining of SS304 on Lathe Machine and Observing Forces on Dynamometer

Table 4.3: Machining parameters and their levels

Input parameters	Level 1	Level 2	Level 3
Speed (RPM)	300	500	700
Feed (mm/rev)	0.01	0.15	0.2
Depth of cut(mm)	0.5	1	1.5

Table 4.4: Experimental input parameters L9 orthogonal array

S.NO	Speed(rpm)	Feed(mm/rev)	Depth of cut(mm)
1	300	0.1	0.5
2	300	0.15	1
3	300	0.2	1.5
4	500	0.1	1
5	500	0.15	1.5
6	500	0.2	0.5
7	700	0.1	1.5
8	700	0.15	0.5
9	700	0.2	1

Table 4.5: Measurement of Surface Roughness

S.NO	R_A(μm)	R_Z(μm)	R_T(μm)
1	2.76	12.21	15.04
2	6.21	27.35	30.36
3	7.45	31.59	36.8
4	3.19	14.79	16.63
5	6.16	26.85	30.33
6	8.26	32.07	36.08
7	3.12	15.18	17.98
8	6.34	26	29.63
9	8.85	27.49	34.27

Table 4.6: Measurement of Forces

S.NO	F_X(N)	F_Y(N)	F_Z(N)
1	9.686	6.944	8
2	29	14.69	18
3	39.98	20.61	28
4	13.376	7.794	14
5	33.69	17.54	20
6	22.62	11.41	20
7	22.06	9.64	16
8	20.33	7.34	19
9	29.33	11.26	21

CHAPTER V

RESULTS AND DISCUSSIONS

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

5.1 Regression Analysis

When we want to predict the value of a dependent variable based on the value of an independent variable, we utilise linear regression, also referred to as simple linear regression or bivariate linear regression. The independent variable is also known as the predictor, explanatory, or regressor variable, whereas the dependent variable is also known as the outcome, goal, or criteria variable. Throughout this guide, we'll refer to these as dependent and independent variables.

In mini tab to do the regression analysis:

Click **Stat > Regression > Regression...** on the top menu

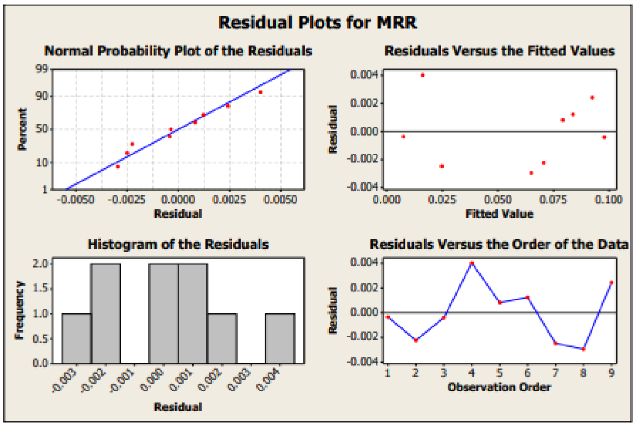
You will be presented with a **Regression** dialogue box

Transfer the dependent variable, speed, feed and depth of cut into the Response box,and the independent variable, MRR,forces and surface roughness one on one individually into the predictors box. You will end up with the dialogue box shownThe proportion of variance in the dependent variable that can be explained by our independent variable is indicated by the R2 value (also known as the R-Sq value; formally, it is the portion of variation accounted for by the regression model above and above the mean model). R2, however, is based on a sample and is an overly optimistic estimate of the percentage of the dependent variable's variance that the regression model can explain and Figure 5.1 shows the graphs and regression analysis.

The experimental results of Material removal rate and the surface roughness characteristics Ra, Rq and Rz are measured . From the experimental results the Signal to Noise ratios were calculated and the values are given in the table

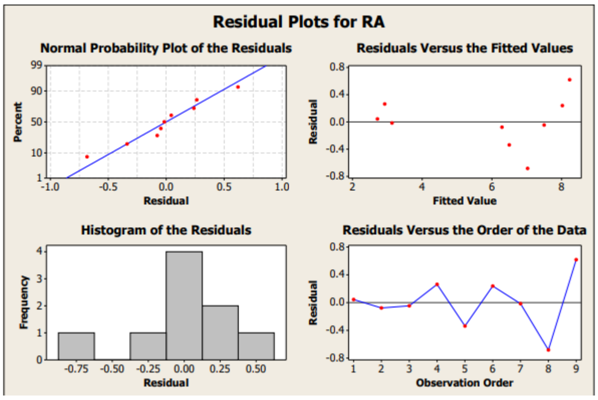
Table 5.1: Out parameters Using GRA

RUN NO.	SPEED (rpm)	Feed (mm/rev)	DOC (mm)	MRR (cm^3/min)	TEMP(°C)		Surface roughness(μm)			Forces(N)		
					Initial	final	R_A	R_Z	R_T	F_X	F_Y	F_Z
1	300	0.01	0.5	0.00708	28	40	2.76	12.21	15.04	9.686	6.94	8
2	300	0.15	1	0.0683	29	40	6.21	27.35	30.36	29	14.69	18
3	300	0.2	1.5	0.09755	28	43.5	7.45	31.59	36.8	39.98	20.61	28
4	500	0.01	1	0.02011	28	34	3.19	14.79	16.63	13.376	7.79	14
5	500	0.15	1.5	0.08	29	31	6.16	26.85	30.33	33.69	17.54	20
6	500	0.2	0.5	0.08505	28	39	8.26	32.07	36.08	22.62	11.41	20
7	700	0.01	1.5	0.02226	28	50.4	3.12	15.18	17.98	22.06	9.64	16
8	700	0.15	0.5	0.0621	28	69.6	6.34	26	29.63	20.33	7.34	19
9	700	0.2	1	0.0949	28	51	8.85	27.49	34.27	29.33	11.26	21



Regression Analysis: MRR versus SPEED, FEED, DOC

```
The regression equation is
MRR = - 0.00570 + 0.000005 SPEED + 0.396 FEED + 0.0152 DOC

Predictor        Coef       SE Coef       T      P
Constant    -0.005697      0.004284   -1.33  0.241
SPEED      0.00000527    0.00000608    0.87  0.426
FEED          0.39643       0.01235   32.09  0.000
DOC          0.015193      0.002433    6.24  0.002

S = 0.00298016    R-Sq = 99.5%    R-Sq(adj) = 99.3%
```

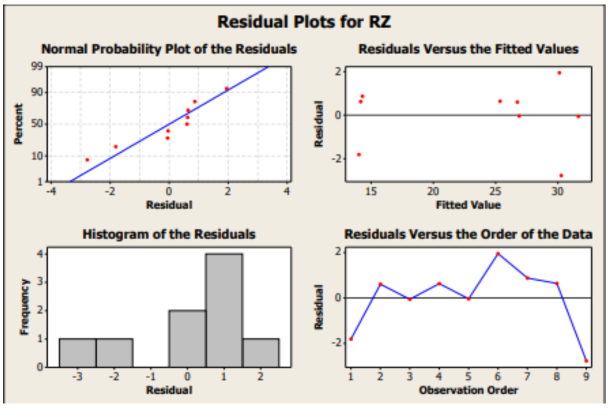


Regression Analysis: RA versus SPEED, FEED, DOC

The regression equation is
RA = 2.09 + 0.00157 SPEED + 26.3 FEED - 0.210 DOC

Predictor	Coef	SE Coef	T	P
Constant	2.0867	0.6746	3.09	0.027
SPEED	0.0015750	0.0009578	1.64	0.161
FEED	26.261	1.945	13.50	0.000
DOC	-0.2100	0.3831	-0.55	0.607

S = 0.469202   R-Sq = 97.4%   R-Sq(adj) = 95.8%

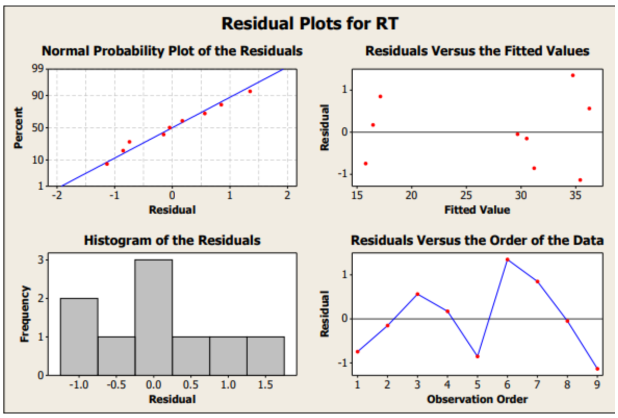


Regression Analysis: RZ versus SPEED, FEED, DOC

The regression equation is
RZ = 13.2 - 0.00207 SPEED + 86.9 FEED + 1.11 DOC

Predictor	Coef	SE Coef	T	P
Constant	13.216	2.628	5.03	0.004
SPEED	-0.002067	0.003731	-0.55	0.604
FEED	86.911	7.577	11.47	0.000
DOC	1.113	1.492	0.75	0.489

S = 1.82784   R-Sq = 96.4%   R-Sq(adj) = 94.2%

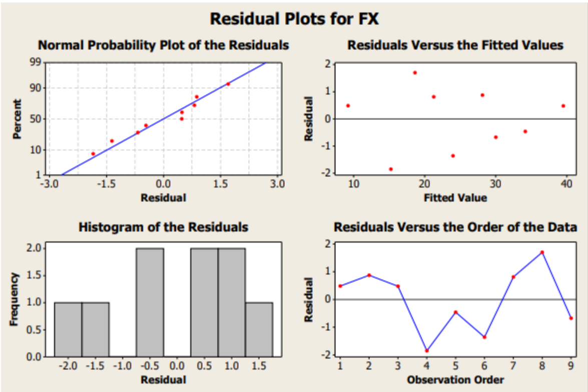


Regression Analysis: RT versus SPEED, FEED, DOC

The regression equation is
RT = 14.1 - 0.00027 SPEED + 100 FEED + 1.45 DOC

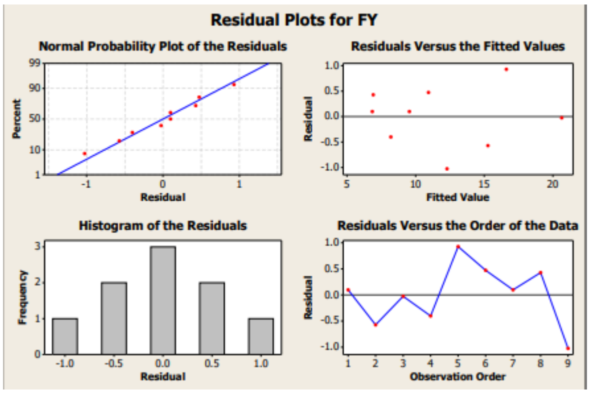
Predictor	Coef	SE Coef	T	P
Constant	14.138	1.505	9.39	0.000
SPEED	-0.000267	0.002137	-0.12	0.906
FEED	100.002	4.340	23.04	0.000
DOC	1.4533	0.8550	1.70	0.150

S = 1.04711   R-Sq = 99.1%   R-Sq(adj) = 98.5%



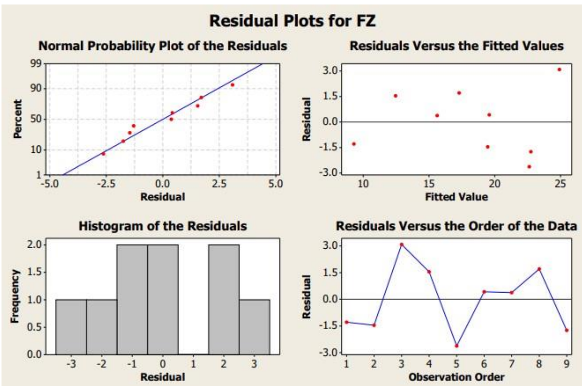
Regression Analysis: FX versus SPEED, FEED, DOC

```
The regression equation is
FX = 2.91 - 0.00578 SPEED + 83.9 FEED + 14.4 DOC

Predictor       Coef   SE Coef      T      P
Constant       2.914     2.106   1.38  0.225
SPEED      -0.005783  0.002990  -1.93  0.111
FEED          83.865     6.071  13.81  0.000
DOC           14.367     1.196  12.01  0.000

S = 1.46464   R-Sq = 98.5%   R-Sq(adj) = 97.7%
```



Regression Analysis: FY versus SPEED, FEED, DOC

```
The regression equation is
FY = 6.32 - 0.0117 SPEED + 33.8 FEED + 7.37 DOC

Predictor       Coef   SE Coef      T      P
Constant       6.325     1.082   5.85  0.002
SPEED      -0.011667  0.001536  -7.60  0.001
FEED          33.805     3.118  10.84  0.000
DOC           7.3667    0.6143  11.99  0.000

S = 0.752316   R-Sq = 98.5%   R-Sq(adj) = 97.5%
```



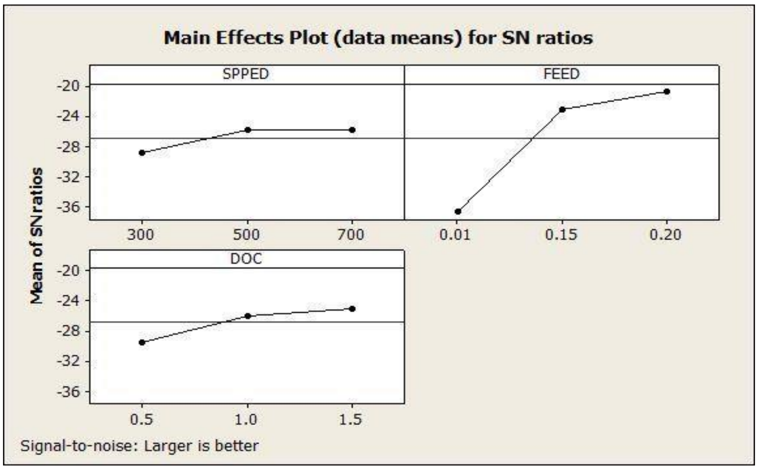
Regression Analysis: FZ versus SPEED, FEED, DOC

```
The regression equation is
FZ = 5.43 + 0.00167 SPEED + 52.4 FEED + 5.67 DOC

Predictor       Coef   SE Coef     T      P
Constant       5.434     3.455  1.57  0.177
SPEED       0.001667  0.004906  0.34  0.748
FEED          52.405     9.963  5.26  0.003
DOC            5.667     1.962  2.89  0.034

S = 2.40356   R-Sq = 87.8%   R-Sq(adj) = 80.5%
```

Figure 5.1 Graphs and Regression analysis of MRR, Ra, Rz, Rt, Fx, Fy, and Fz

Table 5.2: S/N ratios of the response

RUN NO.	MRR (cm^3/min)	R_A(µm)	R_Z(µm)	R_T(µm)	F_X(N)	F_Y(N)	F_Z(N)
1	42.9993	-8.818	-21.734	-23.545	-19.722	-16.832	-18.061
2	23.3116	-15.861	-28.739	-29.646	-29.248	-23.340	-25.105
3	20.2155	-17.443	-29.991	-31.317	-32.036	-26.281	-28.943
4	33.9318	-10.075	-23.399	-24.417	-22.526	-17.835	-22.922
5	21.9382	-15.791	-28.578	-29.637	-30.550	-24.880	-26.020
6	21.4065	-18.339	-30.122	-31.145	-27.089	-21.145	-26.020
7	33.0495	-9.883	-23.625	-25.095	-26.874	-19.685	-24.082
8	24.1382	-16.041	-28.299	-29.434	-26.162	-17.313	-25.575
9	20.4547	-18.938	-28.783	-30.698	-29.346	-21.030	-26.444



5.2 S/N ratio of MRR

Table 5.3: Response table for signal to noise ratio (MRR)
****

LEVEL	SPEED	FEED	DOC
1	-28.84	-36.66	-29.51
2	-25.76	-23.13	-25.90
3	-25.88	-20.69	-25.07
DELTA	3.08	15.97	4.45
RANK	3	1	2

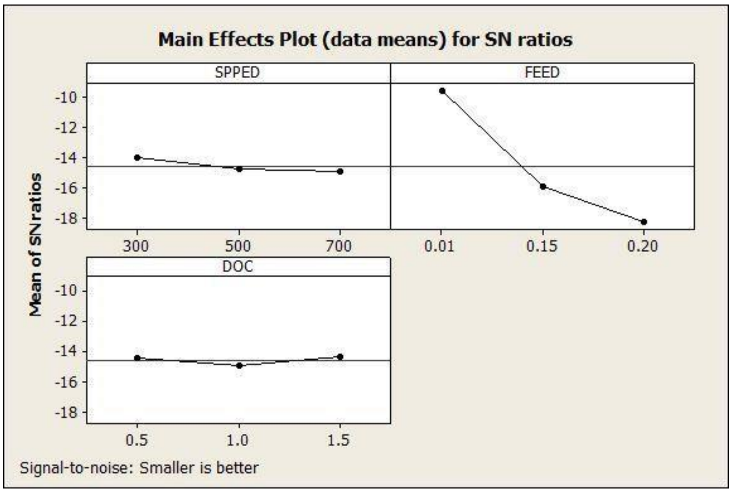


Figure 5.3: S/N ratio of Ra

Table 5.4: Response table for signal to noise ratio (Ra)

LEVEL	SPEED	FEED	DOC
1	-14.041	-9.592	-14.400
2	-14.736	-15.898	-14.959
3	-14.955	-18.241	-14.373

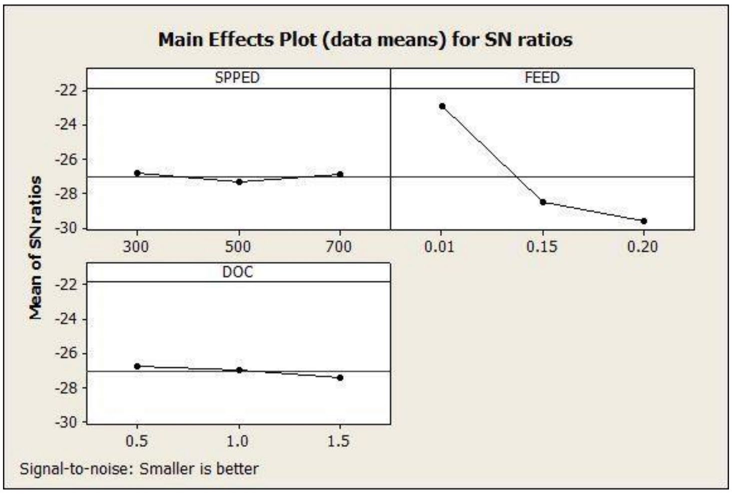
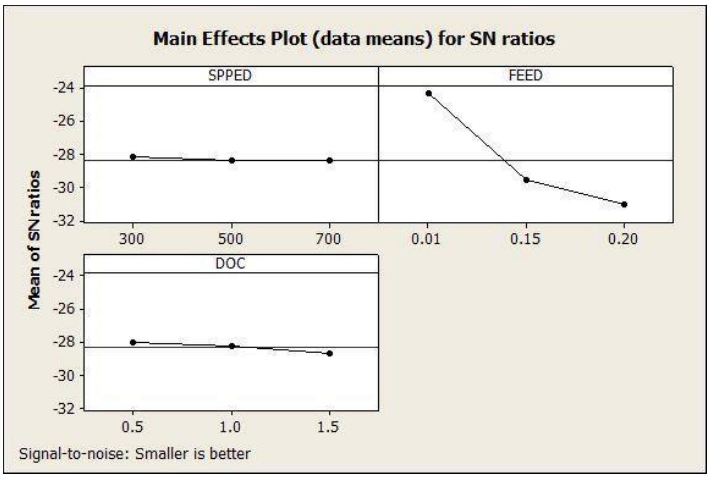


Figure 5.4: s/n ratio of R_t

Table 5.5: Response table for signal to noise ratio (Rt)

LEVEL	SPEED	FEED	DOC
1	-26.82	-22.92	-26.72
2	-27.37	-28.54	-26.97
3	-26.90	-29.63	-27.40
DELTA	0.55	6.71	0.68
RANK	3	1	2



5.5: S/N ratio of Rz

Table 5.6: Response table for signal to noise ratio (Rz)

LEVEL	SPEED	FEED	DOC
1	-28.17	-24.35	-28.04
2	-28.40	-29.57	-28.25
3	-28.41	-31.05	-28.68
DELTA	0.24	6.70	0.64
RANK	3	1	2

- the figure 5.2,5.3,5.4,5.5 shows the signal to nose ratios graphs The mean s/n ratios were calculated for the grey relational grade as shown in the table from the DOC Taguchi results of GRG as shown in the table, it is clear that feed is the most influencing parameter on the multi response and followed by speed and depth of cut.

Table 5.7: GREY RELATION GENERATION

GRAY RELATIONAL GENERATION							
Run No.	MRR (cm^3/min)	R_A(µm)	R_Z(µm)	R_T(µm)	F_X(N)	F_Y(N)	F_Z(N)
1	0.0000	1.0000	1.0000	1.0000	1.0000	1	1.000
2	0.6767	0.4335	0.2377	0.2960	0.3624	0.4332	0.500
3	1.0000	0.2299	0.0242	0.0000	0.0000	0.0000	0.000
4	0.1440	0.9294	0.8701	0.9269	0.8782	0.9378	0.700
5	0.8060	0.4417	0.2628	0.2973	0.2076	0.2246	0.400
6	0.8618	0.0969	0.0000	0.0331	0.5731	0.6732	0.400
7	0.1678	0.9409	0.8505	0.8649	0.5913	0.8024	0.600
8	0.6082	0.4122	0.3056	0.3295	0.6486	0.9710	0.450
9	0.9707	0.0000	0.2306	0.1163	0.3516	0.6842	0.350

Table 5.8 : Loss function values

LOSS FUNCTION VALUES							
Run No.	MRR (cm^3/min)	R_A(µm)	R_Z(µm)	R_T(µm)	F_X(N)	F_Y(N)	F_Z(N)
1	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000
2	0.3233	0.5665	0.7623	0.7040	0.6376	0.5668	0.500
3	0.0000	0.7701	0.9758	1.0000	1.0000	1.0000	1.000
4	0.8560	0.0706	0.1299	0.0731	0.1218	0.0622	0.300
5	0.1940	0.5583	0.7372	0.7027	0.7924	0.7754	0.600
6	0.1382	0.9031	1.0000	0.9669	0.4269	0.3268	0.600
7	0.8322	0.0591	0.1495	0.1351	0.4087	0.1976	0.400
8	0.3918	0.5878	0.6944	0.6705	0.3514	0.0290	0.550
9	0.0293	1.0000	0.7694	0.8837	0.6484	0.3158	0.650

The grey relational coefficient (GRC) and the GRG values of responses can be calculated by using the equations, corresponding values were depicted in the above Table . The experiment with high grey relational grade value represents the optimal parametric combination for the multi responses..

$$\textbf{GRC} = \frac{\Delta min + \delta \Delta max}{\Delta oi + \delta \Delta max}$$

GRC = Grey relational coefficient

Δ_{oi} = quality loss = | Y_O-Y_{ij} |

Δ_{min}= minimum value of Δ_{oi}

Δ_{max}= maximum value of Δ_{oi}

δ = Distinguishing coefficient range from 0 to 1.

GRG = (1/m)$\sum GRG$

Table 5.8: Grey Relation Coefficient & Grade Values

RUN NO.	GRC							GRG
	MRR (cm^3/min)	R_A(µm)	R_Z(µm)	R_T(µm)	F_X(N)	F_Y(N)	F_Z(N)	
1	0.3333	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9048
2	0.6073	0.4688	0.3961	0.4153	0.4395	0.4687	0.5000	0.4708
3	1.0000	0.3937	0.3388	0.3333	0.3333	0.3333	0.3333	0.4380
4	0.3687	0.8763	0.7938	0.8725	0.8041	0.8894	0.6250	0.7471
5	0.7205	0.4725	0.4042	0.4157	0.3869	0.3920	0.4545	0.4638
6	0.7835	0.3563	0.3333	0.3409	0.5394	0.6047	0.4545	0.4875
7	0.3753	0.8943	0.7698	0.7873	0.5503	0.7168	0.5556	0.6642
8	0.5606	0.4596	0.4186	0.4272	0.5873	0.9452	0.4762	0.5535
9	0.9447	0.3333	0.3939	0.3613	0.4354	0.6129	0.4348	0.5023

Table 5.9: Optimum Cutting parameters

Cutting parameter	Level	Value
Speed, v	1	300
Feed, f	1	0.1
Depth of cut, DOC	1	0.5

The optimum cutting parameters are of speed 300RPM and feed 0.1mm/rev and depth of cut 0.5mm

5.3 Grey Relational Analysis for Validation:

The output parameters are optimized using individual optimality and Grey Gelational Analysis(GRA) from the above tables it is inferred that the experiment no 1 is having rank 1 which is the best optimum combination of input parameters(speed, feed and depth of cut).it is further observed that the experiment no 4 and 7 are having ranks of 2 and 3 respectively which are also another set of optimum set of combination of input values.

CHAPTER VI

CONCLUSION

Castrol was used as lubricant during the turning of stainless steel 304 while the process variables (speed, feed, and depth of cut) were changed. Nine trials were conducted based on Taguchi Design of trials (DOE) for varying speed, feed, and depth of cut. Surface Finish (SF), Material Removal Rate (MRR), and cutting tool tip temperature are measured as output machining characteristics. taguchi based grey relational grade method to optimise the multi-responses is used to optimise the output parameters.The following conclusions were drawn based on the experimental results:

1. The experimentation of orthogonal lathe machining process under castrol conditions were analysed.
2. The mean s/n ratios for the grey relational grade were determined from the Taguchi results of GRG as given in the table, and it is obvious that feed is the most influencing parameter on the multi response, followed by speed and depth of cut.
3. According to the trial results, the best combination of input parameters is a speed of 300 rpm, a feed of 0.1 mm/rev, and a depth of cut of 0.5 mm. subsequently the output responses are discovered to be as tool tip temperature as 40°c, surface roughness as 1.00 micro meters, MRR as 0.3333 mm^3/min
4. The grey relational grade approach based on Taguchi is a highly successful method for solving multi-objective issues.

6.1 Scope of the Future Work

In this work, we have chosen SS304 as base material with input parameters of speed, feed and depth of cut under the Castrol to predict the responses are MRR, Surface roughness and tool tip temperature.

Further we validated the obtained results using GRA methods for finding the optimum combination of input parameters from this work we can understand that we will get good material removal rate and surface roughness at low speed and low depth of cut and at low feed on SS304 while using Castrol .

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