OPTIMIZATION OF CUTTING PARAMETERS USING TOPSIS AND TAGUCHI TECHNIQUES ON SS 304 IN BOTH WET AND DRY CONDITIONS USING HSS CUTTING TOOL

A project report submitted in partial fulfillment of the requirement for the award of the degree of

BACHELOR OF TECHNOLOGY IN MECHANICAL ENGINEERING

by

P. SRI HARI: 318126520106

Y. VINEETHA: 318126520116

A. HARSHAVARDHAN: 318126520061

SK. SHADIQ: 318126520112

K. SURYA PRAKASH: 318126520086

Under the esteemed guidance of

Dr. N. V. N. INDRA KIRAN

PRAGNANAM BRAHMA
ANITS

DEPARTMENT OF MECHANICAL ENGINEERING

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CERTIFICATE

This is to certify that the Project Report entitled **"OPTIMIZATION OF CUTTING PARAMETERS USING TOPSIS AND TAGUCHI TECHNIQUES ON SS 304 IN BOTH WET AND DRY CONDITIONS USING HSS CUTTING TOOL"** being submitted by **Y. Vineetha (318126520116)** in partial fulfilment for the award of Degree of Bachelor of Technology in Mechanical Engineering. It is the work of bonafide, carried out under the guidance and supervision of **Dr. N. V. N. Indra Kiran**, Professor, Department of Mechanical Engineering during the academic year 2018 to 2022.

APPROVED BY	PROJECT GUIDE
26.5.22	25/5/2022
Dr. B. Naga Raju	**Dr. N. V. N. Indra Kiran**
Head of the Department	**Professor**
Dept. of Mechanical Engineering	**Dept. of Mechanical Engineering**
ANITS, Visakhapatanam	**ANITS, Visakhapatnam**

PROFESSOR & HEAD
Department of Mechanical Engineering
ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY & SCIENCES
531 162, VISAKHAPATNAM Dist A.P.

THIS PROJECT IS APPROVED BY THE FOLLOWINGBOARD OF EXAMINERS

1. INTERNAL EXAMINER

PROFESSOR & HEAD
Department of Mechanical Engineering
ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY & SCIENCES
Sangivalasa-531 162, VISAKHAPATNAM Dist. A.P.

2. EXTERNAL EXAMINER

ABSTRACT

The cutting tool plays a significant role in the machining process of a part in the production. It not only performs the cutting action but also helps get the required surface finish and accuracy. To perform these tasks the tool has to be strong enough to withstand wear-resistance and serve for a prolonged period to produce more components with the same accuracy. Machining is essential in the metal manufacturing process to achieve near-net shape, good dimensional accuracy, and aesthetic requirements.

While machining a substance, it is desired to obtain maximum material removal rate and a good surface finish (i.e., lowest surface roughness) without generating high temperatures (as they lead to sour surface finish and tool failure). While machining SS 304 Stainless steel, inevitable consequences are arising due to unique properties of the material like low specific heat, tendency to strain harden e. t. c. This study mainly concentrates on comparing various effects of cutting parameters like speed, feed, and depth of cut on SS304 Stainless steel under dry and wet conditions. We observed the variations in temperature, type of chips formed and chip thickness ratio. The behavior of the above output parameters is compared at different input conditions by using response surface methodology (RSM). SS 304 Stainless steel is widely used in automotive gears and parts, shafts, load-bearing tie rods.

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P. SRI HARI: 318126520106

Y. VINEETHA: 318126520116

A. HARSHAVARDHAN: 318126520061

SK. SHADIQ: 318126520112

K. SURYA PRAKASH: 318126520086

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CHAPTER 1

INTRODUCTION

1. INTRODUCTION

In this chapter, concept of turning is defined. The adjustable cutting parameters for the turning process that affect the workpiece output.

1.1 TURNING OPERATION

Figure 1. 1: Turning Operation

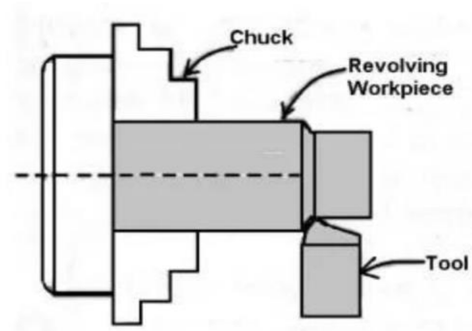


Figure 1.2: Turning Operation in 2-D View

Turning is a form of machining, a material removal process, which is used to create rotational parts by cutting away unwanted material. The turning process requires a turning machine or lathe, workpiece, fixture, and cutting tool. The workpiece is a piece of pre-shaped material that is secured to the fixture, which itself is attached to the turning machine, and allowed to rotate at high speeds. The cutter is typically a single-point cutting tool that is also secured in the machine, although some operations make use of multi-point tools. The cutting tool feeds into the rotating workpiece and cuts away material in the form of small chips to create the desired shape.

Turning is used to produce rotational, typically axi-symmetric, parts that have many features, such as holes, grooves, threads, tapers, various diameter steps, and even contoured surfaces. Parts that are fabricated completely through turning often include components that are used in limited quantities, perhaps for prototypes, such as custom designed shafts and fasteners. Turning is also commonly used as a secondary process to add or refine features on parts that were manufactured using a different process. Due to the high tolerances and surface finishes that turning can offer, it is ideal for adding precision rotational features to a part whose basic shape has already been formed.

1.2 ADJUSTABLE CUTTING PARAMETERS IN TURNING

The three primary factors in any essential turning operation are speed, feed, and depth of cut. Other factors such as the kind of material and type of tool have a significant influence, of course, but these three are the ones the operator can change by adjusting the controls right on the machine.

1.2.1 Speed:

Speed always refers to the spindle and the work piece. When it is stated in revolutions per minute (rpm), it defines the speed of rotation. But, the vital feature for a particular turning operation is the surface speed or the speed at which the work piece material is moving past the cutting tool. The product of the rotating speed times the circumference of the work piece before the cut is started. It is expressed in meter per minute (m/min), and it refers only to the work piece. Every different diameter on a work piece will have a different cutting speed, even though the rotating speed remains the same

$$V = \pi \, DN/1000$$

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.

1.2.2 Feed:

Feed always refers to the cutting tool, and it is the rate at which the tool advances along its cutting path. On most power-fed lathes, the feed rate is directly related to the spindle speed and is expressed in mm (of tool advance) per revolution (of the spindle), or mm/rev.

$$F_m = f \times N \text{ (mm/min)}$$

Here,

F_m is the feed in mm per minute,

f - Feed in mm/rev and

N - Spindle speed in r.p.m.

1.2.3 Depth of Cut:

Depth of cut is practically self-explanatory. The thickness of the layer being removed (in a single pass) from the work piece or the distance from the uncut surface of the work to the cut surface is expressed in mm. It is important to note, though, that the diameter of the work piece is reduced by two times the depth of cut because this layer is being removed from both sides of the work

$$D_{cut} = D - d/2$$

D_{cut} - Depth of cut in mm

D - Initial diameter of the work piece

d - Final diameter of the work piece

1.3 Single Point Cutting Tool

Single point cutting tools are commonly used in lathe, players, Shapers machine for cutting operation. These tools are classified as left-handed and right-handed. A tool is said to be right-handed if their cutting edge is on the right side when the tool is viewed from the point end.

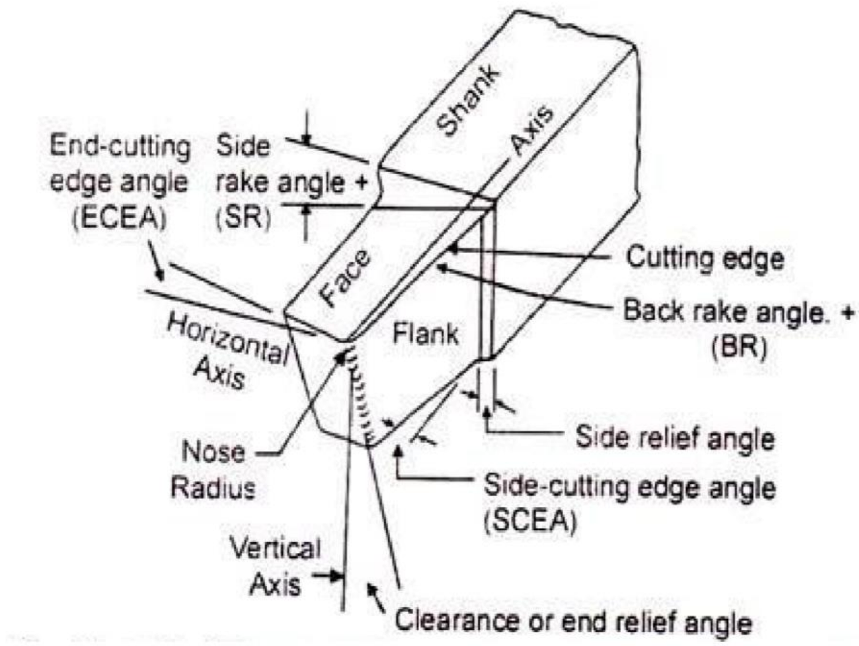
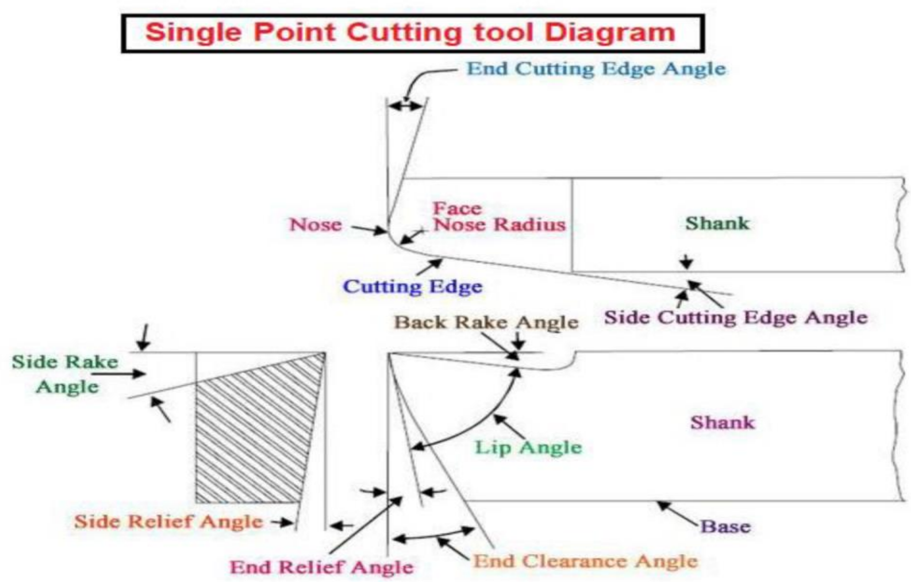


Figure 1. 3: Tool geometry of single point cutting tool

1.3.1Terminology or Nomenclature of Single Point Cutting tool.



This specification is according to the American Standards Association (ASN) Systems.

Figure 1. 4: Single-Point Cutting Tool Diagram

Shank: The main body of the tool is known as the shank. It is the backward part of the tool which is held by tool post.

Face: The top surface tool on which chips passes after cutting is known as a face. It is the horizontal surface adjacent of cutting edges.

Flank: Sometime flank is also known as cutting face. It is the vertical surface adjacent to the cutting edge. According to cutting edge, there are two flank side flank and end flank.

Nose or Cutting Point: The point where both cutting edge meets known as cutting point or nose. It is in front of the tool.

Base: The bottom surface of the tool is known as the base. It is just the opposite surface of the face.

Heel: It is an intersecting line of face and base.

End Cutting Edge Angle: The angle between the end cutting edge or flank to the plane perpendicular to the side of the shank is known as the end cutting angle.This angle usually varies from 5 to 15 degree

Side Cutting Edge Angle: The angle between the side cutting edge or flank to the plane parallel to the side of the shank known as side cutting edge angle.

Back Rake Angle:

- The angle form to smooth flowing of chips from the face, known as rack angle. It allows to smooth flow of chips.
- The back rack angle is the angle between the face and the plane perpendicular to the end cutting edge.
- Softer the material, greater should be the positive rake angle.
- The back rake angle may be positive negative or neutral.

Side Rack Angle:

- The angle between the face and plane perpendicular to the side cutting edge is known as the side rack angle. It allows chips to flow smoothly when material cut by side cutting edge.
- The amount by which a chip is bent depends upon this angle. When the side rack angle increases, the magnitude of chip bending decreases. Smoother surface furnish is produced by a larger side rake angle.

End Relief Angle:

- It is also known as a clearance angle. It is the angle that avoids tool wear. It avoids the rubbing of flank with a workpiece.
- End cutting angle made by end flank to the plane perpendicular to the base.
- This angle may vary from 6 to 10 degrees.

Side Relief Angle: It is the angle made by the side flank to the plane perpendicular to the base. It avoids rubbing of side flank with a workpiece.When the side relief angle is very small, the tool will rub against the job and therefore it will get overheated and become blunt and the surface finish obtained will be poor.

Nose Radius: The intersecting area of both cutting edges is known as the nose of the tool.

1.3.2. Factors influencing rake angle of the single point cutting tool:

1. **Type of material being cut:** a harder material like cast iron may be machined with a smaller rake angle than that required by a soft metal like mild steel or aluminium.
2. **Type of tool material being used:** tool material like cemented carbide permits turning at a very high speed. It has been observed that in machining at a very high cutting speed rake angle has a little influence of cutting pressure.
3. **Depth of cut:** in rough turning, a high depth of cut is given to withstand severe cutting pressure. So, the rake angle should be decreased to increase the lip angle that provides strength to the cutting edge.

4. **The rigidity of the tool holder and condition of the machine:** an improperly supported tool on an old and worn-out machine can't take up severe cutting pressure. so, machining under such conditions the tool used should have a larger rake angle than that at the normal condition to reduce the cutting pressure.

1.3.3. Tool Signature

The tool signature or tool designation is used to denote a standardized system of specifying the principal tool angles of a single-point cutting tool. Some common systems used for tool designation or tool nomenclature are the following-

1. **American or (ASA) System.**

   It defines the principle angles like side rake, back rack, nose, etc. without any reference to their location concerning cutting edge. As such, this system of nomenclature does not give any indication of the tool behaviour with regard to the flow of chip during the cutting operation the three reference planes adopted for designating different tool angles are similar to those used in conventional machine drawing i.e., x-x, y-y, and z-z the last one containing the base of the tool and the two plane being normal to this plane as well as mutually perpendicular. Thus, this system is a coordinate system of tool nomenclature.
2. **British system:**

   This system, according to B-S1886-1952, defines the maximum rake. The various tool parameters in this system are indicated if the order of Back rake, Side rake, End relief angle, Side relief angle, End cutting angle, Side cutting edge angle, and Nose radius.
3. **Continental systems:**

   This category of tool nomenclature systems includes the German or DIN System (DIN-6581), Russian Systems (OCT-BKC 6897and 6898), and Czechoslovakian System (CSN-1226). The various tool parameters in these systems are specified with reference to the tool reference to the tool reference planes.
4. **International system:**

It is an internationally adopted system, developed recently. It incorporates the salient features of tool nomenclature of different systems in it.

1.3.4. Single Point Cutting Tool Examples:

Single Point Cutting tool consists of only one main cutting edge that can perform material removal action at a time in a single pass.

1. Turning tool
2. Shaping tool
3. Planing tool
4. Slotting tool
5. Boring tool
6. Fly Cutter

1.3.5. Material Used for Single Point Cutting tools:

Tool bits generally made of seven materials

- High-speed steel
- Cast alloys (such as stellite)
- Carbides
- Ceramics
- Cermets
- Cubic Boron Nitride
- Polycrystalline Diamond

Advantages of Single Point Cutting Tool:

- Single Point Cutting tool is simple in construction hence easy to Design and Manufacture.

- As compare to multipoint cutting tool single point cutter are cheaper.'
- Resharpening of cutter is easy

Disadvantages of Single-point Cutting Tools:

- These tools have low material removal rates (MRR) hence productivity is low.
- The tool wear rate is high.
- Tool life is short.
- High Cutting temperature

1.4 Lathe Machine

A Lathe machine Lathe Machine is a Production Machine tool. Here today we will study the Definition, Parts, Operation, Specification of Lathe machines.

Lathe Machine Introduction:

The *Lathe* was invented by **Jacques de Vaucanson around 175**1. At the very early stage this machine was developed around 1300 BC at that time there were not developed so many parts except headstock and Tailstock. But during the industrial revolution Metalworking lathes evolved into heavier machines with thicker, more rigid parts.Between 19 and 20 centuries the electric motor is replaced line shafting as a power source.Then in 1950, the servomechanism is applied to control lathe and other machine tools by numeric, Direct numerical control machine.The Lathe is the most versatile machine tool among all standards of the machine tool.

Nowadays the manually controlled machine exists like a CNC machine and even do with the help of a feed mechanism the lathe machine operates manually.

Lathe Machine Definition:

A lathe machine is a machine tool that is used to remove metals from a workpiece to give a desired shape and size. Lathe Machines are used in metalworking, woodturning, metal spinning, thermal spraying, glass working, and parts reclamation.The various other operations that you can perform with the help of a Lathe Machine can include sanding, cutting, knurling, drilling, and deformation of tools that are employed in creating objects which have symmetry about the axis of rotation.

There are several components of a lathe, later on, I discuss the most important Parts of the Lathe with their function. It is also known as the father of all standard machine tools.The function of Lathe is to remove the metal in the form of chips from a piece of work by mounting the same rigidly on a machine spindle and revolving at the required speed and the cutting tool is fed against the work either longitudinally or crosswise to make the work to the required shape and size.

1.4.1 Parts of the Lathe Machine and their functions:

So what are the Parts of a Lathe machine? A *lathe machine tool consists of several parts* like:

1. Headstock
2. Bed
3. Tailstock
4. Carriage
5. Saddle
6. Cross-slide
7. Compound rest
8. Toolpost
9. Apron
10. Lead Screw
11. Feed rod
12. Chuck
13. Main spindle
14. Leg

Let me explain all these parts in detail.

Head Stock:

Head Stock is situated at the left side of the lathe bed and it is the house of the driving mechanism and electrical mechanism of a Lathe machine tool.

- It holds the job on its spindle nose having external screw threads and internally Morse taper for holding lathe center. And it is rotating at a different speed by cone pulley or all geared drive. There is a hole throughout spindle for handling long bar work.

- Head Stock transmit power from the spindle to the feed rod, lead screw and thread cutting mechanism.

Accessories mounted on headstock spindle:

1. Three jaw chuck
2. Four jaw chuck
3. Lathe center and lathe dog
4. Collect chuck
5. Faceplate
6. Magnetic chuck

A separate speed change gearbox is placed below the headstock to reduce the speed in order to have different feed rates for threading and automatic lateral movement of the carriage. The feed rod is used for most turning operations and the lead screw is used for thread cutting operations.

H1: Geared headstock housing
H2: Intermediate gears lever
H3: High Low gear lever
H4: D6 Camlock spindle
H5: Tumbler gears - forward/reverse and engage/disengage
H6: Quick change gearbox with 4 selectors (3 levers)
H7: Lead screw
H8: Feed screw
H9: Forward reverse

Figure 1. 5: Head Stock of a Lathe Machine & Their Parts

H10: Change gear

Bed:

It is the base of the lathe machine. It is made of the single-piece casting of Semi-steel (Chilled Cast Iron). The bed consists of two heavy metal slides running lengthwise, with ways or 'V' formed upon them and rigidly supported with cross girths.

- It is sufficiently rigid and good damping capacity to absorb vibration.
- It supports the headstock, tailstock, carriage and other components of the lathe machine.

Tail Stock:

Tail Stock is situated on the right side above the lathe bed.

It is used for:

- Support the long end of the job for holding and minimizes its sagging.
- It holds the tool for performing different operations like drilling, reaming, tapping, etc.
- And it is also used for a small amount of taper for a long job by offsetting the tailstock.

Figure 1. 6: Tail Stock of a Lathe Machine & Their Parts

Carriage:

The carriage is used to support, guide, and feed the tool against the job when the machining is done.

- It holds moves and controls the cutting tool.
- It gives rigid supports to the tool during operations.
- It transfers power from feed rod to cutting tool through apron mechanism for longitudinal cross-feeding.
- It simplifies the thread cutting operation with the help of lead screw and half nut mechanism.

It consists of :

1. Saddle
2. Cross-slide
3. Compound rest
4. Tool post
5. Apron

It provides three movements to the tool:

1. Longitudinal feed-through carriage movement
2. Cross feed-through cross slide movement

3. Angular feed-through top slide movement

Figure 1. 7: Carriage of a Lathe Machine & Their Parts

Saddle:

Generally, it is made up of 'H' shaped casting and it has a 'V' guide and a flat guide for mounting it on the lathe bed guideways.

Cross-slide:

It is assembled on the top of the saddle. The top surface of the cross-slide is provided with T-slot.

Compound rest:

It supports the tool post and cutting tool in its various positions. It can be swivelled at any desired position in the horizontal plane. It is necessary for turning angles and boring short tapers.

Tool post:

It is the topmost portion of the carriage and it is used to hold various cutting tools or tool holders.

There are three types of tool post commonly used and those are:

1. Ring and rocker tool post
2. Square head tool post

3. Quick change tool post

Apron:

An apron is a house of the feed mechanism. It is fastened to the saddle and hangover in front of the bed.

Lead screw:

A lead screw is also known as a power screw or a translation screw. It converts rotational motion to linear motion. Lead Screw is used for **Thread Cutting operation** in a lathe machine tool.

Feed Rod:

Feed rod is used to move the carriage from the left side to the right side and also from the right side to the left side.

Chuck:

Chuck is used to holding the workpiece securely.
There are generally 2 types of chucks:

1. 3 jaw self-centring chuck
2. 4 jaw independent chuck

Main Spindle:

The spindle is a hollow cylindrical shaft in which long jobs can pass through it. It is designed so well that the thrust of the cutting tool does not deflect the spindle.

Leg:

Legs are carrying an entire load of a lathe machine tool and transfer to the ground. The legs are firmly secured to the floor by the foundation bolt.

1.4.2 SPEED LATHE

Speed lathe is also called a **Wood Lathe**.As the name indicates “Speed” the machine works with high speed. The headstock spindle is rotating at a very high speed. The parts having like headstock, tailstock, but it's not having feed mechanism like center or engine lathe having. The feed we provide is manually operated.

The speed ranges of this machine operated between **1200 to 3600 RPM**.

Speed lathe is used for spinning, centering, polishing, and machining wood.

Figure 1. 8: Speed Lathe

Tool Room Lathe:

The toolroom lathe machine operates to speed up to **2500 rpm**.

The parts are almost the same similar to the engine lathe machines but the parts are built very accurately and should be arranged in proper sequence because this lathe is used for highly precious work with very fewer tolerances.

It is mainly used in grindings, working on the tool, die gauges, and machining where accuracy is needed.

Figure 1. 9: Tool Room Lathe

1.5 Temperature Measurement

Temperature guns have electronic sensors that enable them to collect the amount of heat energy from a given object whose temperature would otherwise be difficult to measure. These guns often use infrared beams, and you only have to aim at the object whose temperature you are interested in measuring without touching it.The sensors have the capability to collect the accurate temperature provided the gadget is functional.There are, however, some basics that you must know to use these temperature guns correctly.

First, the temperature gun uses beams to collect information on the heat energy coming from a given object. Thus, the gun does not state whether the heat comes from the intended object or the surroundings. This means that to collect the correct temperature measurement, you will have to ensure that you point the gun directly at the object whose temperature you

Figure 1. 10: Thermal Gun

intend to measure. You need to be as close as possible to avoid reading other heat waves that may interfere with your reading's accuracy. The gun will only read the heat energy on the area where it is pointing, and for accuracy, you must aim directly at the object whose temperature you intend to measure

1.6 Workpiece Materials and Their Specific Applications

Stainless steels get their names from the American Iron & Steel Institute (AISI) and the Society of Automotive Engineers (SAE), who have separately created their own naming systems for steel alloys based on alloying elements, uses, and other factors. Steel names can get confusing, as the same alloy can have different identifiers depending on which system is used; however, understand that the chemical composition of most alloy blends remains the same across classification systems. In the case of stainless steels, they are often composed of 10 to 30% chromium and are made to withstand varying degrees of corrosion exposure. To learn more about the differences among stainless steels, feel free to read our article on the type of stainless steel.

Type 304 steel is part of the 3xx stainless steels or those alloys which are blended with chromium and nickel. Below is a chemical breakdown of 304 steel:

- <=0.08% carbon
- 18-20% chromium
- 66.345-74% iron
- 8-10.5% nickel
- <=0.045% phosphorus
- <=0.03% sulfur
- <=1% silicon

1.6.1 Corrosion resistance & temperature effects

Type 304 steel, being the most popular stainless steel, is naturally chosen for its corrosion resistance. It can resist rusting in many different environments, only being majorly attacked by chlorides. It also experiences increased pitting in warm temperatures (above 60 degrees Celsius), though the higher carbon grades (304H) mitigate this effect considerably. This means that 304 steel mainly rusts not in high temperatures, but in aqueous solutions where continuous contact with corrosive materials can wear down the alloy.

1.6.2 Applications of 304 Steel

304 steel is often referred to as "food-grade" stainless steel, as it is unreactive with most organic acids and is used in the food processing industry. Its excellent weldability,

machinability, and workability suits these stainless steels to applications that require a level of corrosion resistance as well as complexity. As a result, 304 has found many uses, such as:

- Kitchen equipment (sinks, cutlery, splashbacks)
- Tubing of various types
- Food equipment (brewers, pasteurizers, mixers, etc.)
- Pharmaceutical processing equipment
- Hypodermic needles
- Pots and pans
- Dyeing equipment

as well as other uses.

AISI 304 has good machinability, however, its low thermal conductivity means coolants and lubricants should be used liberally, especially on the cutting edges.

Figure 1. 11 : SS 304

1.7 Cutting Tool (HSS):

1.7.1 Introduction

High-speed steel (**HSS** or **HS**) is a subset of tool steels, commonly used as cutting tool material.

It is often used in power-saw blades and drill bits. It is superior to the older high-carbon steel tools used extensively through the 1940s in that it can withstand higher temperatures without losing its temper (hardness). This property allows HSS to cut faster than high carbon steel, hence the name *high-speed steel*. At room temperature, in their generally recommended heat treatment, HSS grades generally display high hardness (above Rockwell hardness 60) and abrasion resistance (generally linked to tungsten and vanadium content often used in HSS) compared with common carbon and tool steels.

Figure 1. 12: HSS Tool

1.7.2 Composition of HSS Tool

High-Speed Steel (HSS) is usually carbon steel containing 1.5 to 2% carbon, 18 % tungsten, 4% chromium, 1% vanadium, and rest is iron. Tungsten is added to increase hardness. Chromium is added to increase hot hardness. Vanadium is added to increase wear resistance. The method of fabrication for HSS is forging. The cutting velocity of HSS is 40-60 m/min. It gives a higher speed than HCS. The hot hardness temperature of HSS is about 600°C.

Sometimes 18% molybdenum is added instead of tungsten to increase the wear resistance of the tool. Then this HSS is called as molybdenum based HSS. But tungsten-based HSS is commonly used. HSS has the only disadvantage that during machining of pure carbon work material, diffusion of carbon atoms into iron is much more because iron has a stronger affinity to attract carbon.

1.7.3 Applications of HSS Tool

The main use of high-speed steels continues to be in the manufacture of various cutting tools: drills, taps, milling cutters, tool bits, hobbing (gear) cutters, saw blades, planer and jointer blades, router bits, etc., although usage for punches and dies is increasing.

High speed steels also found a market in fine hand tools where their relatively good toughness at high hardness, coupled with high abrasion resistance, made them suitable for low speed applications requiring a durable keen (sharp) edge, such as files, chisels, hand plane blades, and damascus kitchen knives and pocket knives.

High speed steel tools are the most popular for use in woodturning, as the speed of movement of the work past the edge is relatively high for handheld tools, and HSS holds its edge far longer than high carbon steel tools can. High speed steel is used for cast iron cutting as well in CNC Machines.

Fig 1.13: HSS Cutting Tools

1.8 INTRODUCTION TO MINITAB

Minitab is a statistics package. It was developed at the Pennsylvania State University by researchers Barbara F. Ryan, Thomas A. Ryan, Jr., and Brian L. Joiner in 1972. Minitab began as a light version of OMNITAB, a statistical analysis program by NIST. It can be used for learning about statistics as well as statistical research. Statistical analysis computer applications have the advantage of being accurate, reliable, and generally faster than computing statistics and drawing graphs by hand. Minitab is relatively easy to use once you know a few fundamentals. Minitab is distributed by Minitab Inc, a privately owned company headquartered in State College, Pennsylvania, with subsidiaries in Coventry, England (Minitab Ltd.), Paris, France (Minitab SARL), and Sydney, Australia (Minitab Pty.).

Today, Minitab is often used in conjunction with the implementation of six sigma, CMMI, and other statistics-based process improvement methods. Minitab 16, the latest version of the software, is available in 7 languages: English, French, German, Japanese, Korean, Simplified Chinese, & Spanish. Minitab is statistical analysis software. It can be used for learning about statistics as well as statistical research. Statistical analysis computer applications have the advantage of being accurate, reliable, and generally faster than computing statistics and drawing graphs by hand. Minitab is relatively easy to use once you know a few fundamentals. Minitab Inc. produces two other products that complement Minitab 16: Quality Trainer, an eLearning package that teaches statistical tools and concepts in the context of quality improvement that integrates with Minitab 16 to simultaneously develop the user's statistical knowledge and ability to use the Minitab software and Quality Companion 3, an integrated tool for managing Six Sigma and Lean Manufacturing projects that allows Minitab data to be combined with management and governance tools and documents.

Minitab has two main types of files, projects and worksheets. Worksheets are files that are made up of data; think of a spreadsheet containing variables of data. Projects are made up of commands, graphs, and worksheets. Every time you save a Minitab project, you will be saving graphs, worksheets, and commands. However, each one of the elements can be saved individually for use in other documents or Minitab projects. Likewise, you can print projects and their elements.

1.8.1 Minitab Project and Worksheets.

Minitab has two main types of files, projects, and worksheets. Worksheets are made up of data; think of a spread sheet containing data variables. Projects are made up of commands, graphs, and worksheets. Every time you save a Minitab project, you will be saving graphs, worksheets, and commands. However, each element can be saved individually for use in other documents or Minitab projects. Likewise, you can print projects and their elements.

The Menu bar: You can open menus and choose commands. Here you can find the built-in routines.

The Toolbar: Shortcuts to some Minitab commands.

1.8.2 Two windows in MINITAB

1.<u>Session Window</u>: The area that displays the statistical results of your data analysis and can also be used to enter commands.

2.<u>Worksheet Window</u>: A grid of rows and columns used to enter and manipulate the data. Note: This area looks like a spreadsheet but will not automatically update the columns when entries are changed.

Other windows include:

• Graph Window: When you generate graphs, each graph is opened in its own window.

• Report Window: Version 13 has a report manager that helps you organize your results in a report.

• Other Windows: History and Project Manager are other windows. See Minitab help for more information on these if needed

1.9 INTRODUCTION TO TOPSIS

TOPSIS, known as **T**echnique for **O**rder of **P**reference by **S**imilarity to **I**deal **S**olution, is a multi-criteria decision analysis method. It compares a set of alternatives based on a pre-specified criterion. The method is used in the business across various industries, every time we need to make an analytical decision based on collected data.

Let's imagine the situation when we want to compare several companies and find out which one has the strongest financials. These companies are our alternatives set. To combine them together and decide which one is the strongest, we need to employ some reliable metrics. In such a case we can use some indicators derived from financial statements like for example **ROA** (return on assets), **ROE** (return on equity), **DR** (debt ratio), or **CG** (capital gearing). These indicators will form our criteria set.

The mysterious logic of **TOPSIS** is based on the concept that the chosen alternative should have the shortest geometric distance from the best solution and the longest geometric distance from the worst solution. Pretty simple huh?

Such methodology allows finding trade-offs between criteria when a poor performance in one can be cancelled by a good performance in another criterion. This provides a pretty comprehensive form of modelling because we are not excluding alternative solutions based on pre-defined thresholds.

1.9.1 TOPSIS algorithm

Generally, the whole **TOPSIS** process can be encapsulated in 7 steps:

1. Create a matrix consisting of **M** alternatives and **N** criteria. This matrix is usually called an "evaluation matrix".

$$(a_{ij})_{M \times N}$$

As an example: **M** will be the number of our companies, while **N**, the number of metrics (ROA, ROE, DR, CG).

2. Normalize evaluation matrix:

$$\alpha_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{M}(a_{ij})^2}}$$

Each metric **j** for each company **i** is normalized to be in between 0 and 1. The higher its value the better the metric.

3. Calculate the weighted normalized decision matrix. It is important to note that each criterion should have its own weight so that all of them will sum up to 1. The weights can be derived randomly (not recommended) or based on expert knowledge (industry standard).

$$\chi_{ij} = \alpha_{ij} * \omega_j$$

$$\omega_j = \frac{w_j}{\sum_{j=1}^{N} w_j}$$

$$\sum_{j=1}^{N} \omega_j = 1$$

After we assign a weight to each financial metric, we need to normalize those so that these sum up to 1. Then we need to multiply each normalized metric from step 2 by corresponding normalized weight.

4. Determine the best and the worst alternative for each criterion:

$$\chi_j^b = \max_{i=1}^{M} \chi_{ij}$$

$$\chi_j^w = \min_{i=1}^{M} \chi_{ij}$$

We want to find the maximum and minimum value of each financial metric among all Readings.

5. Calculate the Euclidean distance between the target alternative and the best/worst alternative:

$$d_i^b = \sqrt{\sum_{j=1}^{N} (\chi_{ij} - \chi_j^b)^2}$$

$$d_i^w = \sqrt{\sum_{j=1}^{N} (\chi_{ij} - \chi_j^w)^2}$$

This is a calculation of the geometric distance between the value of each financial metric for a given company **i** and the best/worst value of such a metric among all companies.

6. For each alternative calculate the similarity to the worst alternative. The results are our **TOPSIS** scores.

$$s_i = \frac{d_i^w}{d_i^w + d_i^b}$$

We compute a score for each company that is based on distances obtained in a step before.

7. Rank alternatives according to the **TOPSIS** score by descending order.

The company with metrics closest to the best will obtain the highest score and therefore will be at the top of our ranking.And… that’s all. We obtained a ranked set of alternatives based on specified criteria!