"Study of Surface Roughness & residual stresses in CNC Turning using Taguchi and Genetic algorithm"

A DISSERTATION

submitted in partial fulfilment to the

requirement for the award of the degree of

Master of Technology

in

Production and Industrial Engineering

By

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DECLARATION

I, **ABU SAAD, (2K18/PIE/22),** Department of Mechanical Engineering, Delhi Technological University, Delhi hereby declare that the project Dissertation titled**, "Study of Surface Roughness & residual stresses in CNC Turning using taguchi and Genetic Algorithm"** submitted by me in partial fulfilment of the requirement for the award of Master of Technology degree in Production Engineering from Delhi Technological University, Delhi is a record of authentic work carried out by me under supervision and guidance of **Dr. QASIM MURTAZA (Professor)**, Department of Mechanical Engineering, Delhi Technological University, Delhi. The matter embodied in the project report has not been submitted to any other University/Institute for the award of any degree or diploma. Literature bestowed in this report is being provided with proper citing.

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ABSTRACT

To remain competitive, the mechanical manufacturing industries are challenged on a regular basis for having better productivity and good quality products. The required shape, size and finished ferrous and non-ferrous products are conventionally developed by turning the preformed blanks with the aid of cutting tools that have moved in a machine tool past the work piece. Within a real production system, turning process is one of the simple and frequently applied metal removal process among different cutting processes. The surface roughness of the machined components is one of the most important characteristics of quality of product which refers to the variation from the nominal surface. In many applications, surface roughness plays a vital role, such as highly precise fits, fastener holes, artistic requirements and components subject to dynamic loading. Roughness of the surface imposes one of the most major constraint in the choice of cutting parameters and machine tools in process development. A variety of factors such as feed rate, working material properties, hardness, uneven built-up edge, cutting speed, DOC, cutting distance, tool nose radius and cutting edge angles, consistency of the machine tool and configuration of workpiece, chatter, and use of cutting fluids have been found to affect surface finish in turning in varying amounts.

Residual stresses have important part to play in machined component performance. Component characteristics affected by residual stress include fatigue life, resistance to corrosion and portion distortion. Residual stresses are improved the functional conduct of machined components. Because of all this, it is required to understand residual stresses conveyed by machining. Research efforts were made up of experimental results, theoretical simulation, simulation of finite elements and different combinations of those efforts. The aims of the current research are as follows: 1. To study the effect of surface roughness and residual stresses on CNC machine by changing the various input factors i.e. CS, FR, DOC. 2. To research the impact of process variables such as CS, FR and DOC on surface roughness and residual stress while CNC turning of the super alloy Inconel718 super alloy

KEYWORDS: Productivity, Surface Roughness, Turning, Cutting Parameters, Residual stresses

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Abbreviation

ANNOVA	Analysis of variance
CNC	Computer numeric control
CS	Cutting speed
F	Feed
DOC	Depth of cut
RS	Residual stresses
SR	Surface roughness

DOE	Design of experiment
OA	Orthogonal array
MRR	Metal removal rate
HSS	High speed steel
FR	Feed rate
CBN	Cubic boron nitride
MCU	Machine control unite

Chapter1

1.Introduction

Inconel718 superalloy is hard-to-cut materials, and is the most commonly used commodity in manufacturing, among other nickel-based alloys. Inconel718 possesses superior characteristics such as high melting point and heat resistance, high corrosion and creep resistance, and high strength and hardness are maintained at high temperatures. Consequently, Inconel718 sees a variety of applications in the aerospace industry and in the hottest sections of gas turbine engines produced by process machining. [1]

Surface integrity is one of the customer criteria that includes observing the changes caused to the workpiece during the manufacturing process [2]. Such modifications are measured from two major perspectives: structural inconsistencies and surface variations. Residual pressures, metallurgical changes and fractures are due to surface variations. Surface roughness and residual stresses are also regarded as the most important measures of surface integrity in turning processes. [3]

Thermomechanical loads and phase change caused in the surface / subsurface of the machined workpiece produce residual stress in the traditional machining processes. Due to the thermal and mechanical loads, respectively, tensile and compressive residual stresses are generated while turning operation. [4] Tensile one is undesirable kind of stress which need to be remove or optimize because it helps in crack propagation under cyclic loading and result in short life. Compressive one is positive and helps in achieving good mechanical properties. Residual stresses which is tensile in nature is generated because of sudden rise in temperature at machining zone. Compressive nature is achieved only when we have clear understanding of Mechanical loading.

High temperature resilience, outstanding corrosion resistance and durability at 701 ° C have contributed to those used in a large number of high-requirement conditions.

1. Can be used in Steam turbine

2.Major importance in field of Liquid-fuel rocket

3.Can be have great role in engineering relating to Cryogenic

4.Have major significance in environment which may be subjected to Acid

5.Nuclear field have also important utilized this material

Table:1.1 Comparison among different methods

Parameters	X-RAY	NEUTRON	ELECTRON
Phase identification	Yes	Yes	Yes
Amorphous or Crystalline	Yes	Yes	Yes
Unit cell space group	Yes	Yes	Yes
Crystal structure	Yes	Yes	Yes
Local structure co-ordination number	Yes	No	No
Crystal defect	Yes	Yes	Yes
Surface structure	No	Yes	No
Polycrystalline texture	Yes	Yes	No
Elemental analysis	No	Yes	No
Magnetic information	No	No	Yes

The primary challenges facing the metal-based sector are to increase the productivity and performance of the machined components; there has been an improved concern in tracking all machining method elements. Turning is cutting process which is most commonly used. Determination of materials' machinability is done by measurement of SF and the rate of material removal; Surface finishing is a critical metric of product quality, because it hugely impacts the efficiency of mechanical components as well as the production cost. The optimization of machining variables increases the machining cost-effectiveness and also significantly enhances the efficiency of the metal.

The goal in the contemporary sector is to produce high-quality, low-price products in a short time. For this purpose, together with CNC, automated and flexible manufacturing devices were used; computers capable of attaining high precision and very small moment of handling. Turning was the utmost popular cutting technique usually for finished machined components [5].

Turning is the utmost first popular cutting technique usually for completion of machined components. It is essential to pick reducing parameters in the switching procedure in order to achieve a strong reduction in efficiency. The cutting parameters reflect the ruggedness of the surface, the composition of the ground and the variation in the material size [6]. The surface finish obtained during the manufacturing process depends primarily on the combination of two aspects: the ideal SF provided by the marks produced by the surface manufacturing process and the actual SF produced, taking into consideration lack of regularities and lack of efficiency that might occur during the manufacturing process, and varying the initial production process behaviour [7].

The surface of each portion involves some kind of texture produced by any mixture of the preceding variables: the microstructure of material, the behavior of cutting tool, the distortion of the instrument milling, the errors of instrument guidance and the deformations induced by the stress models of the component. The composition of ground of an architectural component was very crucial. The machining procedures affected it by changes in the circumstances of the product or machine [8]. A machined texture contains a ton of useful data on methods including tool wear, built-up edge, earthquakes, damaged machine components, etc. Under stable machining conditions, substrate changes texture is significantly due to wear-induced modifications in the cutting tool shape.

Most realistic machining operations use machines with two or more cutting edges but a close inspection of such operations show significant similarities with orthogonal and oblique cutting.

1.1 TURNING OPERATION

Turning removes material from cylindrical rotating shaped material in the form of chips from the diameter of workpiece especially from outer diameter. Turning basically removes material and reduces the diameter of material and give it proper shape and size as required and also provide smooth surface and having shinny like lustered. The piece of work is often turned in such a way that neighboring sections have unlike same diameter.

Through turning we usually get cylindrical parts(Fig.1). In its normal form, we can define turning with respect to external surface as:

- In regard to rotation of the work piece
- Single cutter having one point for machining, and
- Workpiece is arranged in such a way that its feed is directed parallel to it and is at some distance and remove material from surface which is outer one.

Taper turning similar but its direction of cutting is little inclined if comparison is done with turning. Contour turning having cutter whose distance is little varied in order to achieve require configuration from motion of work axis in regard to turning. As we have already said it is single point cutter but it has multiple point setup often being used. Each tool which is single point work independently but at a time separately.

1.2 EXPANDABLE CUTTING VARIABLES IN TURNING

Three main variables in any essential turning are DOC, Speed and feed.

1.2.1 Speed: Speed is always about the spindle and the piece of work. When stated in revolutions per minute (rpm) it tells the speed of their rotation. It is the multiplication of rotating velocity times work piece circumference before cutting is started. It is expressed in meter by minute (m / min), and only refers to the piece of work. Workpiece having different diameter will be having different speed even if its spinning speed being similar.

$$V=3.14*D*N/1000 \text{ m/min}$$

In this case, v is speed of cutting in turning, D is starting diameter of workpiece in mm and N is speed of spindle in RPM.

1.2.2 Feed: It is the rate at which the tool accelerates along its path of cutting. The feed rate is closely related to the speed of the spindle on most power-fed lathes and is presented in mm / rev.

$$F = f*N \text{ mm/min}$$

where Feed is F in mm per minute, feed is f in mm / rev and spindle speed is n in RPM.

1.2.3 Depth of Cut: It is amount of layer of material being taken out from work piece in just one pass or the distance from the uncut surface of the work to the cut surface, measured in mm. However, actual amount of material taken out is basically twice because this happen from both side of material.

$$d = (D - d)/2 \text{ mm}$$

Here, D and d respectively represent the initial and final diameter (in mm) of the job.

1.3Dynamics of turning

1.3.1Forces

In the design of machine tools, the comparative forces in a turning operation are significant. These forces must be resisted by the machine tool and its components during the operation without having any significant deflections, vibrations or chatter. While turning process there are three principal forces:

- The cutting or tangential force works down upon the tip of the blade causing the material to be deflected upwards. It provides the energy needed to cut operation. Depends on the material, cutting force.
- Longitudinal force also known as feed force because it acts in direction similar to direction of feed. This force has ability to partition the device from chuck.
- Tool is being pushed away from material because radial or thrust force being radial in nature

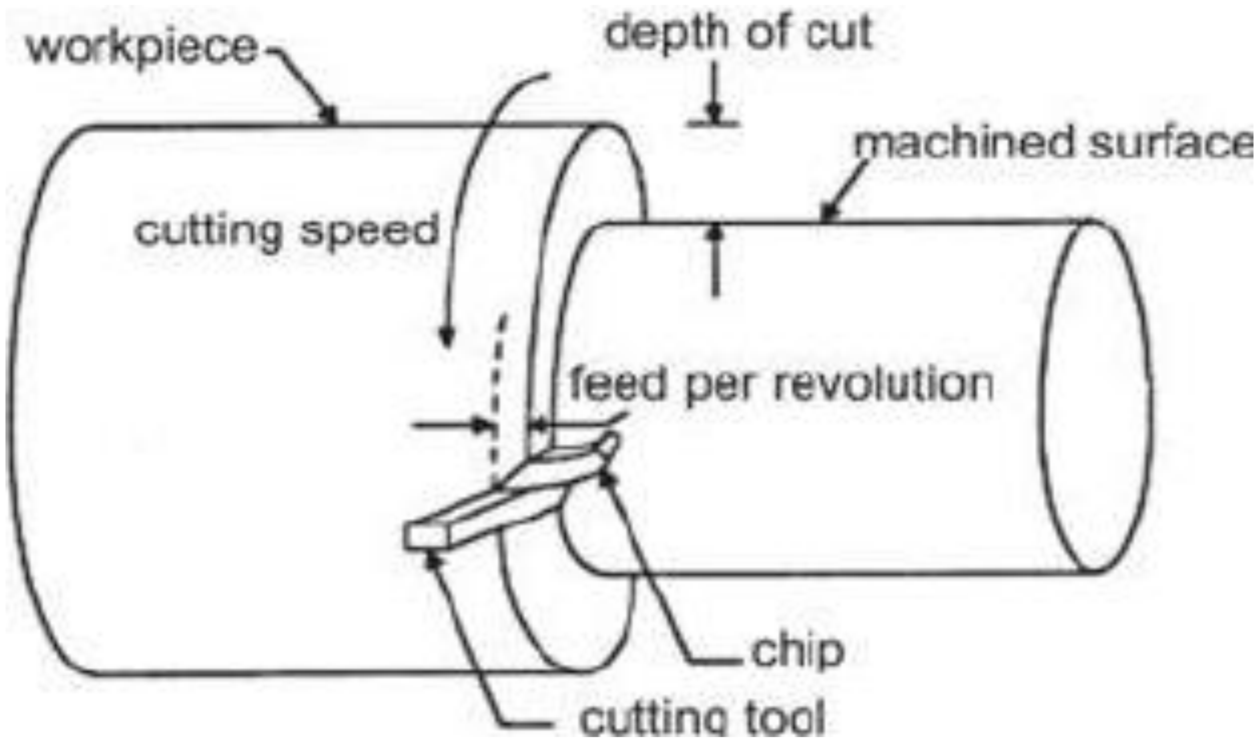


Fig 1.1 structure turning operation diagram [31]

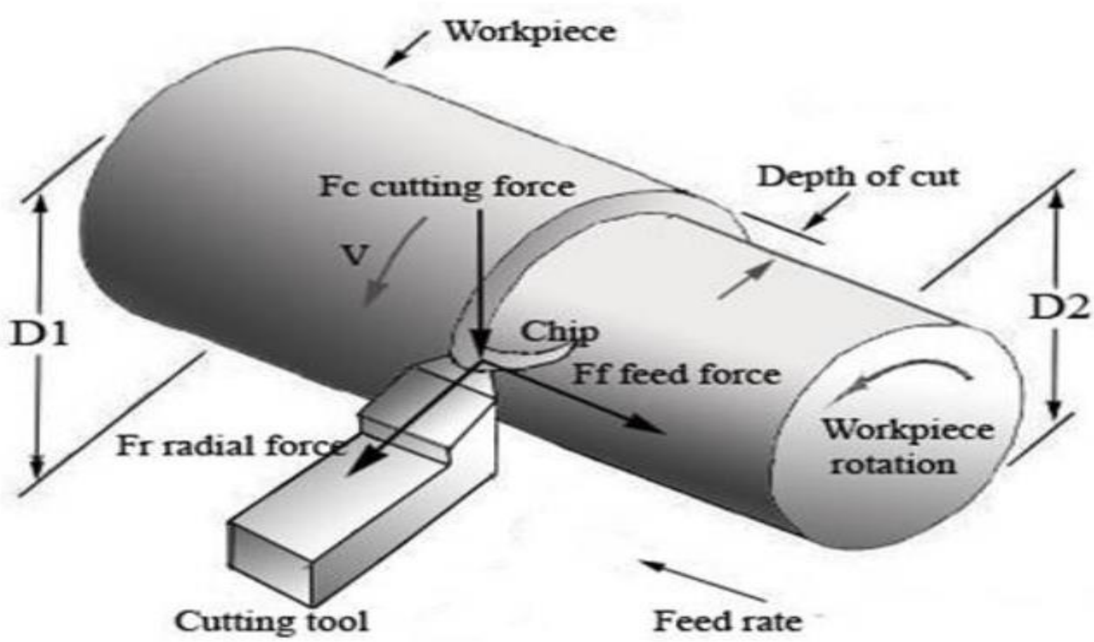


Fig.1.2 Structured turning operation and cutting forces diagram [31]

1.4 Residual stresses

Surface roughness, residual stress, and microstructure significantly impact a component's fatigue life. Applied stress is produced within a material due to an external load (often calculated with such a strain Gage). Residual stress is existing within the material regardless of loading. The total stress felt by the material at a given position inside a component is equivalent to the residual stress including the applied stress.

TOTAL STRESS = RESIDUAL STRESS + APPLIED STRESS

Those stresses which remain in material even after the withdrawal of external force are residual stresses. They have two different category one is positive known as tensile other is negative one known as compressive in nature. Tensile one is undesirable kind of stress which need to be remove or optimize because it helps in crack propagation under cyclic loading and result in short life. Compressive one is positive and helps in achieving good mechanical properties. Residual stresses which is tensile in nature is generated because of sudden rise in temperature at machining zone. Compressive nature is achieved only when we have clear understanding of Mechanical loading. [22] The strain in the crystal lattice has to be measured for at least two precisely known orientations comparative to the sample surface to determine the stress. Thus, residual stress calculation of x-ray diffraction is applicable to materials that are crystalline, fairly fine grained, and that produce diffraction for any sample surface orientation. Samples may be metallic or ceramic, given that with the radiation available, a diffraction peak of appropriate intensity and free of interference from adjacent peaks may be created in the high back-reflective zone. [55]

Stress components inside a material

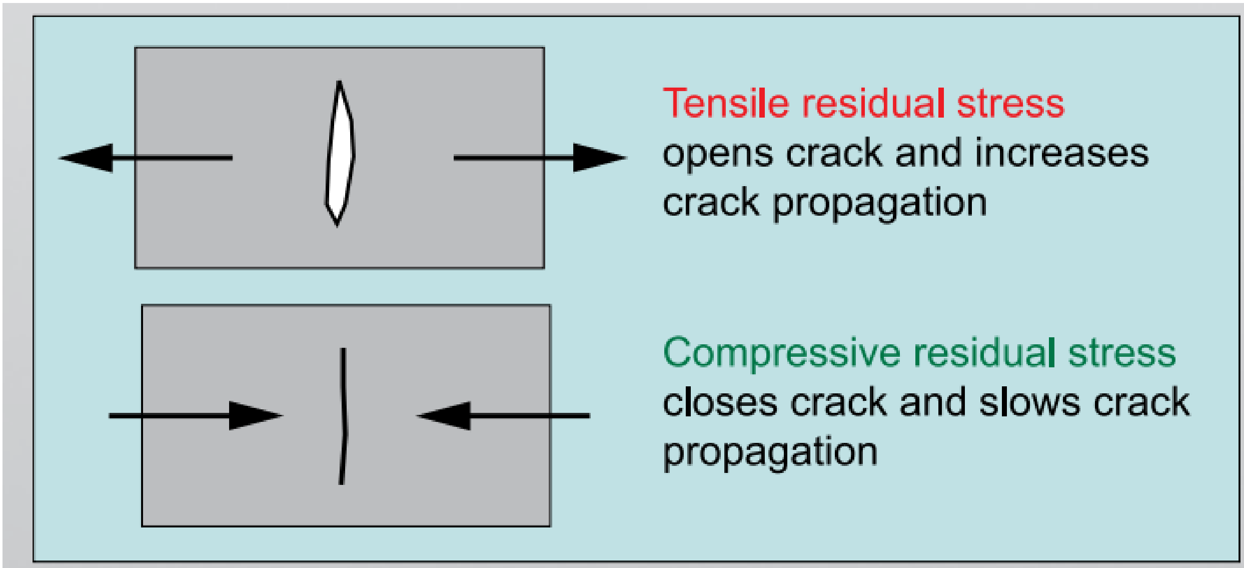


Figure1.3: showing effect of tensile and compressive residual stresses [57]

1.5 Type of Stresses

Type I Stresses: Macro-stresses arising across distances that include several grains within a substance.

Type II Stresses: Micro-stresses induced by variations in the micro structure of the sample and occur across distances equal to the size of the grain in the sample. Can happen in single-phase materials because of the an-isotropic activity of individual grains, or can happen in multi-phase material attributed to the prevalence of different phases.

Type III Stresses: Exist within a grain as a consequence of crystal flaws inside the grain.

1.6 Causes of residual stresses

Shape and properties of various material gets altered while performing different operation and this happen due to one main reason which is residual stresses [22] generation and thus we obtain material which get cracked or deformed while applying some kind of force to it.so it is necessary to remove this kind of undesirable stresses which develop inside a material. There is various reason for such force to exit so we need to optimize it and remove tensile stress because which is the root cause of all this but compressive stress being favorable one.

The root cause of residual stresses may be classified as:

- variability flow of plastic;
- variable rates of cooling;
- Phase modifications, with volume changes. [22]

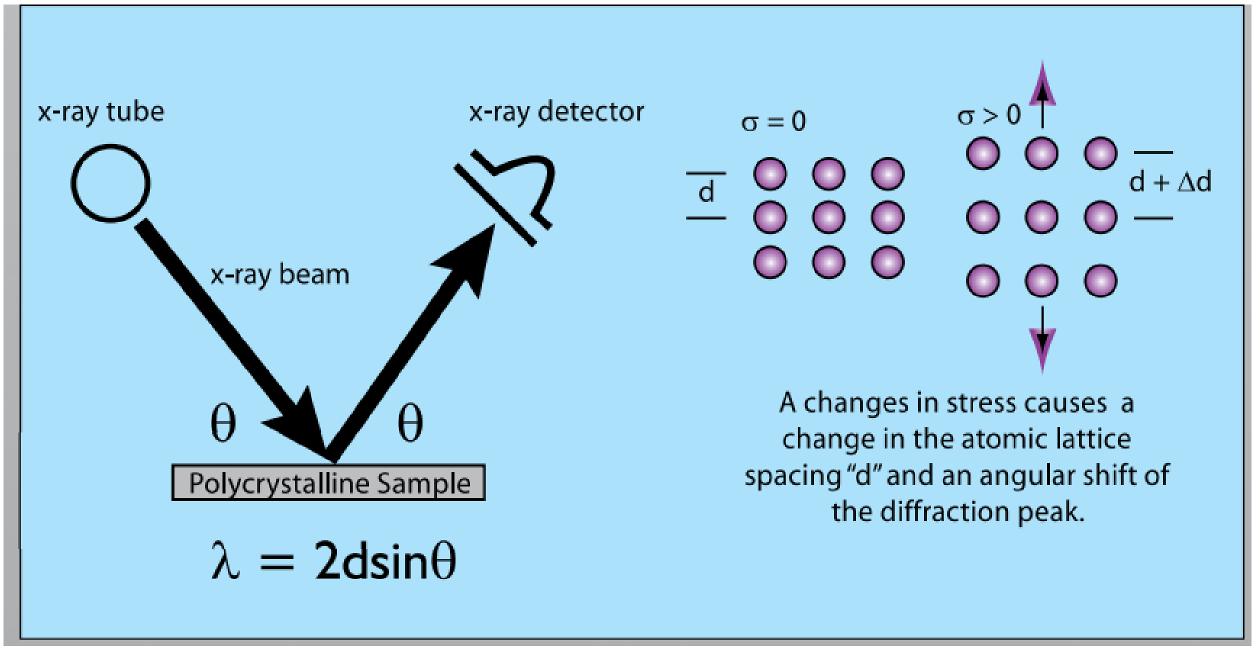


Figure:1.4 showing the process of finding out the atomic lattice spacing in x-ray diffraction [57]

1.7Computer Numerical Control (CNC)

CNC is one that controls feature and movements of a tool through a ready program which contains written alphanumeric information. CNC can regulate workpiece or instrument movements, interface parameters such as feed, slice volume, velocity, and features like spindle switching on / off, switching coolant on / off.

1.7.1 Applications

CNC 's apps include machine tool regions as well as non-machine instrument regions. CNC is frequently used in machine tool classification for lathe, drill press, processing device, processing unit, laser, sheet metal pressure operating system, tube bending machine, etc. Completely automated machine tools, like switch center and center of machining, have been created to automatically alter the tools used for cutting under CNC command. In anti-machine instrument community CNC implementations include equipment of welding, position evaluation equipment, electronic installation, touch setting and composite filament winding systems etc.

1.7.2 ADVANTAGES AND LIMITATIONS

CNC is having several good impact some are listed below:

- Accuracy is very good
- Production time is less and good versatility.
- Installation can be done in very easy and simple manner.
- Chances of error by human is very less.
- Simpler installation
- Machining of contours

The negatives part include repair, increase in cost and someone who is expert in part programming.

1.7.3 Elements of a CNC

The 6 elements comprise a typical CNC system.

- Part Program
- Program Input Device
- MCU
- Drive System
- Machine Tool
- Feedback Device

1.7.4 Classification of CNC Machine

CNC machine instrument devices can be classified in different respects:

1. Point-to-point or contouring: Depending on whether metal is cut off from the device although the workpiece passes near the device

2. Incremental or complete: The settings of motion commands depend on the nature of coordinate system that has been adopted.

3. Open loop or closed loop: Based on management system used it to power object movement.

1.7.5 G & M Codes

G00 – rapid move

G01 – linear move

G02 – clockwise circular motion

G03 – counter clockwise circular motion

G04 – dwell

G05 – pause

G08 – acceleration

G09 – deceleration

G17 – x-y plane for circular interpolation

G18 – z-x plane for circular interpolation

G19 – y-z plane for circular interpolation

G20 – turning cycle or inch data specification

G21 – thread cutting cycle or metric data specification

G24 – face turning cycle

G25 – wait for input to go low

G26 – wait for input to go high

G28 – return to reference point

G29 – return from reference point

G31 – stop on input

G33 – thread cutting functions

G35 – wait for input to go low

G36 – wait for input to go high

G40 – cutter compensation cancel

G41 – cutter compensation to the left

G42 – cutter compensation to the right

G43 – tool length compensation positive

G44 – tool length compensation negative

G90 – absolute dimension program

G91 – incremental dimensions

G92 – spindle speed limit

G93 – coordinate system setting

G94 – feed rate in ipm

G95 – feed rate in ipr

G96 – surface cutting speed

G97 – rotational speed rpm

G98 – withdraw the tool to the starting point or feed per minute

G99 – withdraw the tool to a safe plane or feed per revolution

M00 – program stop

M01 – optional stop

M02 – end of program

M03 – spindle on clockwise

M04 – spindle on counter-clockwise

M05 – spindle off

M06 – tool change

M07 – flood with coolant

M08 – mist with coolant

M09 – coolant off

M10 – turn on accuracy

M11 – turn off accessory or tool change

M17 – subroutine end

M20 – chain to next program

M21 – tailstock forward

M22 – write current position to data file

M25 – open chuck

M26 – close chuck

1.8 Cutting Tool Materials

HSS Device, alloys based on cobalt, cemented carbides, ceramics, polycrystalline CBN and polycrystalline diamond are commonly used for machining purposes. Specific machining techniques require different work tool components. The perfect fabric of the drafting instrument should have all the previous features

- It's more difficult than the job it's drawing
- High heat resistance
- Friction and heat stress resistance
- Resistant to impact

In order to effectively pick machine tools from a device manufacturer or engineer, specific information must be provided on:

- Start and complete shape of the portion
- Hardness of the work piece
- Material strength in tensile is taken into consideration
- Abrasive content
- Chip size is also taken into consideration
- Work to maintain configuration
- Strength and speed of machine tools

Below are some popular cutting tool materials listed: -

1.8.1 Carbon Steel

Carbon steels have been in use for cutting tools since the 1880s. Carbon steels, however, begin softening at around 179oC. This weakness sums up that such instruments are seldom utilized when cutting metal. Plain Carbon Steel Tools, is having approximately 0.89 percent Carbon and approximately 1 percent Manganese, hardened to approximately 61.9 Rc, are frequently utilized for work related to wood and can be utilize for machining aluminum sheets up to approximately 3 mm thick in a router.

1.8.2 High Speed Steels (HSS)

HSS instruments are designed for cutting at higher rates. Around 1899 the far more remarkably alloyed instrument steels were established by HSS. The tungsten was first produced and typically includes tungsten containing around 3.9 percent chromium and 1.1-5.2 percent vanadium at 12.1-18.1 per cent. Some grades make up about 0.5 per cent of molybdenum and most grades make up 4-12 per cent of cobalt. Consequently, approximately 95 per cent of every HSS instruments are made from M- series classes. This having 6-10% molybdenum, 2.3-9.8% tungsten, 1.1-3.9% vanadium and 3.9% chromium. HSS instruments are hard and suitable for disrupted processing, and are used in the production of complicated shaped instruments such as presses, reamers, presses, presses and cutters for equipment. Tools can also be coated to enhance wear quality. HSS represents the greatest tonnage of instrument components currently in use. Typical slicing speed; 9–59 m / min.

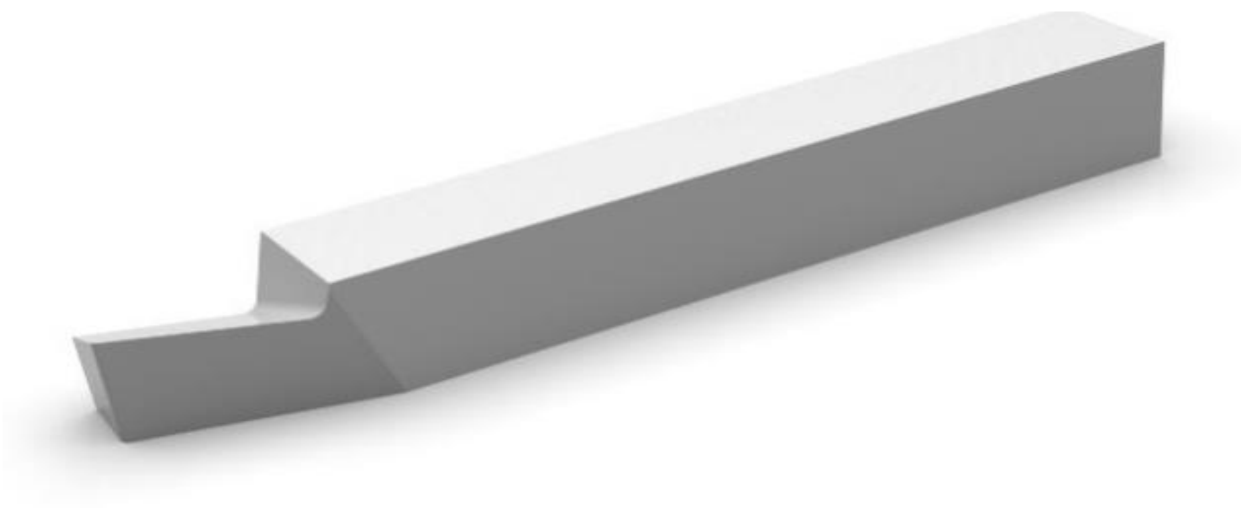


Figure:1.5HSS Cutting tool [58]

1.8.3 Cast Cobalt Alloys

These alloys having proportions of approximately 39.9-54.9 percent cobalt, 30.1% chromium and 10.1-19.9 percent tungsten introduced in the early 1900s. Max hardness value of 54–63Rc. They have excellent workplace strength, but they aren't as intense as HSS and they can be used at much higher rates than HSS. Used only in small quantities, currently.

1.8.4 Carbides

Also described as cemented carbide or sintered carbide were launched in the 1930s and increased strength over a wide heat spectrum, increased heat conductivity and elevated module for young people. Making them an effective instrument for a wide applications range and die content. The two types used for machining are tungsten carbide and copper carbide; both kinds can be covered or uncoated. Within a silver frame tungsten carbide particle (1-5 micrometer) are joined together using oxide metallurgy. Press and sinter the material into the envelope form required. Titanium and niobium carbides can also be used for imparting special characteristics. A wide variety of grades are accessible for various applications. Sintered carbide guides are the dominant type of fabric used in the slicing process. The cobalt ratio (the usual matrix substance) has a dominant influence on the characteristics of the carbide tool. 3-6 per cent cobalt matrix provides better hardness while 6-15 per cent cobalt matrix provides more durability while reducing stiffness, resistance to tears and strength.

Tungsten carbide instruments are widely used for metal, cast iron, and abrasive non-ferrous products. Typical slicing rates are 30-150m / min, or 100-250 m / min when covered.

Figure:1.6 Carbide cutting tool [58]

1.8.5 Coatings

It is being suggested that the tools which are having coating just like carbide tools add life to tools. From study we can say that life of tool improved by 10times if we compare with uncoated one.

1.8.6 Cermet's

In the 1961s, it comprises 69 percent oxide of aluminum and 29 percent titanium carbide. Certain formulations include molybdenum carbide, niobium carbide, and tantalum carbide. Output seems to provide little benefits among coating done with carbides and ceramics. Typical slicing rates; 150–350 m / min.

1.8.7 Ceramics

1.8.7.1 Alumina

Two classes were introduced in the early 1950s we start using tool coated with Al_2O_3 and SiN_4 and these are basically pressed on the tip of tool at relatively upper limit of temperature. ZrO_2 is also developed which enhances the characteristics but at the same time it also works for toughness related to fracture, but it degrades the hardness and to some extend thermal conductivity. for cutting tools; fine-grained, high-purity aluminum oxide (Al_2O_3) and silicon nitride (Si_3N_4) were pressed into insert tip forms and sintered at high temperatures. SiC whiskers can be mixed to improve the durability and resistance occurring by thermal sock. Typical slicing rates; 149-649 m / min.

1.8.7.2 Silicon Nitride

Depending on silicon nitride, which might also include aluminum oxide, yttrium oxide and zinc carbide, a device design was created in the 1970s. SiN having an iron bond and is not favorable for processing steel which contains silicon, aluminum, oxygen, and nitrogen components. These have greater heat shock strength than carbon nitride, and are suggested for machining wrought steel and super alloys based on nickel at medium slicing rates.

1.8.7.3 Cubic Boron Nitride (CBN)

In 1965s the second strongest accessible material was introduced after diamond. CBN instruments might either utilized in the form of tiny solid guides or as a 0.49 to 1.1 mm thick coating of polycrystalline boron nitride sintered on a carbide under stress. The carbide offers resistance to crash in latter case, and the CBN coating offers very broad slip resistance and border slicing stability. Typical slicing rates: 30–310 m / min.

Figure:1.7 Cubic boron nitride (CBN) cutting tool [59]

1.8.7.4 Diamond

Although single crystal platinum we are using as an instrument, diamond is the most easily recognized material, it is fragile and must be installed in the right crystal position in order to achieve optimum instrument life. PCD had been largely replaced by single glass laser instruments. This containing very small crystals of synthetic linked to density of between 0.5 and 1 mm and attached to a carbide substratum by a method of elevated stress with high temperatures. The results are comparable with those of CBN devices. Accidental direction of the crystalline diamond stops the propagation of the track, enhancing toughness. Typical cutting rates: 201-2001 m / min. Whisker-enhancing technologies, like silicon nitride improved with silicon carbide whiskers, are being kept out to improve instrument durability. As the levels of metal extraction have risen, the required for cutting related to heat-resistant instruments has also increased.

The effect was a transition from HSS to carbide, from ceramics and other super-hard materials as well. HSS trimmed the carbon steels which they replaced four times faster.

There are over 30 HSS grades available in three primary classifications: tungsten-centered grades, molybdenum, and molybdenum-cobalt. In the sector today, carbide instruments had taken over HSS in many fields. These instruments covered in carbide and carbide slice about 2.9 to 4.9 times more than steels of high –speed.

Ceramic tools are heat resistant but brittle than carbides. These are suitable for machining cast iron, tough steels, and super alloys. Two types of ceramic extraction instruments are accessible: alumina and ceramics based on silicon-nitride. Alumina-based ceramics are used at elevated semi-and complete speed to finish ferrous and some non-ferrous products. Ceramics based on silicon nitride are commonly used to roughen and lighten cast iron and super alloys.

1.9 Taguchi method

Dr. Genichi Taguchi suggested the Taguchi system. Taguchi had already envisaged a latest method of designing studies based on well-defined guidelines. A unique set of arrays called orthogonal arrays is used in this method. These generic arrays clearly state the order to conduct the minimum series of experiments that could provide maximum details about all the factors influencing the output factor. The crux of orthogonal array approach lies in selection for each experiment the level combinations of the variables in input design.

Taguchi experiments also use a method of 2-stage optimization. Use the signal to noise ratio in step 1 to recognize those control factors which significantly lower. Identify control variables in phase 2, which transfer the mean to goal and have a slight to no effect on the signal to noise ratio.

Signal-to-noise ratio	Goal of the experiment	Data characteristics	Signal-to-noise ratio formulas
Larger is better	Maximize the response	Positive	$S/N = -10 * \log(\Sigma(1/Y^2)/n)$
Nominal is best	Target the response and you want to base the signal-to-noise ratio on standard deviations only	Positive, zero, or negative	$S/N = -10 * \log(\sigma^2)$
Nominal is best (default)	Target the response and you want to base the signal-to-noise ratio on means and standard deviations	Non-negative with an "absolute zero" in which the standard deviation is zero when the mean is zero	$S/N = 10 \times \log((\bar{Y}^2) \div \sigma^2)$ The adjusted formula is: $S/N = 10 \times \log((\bar{Y}^2 - s^2 \div n) \div s^2)$
Smaller is better	Minimize the response	Non-negative with a target value of zero	$S/N = -10 * \log(\Sigma(Y^2)/n))$

Where $\bar{y}$ is mean data observed, s^2 is the variance of y, n number of responses and y is data observed

OA selection rules

For 2 levels

No. of factors	OA
2 to 3	L4
4 to 7	L8
8 to 12	L12
12 to 15	L16

For 3 levels

No. of factors	OA
2 to 4	L9
5 to 7	L27

1.9.1Designing an experiment

- Choice of independent variables.
- Choose the level setting number for each independent variable.
- Orthogonal array selection
- Assign to each column the independent variables.
- The experiments are conducted.
- Analysis of the results.
- Inference.

1.10 Surface Structure and Properties

SR is an important aspect of product quality, since it hugely affects both the role of mechanical components and the manufacturing price. Surface roughness affects mechanical properties like fatigue behaviour, resistance to corrosion, creep existence etc. It also impacts operational characteristics of other components such as friction, pressure, color reflection, heat transfer etc. Addressing characteristics before surface roughness is also essential, since they are closely linked. It can be discovered after closely examining the layer of a metal piece, that it usually consists of several parts. The characteristics of those strands are briefly described here:

I Bulk glass, also known as a metal substrate, has a frame which is centered on the metal composition and handling record.

(ii) The coating above this mass metal is typically plastically deformed and employed to a higher degree during the manufacturing process. The size and characteristics of the work-hardened layer (the concrete structure) rely on variables such as the technique used in handling.

The application of strong instruments and the selection of correct handling parameters contribute to littler-free substrates. Non-uniform texture distortion or extreme gradients of heat usually cause residual tension in the coating during production activities.

(iii) The metal is refined and deposited in an inert atmosphere, or is a noble metal such as gold or platinum, forming an oxide layer over a hard layer of work.

(iv) Under typical climatic conditions the ground oxide sheets are normally covered with dissolved gas and moisture threads.

Substrate therefore has characteristics that are usually very difficult from substrate ones. The substratum oxide on a layer of metal is usually very harsh. Oxide on a layer of metal is usually much more difficult than base metal. Hence, oxides appear brittle and abrasive.

Surface performance is an important parameter for assessing the efficiency of tool instruments and machined components, thus achieving the soil value necessary for the operational conduct of the mechanical components. The ground roughness is the performance index of the item and affects several features such as fatigue strength, strain ratio, lubrication, corrosion resistance and wear resistance of the machine components. Spatial precision and surface finishing are now being given particular emphasis in the manufacturing industry.

Therefore, the calculation and characterization of the surface finish is considered the indicator of the machining performance.

1.11 Surface finishing affected by factors:

When we brought to machine surface in contact, binding quality of components plays a major part in the efficiency and the coupling components are carried. The height, scale, structure and orientation of these ground defects on the workpiece depends on a number of variables, such as:

1.11.1 DOC

Increasing the working range increases the intensity of slicing and the amplitude of the vibration. As a consequence, the reduction in temperature also increases. So ground performance is expected to worsen.

1.11.2 Feed

Experiments show that as we move from low to high feed roughness of surface also improved because of the increase in working power and vibration.

1.11.3 Cutting Speed

Increasing the CS generally increases surface performance.

1.11.4 Commitment of the cutting tool

It works in a similar manner to thickness of cutting

1.11.5 Cutting Tool Wears

Strain has important effect in many tools and here defect in cutting edge occur by strain which is clearly evident from machine base and also one more problem accumulated which is vibrant event such as noise which will further add to problem and badly affect efficiency of ground.

1.11.6 Role of Cutting Fluid

In SR terms, cutting fluid usually advantageous because it has three distinct effects on the cutting method. First, heat which is generated by cutting is absorbed by CF by mainly cooling the operating surface and the tool point. The cutting fluid can also overcome the friction among the face of the rake and the chip, and among the surface of the flank and surface to be machined. Lastly, the laundry intervention of the CF is significant, since it involves separating chip pieces and wearing droplets. Thus performance of a ground which has to be machined with working fluid is expected to be much better than wet processing.

Depending on the knowledge or use of the handbook the required slicing parameters are generally selected. But a stronger outcome may be achieved by modeling the surface roughness and optimizing slicing parameters. Many mathematical models were established to identify the link among efficiency reduction and slicing parameters depending on statistical regression or neural network methods.

Since Turning is the main procedure in most production cycle of the industry, the surface finishing of turning parts has a greater influence on product quality. The SF in Turning has been found to be affected by a variety of variables such as load frequency, hardness of work, volatile built-up edge, velocity, thickness of slicing, moment of slicing, use of working liquids etc. greatly affected by SF viva turning.

1.12 Quality and Productivity

From many year, two things are utmost important one is quality and another is productivity were seen as indexes of corporate performance, particularly in the manufacturing sectors. They being still stressed individually. The primary causes that at the same time value and productivity are not underlined are that the goals and indicate a favorable connection between value and productivity.

- Efficiency is one such factor of importance
- cost should be reasonable and low to have good profit.
- Makes it possible to spend more in developing customer support and new services for businesses.
- Role quality plays in everyone’s live:
- Increase repetition buys by faithful customers.
- Allows the company to differentiate its products.

Effectively controlling efficiency has become a significant determinant in an organization's quest for reduced operating costs and improved customer service. Service issues were primarily defined or handled in previous days, and related to machinery being unable to produce value customer-wanted parts and products to a desired standard in a reliable fashion. This being mainly a corporate activity for the company and was presented as such. Today's troubles are very distinct. Today, a commodity's performance depends not only on the company's operations performed on it, but also on the value chain at every point.

The performance of its item is every manufacturing organization's concern. While meeting the volume requirements and the manufacturing timetable is essential, it is equally essential that the completed item complies with the specifications developed. It's because the customer's satisfaction is obtained from value products and facilities. At the domestic and global level, strict competition and consumer recognition require the life and growth of the business to deliver value goods and facilities. Performance and productivity always bring fortune to the nation and enhance the way of living for everyone around us.

However, the leadership seeks to get client fulfilment by operating its company at the required financial stage. This can be accomplished by increasing the value of wealth equity, maintaining efficiency, and enhancing product quality.

It should be borne in mind that efficiency is affected by many variables such as skills of worker, motivation and engagement, employment techniques used, performance of workmanship, development of employee, equipment used and leadership efficiency. Productivity is the mainstay of the financial growth of any country. Greater productivity results in higher standards of living.

Higher cost-reduction efficiency results as well as increased marketing incentives, enhanced customer service sensitivity, better cash flow and sales. Increasing performance in the current company can contribute to operational growth and an employment boost. If wages grow without a productivity boost, it will result in higher cost of goods and lead to inflation.

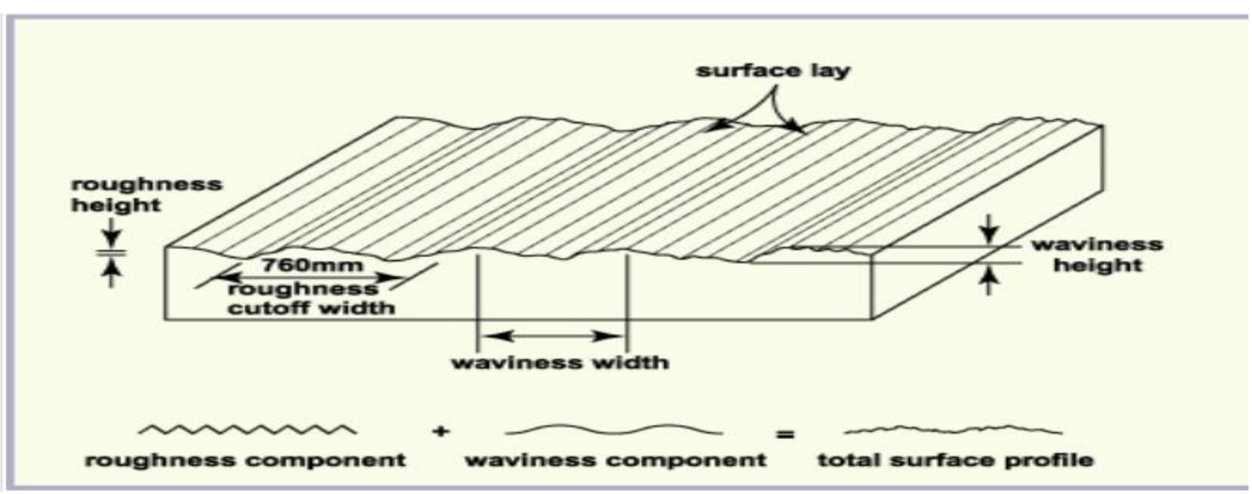


Fig. 1.8: Surface Roughness [60]

Chapter2

Literature review

2.1 A comprehensive literature survey of various surface roughness and residual stresses optimization in CNC Turning operation has been reported in the below literature matrix.

S.NO	AUTHOR	YEAR	JOURNAL	TOPIC	PARAMETER	CONCLUSION
1	Abdallah A. et al. [29]	2014	IOSR Journal of Engineering (IOSRJEN)	Optimization of cutting parameters for surface roughness in CNC turning machining with aluminum alloy 6061 material	The most important parameters, namely, Fd, CS, and DOC which are optimized considering the Ra and MMR.	. It stated that the Taguchi optimization approach was used to determine the optimal process parameters, optimizing MRR and reducing Ra during cutting. . The proportional representations of the impact of CS, Fd, DOC are 44.9 percent, 35.9 percent, and 18.9 percent, and the minimum ra value of error is 4.4 percent. . It resulted that Ra decreases with increasing CS and Fd and DOC lowering.
2.	M. M. Okasha et al. [10]	2017	*Engineering, Technology & Applied Science Research*	Modeling and Parameter Optimization for Surface Roughness and Residual Stress in Dry Turning Process	Four parameters (CS, Fd , DOC and tool overhang) are taken.	• Using Taguchi relationship analysis, process variables are optimized and the optimum cutting conditions for minimizing Ra are t1n1f1d5 while residual stress is t3v4f5d1 for minimizing tensile stress. • Overhang tool works with fd rate. The better Ra value was observed using tool overhang with low or medium value with speed and/or fd rate being low. • Low residual tensile stress can be accomplished with a variation of a 36.9 mm tool overhang with very

						moderate cutting depth, moderate rotational speed and 0.189 mm / rev fd rate
3	Schlauer, C. et al. [16]	2002	In *Materials Science Forum*.	*Residual Stresses in a Nickel-Based Super alloy Introduced by Turning.*	CS(10,410, and810)m/min and Fd (0.01,0.6, and0.11)mm have been changed to study their impact on the residual stresses.	• A strong dependence of the residual stress profile was found on CS. • If the fd is raised or the CS is reduced, the cutting force improves.
4	Thiele, J. D et al. [17]	2002	*J. Manuf. Sci. Eng.*	Effect of Cutting-Edge Geometry and Workpiece Hardness on Surface Residual Stresses in Finish Hard Turning of AISI 52100 Steel.	Edge preparation, hardness(HRC) and feed rate	• Large edge honey radius tools in the axial and hoop directions create more compressive residual stress values than the small edge hone tools. • The resulting microstructure of the workpiece is a strong measure of residual surface stress condition.
5	Sharma, V. et al. [9]	2016	*Ultrasonic*	*Optimization of machining and vibration parameters for residual stresses minimization in ultrasonic assisted turning of 4340 hardened steel. Ultrasonic.*	The influence of feed rate, depth of cut, cutting velocity and percentage intensity of ultrasonic power on generation of residual stress	. The percentage strength of ultrasonic vibration that is tied directly to the vibration amplitude was one of the most key factor (31.77 percentage contribution) for the development of residual stress. . The other cutting variables (fd rate towards the generation of residual stress, but DOC occurred as an irrelevant variables towards the velocity of the residual stress cutting hoop) were also found to make a significant contribution.

6	P.C. Jindal et al.[19]	1999	*International Journal of Refractory Metals and Hard Materials*	Performance of PVD TiN, TiCN, and TiAlN coated cemented carbide tools in turning.	Variables are PVD coating , cutting speed and cutting time.	• In the turning operations carried out in this report, the tool life of the PVD coated carbide tools increased gradually from TiN to TiCN to TiAlN. • At higher velocities, the metal cutting efficiency of TiAlN and TiCN coated devices compared to TiN was also more.
7	Nalbant et al. [6]	2007	Materials and Design	Application of Taguchi method in the optimization of cutting parameters for surface roughness in turning	Three cutting variables namely, insert radius, fd, and DOC, are optimized with considerations of Ra.	. It is observed that the Taguchi method parameter design offers an easy, standardized, and efficient methodology for optimizing the control conditions. . The test results reveal that the insert radius and fd are the crucial components among the three manageable factors which affect Ra in turning AISI 1030 carbon steel. . In turning it is suggested on using higher insert radius (1.21 mm), low fd (0.151 mm / rev) and low DOC (0.51 mm) to achieve better Ra.
8	C. J. Rao et al.[27]	2013	Procedia Engineering	Influence of cutting parameters on cutting force and surface finish in turning operation.	Variables are CS (50-95 m/min), Fd (0.05 -0.15 mm/rev), and DOC (0.25-0.75 mm).	. He concluded that both the cutting force and Ra have a major effect on feed rate. Cutting Speed has no major impact on both the cutting force and Ra. Depth of cutting has a major effect on cutting force, but has a marginal impact on Ra.

2.2. STUDIES RELATED TO SURFACE ROUGHNESS AND RESIDUAL STRESS IN CNC TURNING OPERATION

Varun Sharma et al. [9] emphasizes the influence of feed, DOC, cutting speed and Ultrasonic power level percentage on residual stress generation when turning 4340 hardened steel. He found out that the percentage intensity of ultrasonic vibration is the utmost important variable affecting residual stress of 4340 hardened steel in ultrasonic assisted turn. The other cutting parameter such as (feed, velocity of cutting) was also found to significantly contribute towards generating residual stress. The cut depth, however, concluded as an insignificant parameter towards residual stress on hoop.

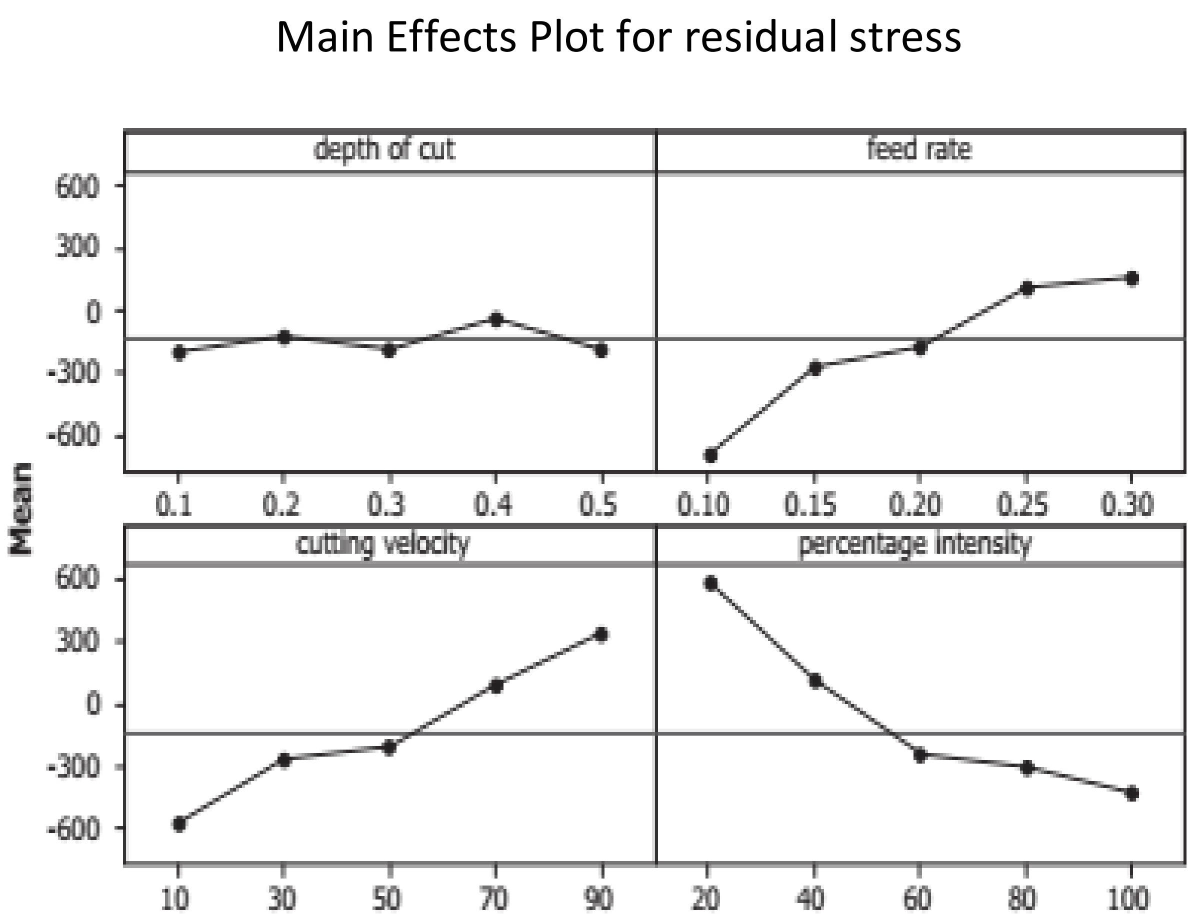


Fig.2.1 Key impact drawing of different parameters on residual stress [9]

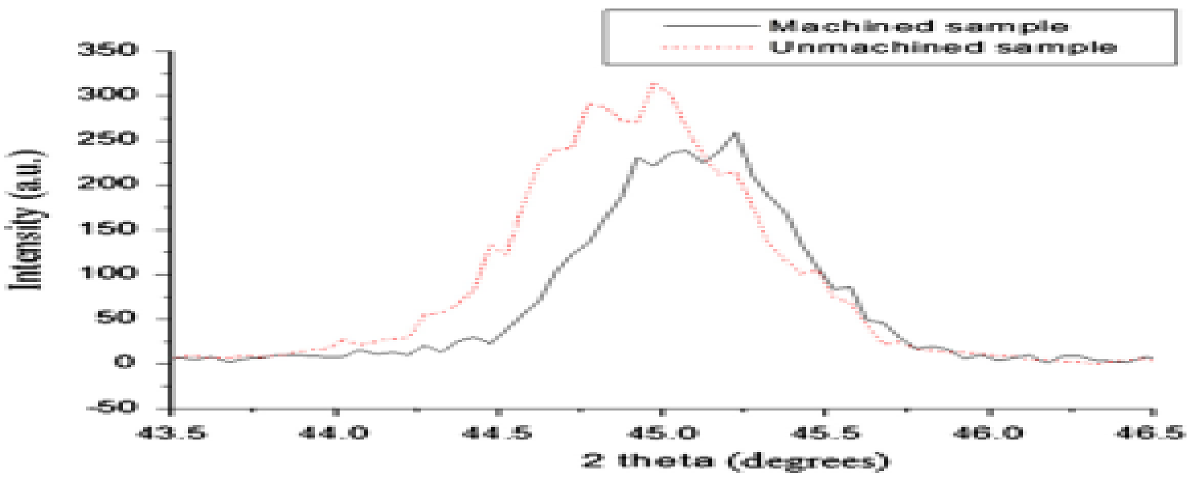


Fig.2.2. XRD plot showing machined and un-machined specimen [9]

Okasha et al. [10] are investigating the impact of certain turning different factors and tool overhanging on surface roughness factors and the residual stress created by 6061-T6 aluminum alloy machining. He concluded that process parameters are optimized using Taguchi relationship analysis and that the favorable cutting conditions to minimize roughness of surface is t1n1f1d5 while t3v4f5d1 is used to reduce tensile residual stress. He reported that feed rate was most influenced by surface roughness parameters. He also stated that minimal residual tensile stress can be acquired by a mix of 37 mm tool overhanging with very little DOC, rotational speed of rotation is low and 0.188 mm / rev feed rate.

Patrik Dahlman et al. [11] research the effect of angle of rake, feed and DOC on hard turning residual stresses. Feed and DOC were investigated in this study but the main task was on the impact of rake angle. His study of work tells us that as we move towards the negative side of rake angle we are going to get more stresses which is compressive in nature. He also said at the same time that we will get broader affected areas under the surface and as we increase the feed then again the stress in compressive form increases. J.L. Lebrun et al. [12] in his work tell us about the role of residual stresses while doing the orthogonal cutting and he has done his work in material AISI 316L and the resulting steels, paying attention to the role of cutting variables such as cutting speed, feed, geometry of the tool and coating of tool. He concluded that Feed rate had a strong impact on the profile generated by residual stress (the compressive point depth; the zone affected by cutting). As this parameter increased, it increased the temperature levels and also positively regulated the shape of the chip. In this situation, mechanical and thermal effects were absolutely interdependent. O¨ zel et al. [13] in his study deals with TiAlN coated and uncoated tool and he did this on two selected material Ti–6Al–4V and other one IN100 and he did face turning on these two material he selected for his operation and he also changes radii and then he comes to know that as radius of edge is increases then compressive nature of stress dominate and he also get to know that tensile nature dominates while using coated tool. Thus in his study he measures both compressive as well as tensile nature of stress. He uses finite element model of 3-D for this conclusion.

Malek HABAK et al. [14] demonstrate the impact under upper limit of pressure generated by water jet on surface residual stresses and chip shape, directed to interface of chip tool, investigated in face turning of AISI 316L stainless steel. The cutting speeds taken here are 80 m / min to 150 m / min, feed here taken is 0.1mm/rev and doc being 0.1 mm. MPa 20, 50 and 80 are the three pressure that is being created by water jet. A well fragmented chips can be created if we opt for jet which is having high pressure directed to the interface of tool and chip as opposed to continuous chip formed by dry-turning. The shape of the chip can also be controlled and the tool life increased. From this paper we come to know that if we increase the pressure of water with the aid of water jet, then we will get less residual stresses on the surface. N.S. Rossin et al [21] in his paper give his insight on how to measure residual stresses and also help us in classifying them based on their behaviour. He concluded that ductile materials are inspected for residual stress by x-ray method of diffraction but one drawbacks are that his all this research is laboratory based and suitable for component which are small in size. Vijay Kumar et al. [34] worked on EN19stainless steel using carbide as cutting tool for turning operation. He chosen CS, FR DOC and Lubricant as the initial factors while SR and MRR are the responses he needed to optimize. Taguchi's L18 orthogonal array he has chosen and he applied ANOVA for the authenticity of process factors. Rajesh Kumar et al. [35] has taken high carbon high chromium steel as work material and conducted CNC turning process by taking input as CS, DOC and FR and optimized roughness of surface and MRR by using Taguchi method. Using regression and variance analysis, optimization is achieved and orthogonal L9 was used. N. Satheesh et al. [36] worked through CNC sturning on Carbon Alloy Steel to understand the effect FR and CS had on the SR. Author selected five separate carbon alloy steel groups namely SAE8620, EN8, EN24, EN19 and EN47. Results shows that SR is directly proportional to FR while cutting speed is inversely proportional. Roopa Tulasi et al. [37] did work on EN24 steel to gather Surface Roughness information that is affected by various parameters such as CS, FR, DOC, Nose Radius, and Rake angle. Experimentation was conducted on conventional lathe, and Taguchi 's approach was the method adopted for optimization. The cutting parameters considered for the cycle are likely to be at a cutting speed of 400 rpm, feed will be maintained at 0.25mm / rev and finally DOC will stay close to 0.5 mm. C.L. He et al. [38] tried developing a model for checking surface roughness through turning. Surface Roughness is primarily studied through analytics via modeling part and then practically considered through ISO standards, thereby finally the modeling factors are categorized into easy and difficult ones. The author finally discussed about the advantages and disadvantages of the modeling and also mentioned about the future scope of the current work. D. Palanisamy et al. [39] started the process on PH stainless steel as work material and grey fuzzy approach being used, which has the power to sustain mixed profits from both the fuzzy logic approach and the gray system. Surendra et al. [40] conducted the CNC turning process on Aluminum alloy 8011 employing L27 Taguchi OA for experiment performance in which the inputs such as CS, FR and DOC were controlled while the output parameters for the experiment were SR and MRR. Taguchi fuzzy framework was chosen for optimization of the experiment. Results showed that feed has remained the key factor besides DOC and then the cutting speed. Korimilli et al. [41] did work on Aluminum 7075 alloy to determine the surface performance and stress generated once turned on CNC by changing inputs such as CS and DOC and by calculating RS and micro hardness at varying circumferential points of the sample using Digital Vickers Micro-hardness tester. Calculation of residual stress using X-Ray diffraction process. Results obtained help in determining service life. Sudhansu et al. [42] experimented on AISI 4340 steel using CVD to investigate different factors, including chip morphology, flank wear and surface roughness, using L9 OA to build a design model with 3 input selected, namely CS, FR and DOC. Results showed that operations CS and FR played a dominant role in manipulating wear on the SR and flank.

Experiments were conducted using Scanning electron microscope for structuring the chips. MRA was used for the mathematical model being prepared for optimization purposes.

Meng Liu et al.[30] is presenting an experimental study in which he considered noise radius of tool and tool wear during hard turning done on JIS SUJ2 bearing of steel for residual stresses .in this three noise radius of tool is being taken which are as (0.4,0.8,and 1.2mm).In his work we get to know that tool nose has very significant impact on residual stresses. It was concluded that radius of nose is indirect relation with force of thrust and thus it is clear from this paper that as we increase the radius of tool, force of thrust to force of cutting ratio rises and also force of thrust to force of feed also rises

2.3Research Gap

The following research gap has been identified based on literature survey

- The literature did not explore the surface characteristics of super alloy inconel718
- In the literature, the residual metal stress of super alloy inconel718 was not investigated much using CNC turning.
- Machinability has not been investigated much in CNC turning.
- The chip tool interface temperature was not thoroughly studied during machining.

2.4 Research Objective

The following study goal was drawn on the basis of a detailed review of research survey

- To carry out the experiment on CNC machine by changing the various input factors i.e. CS, FR, DOC.
- To research the impact of process variables such as CS, FR and DOC on surface roughness and residual stress while CNC turning of the super alloy Inconel718 super alloy
- Statistical study of process variables in CNC turning

Chapter3

3.METHODOLOGY

Residual stresses are stresses which remain in material even after the load is removed from the sample on which a particular operation being conducted. They may be positive (tensile) or negative (compressive) depending upon the certain condition that is being applied to material. There are various methods for measuring the residual stresses developed in material and we have listed some method as follows:

3.1. DIFFERENT RESIDUAL STRESS MEASUREMENT METHODS

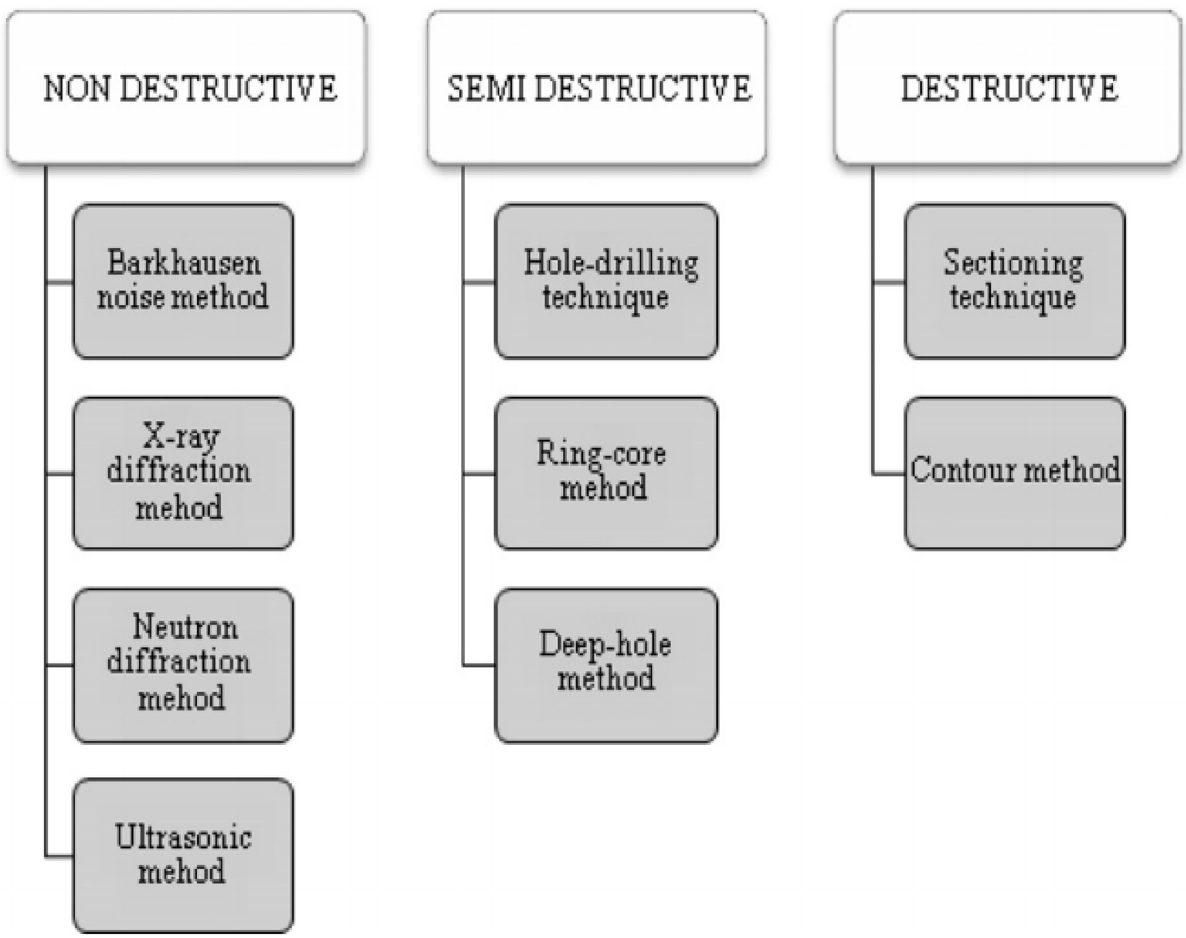


Fig. 3.1 Residual stresses measuring methods [21]

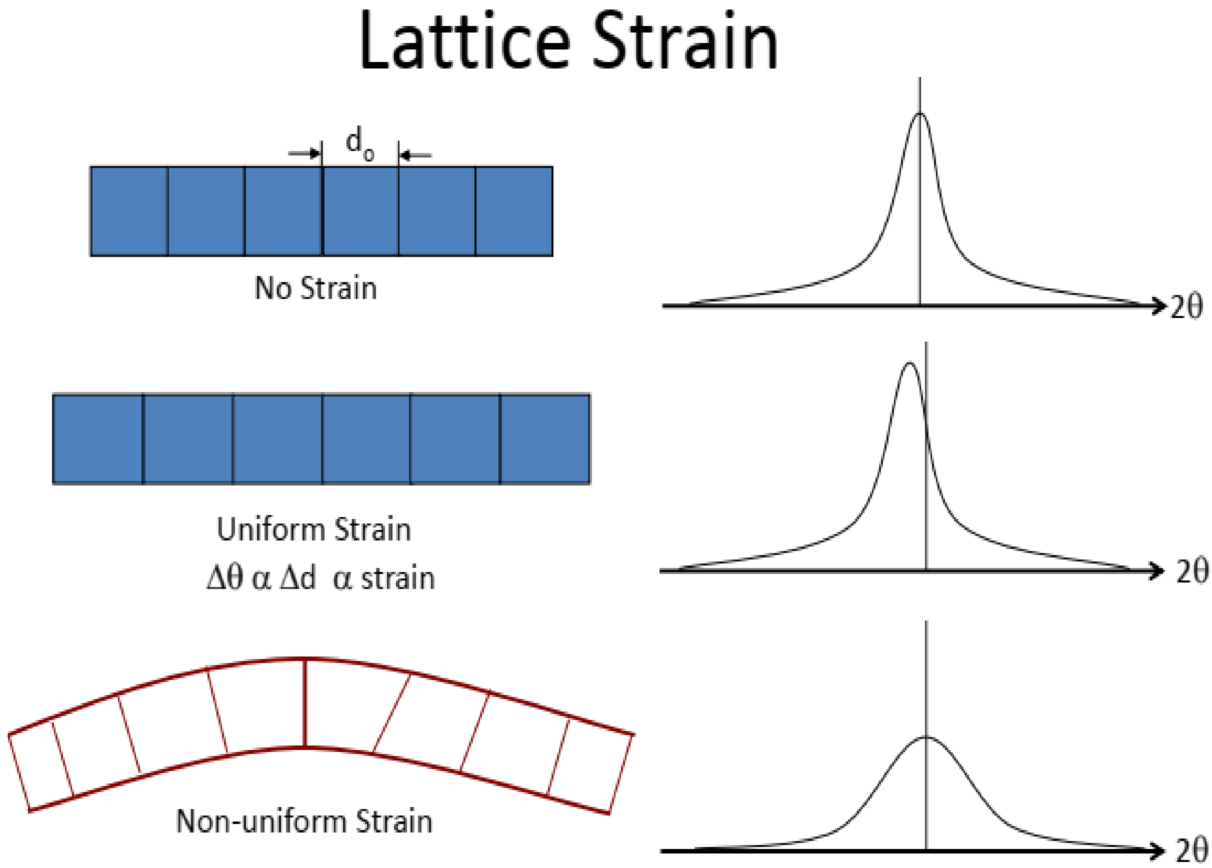
3.2 Diffraction techniques

Methods of diffraction are established on evaluating the deformation of elasticity that will induce variations in interplanar spacing, d, from their stress-free value, d0 Then, the strain can be measured by the law of Bragg and, a precise assessment of interplanar spacing freed from stress is required.

.

Fig:3.2 X-Ray diffraction machine [61]

Image source: Precision Manufacturing Lab, Department of Mechanical Engineering, Delhi Technological University; Dated: 29/01/2020



3.2.1 X-ray diffraction method

The X-ray [21] being non-destructive method used to calculate residual stresses on material surface. Residual stress analysis of X-ray diffraction, estimation of the strain in the crystal lattice and estimate of the residual stress causing the strain, given that the crystal lattice is bent linearly elastically. The strain in the crystal lattice has to be calculated for min two precisely familiar orientations in respect to the sample surface to determine the stress. Thus, residual stress calculation of x-ray diffraction is restricted to materials that are crystalline, fairly fine grained, and that generate diffraction for any sample surface orientation. X-ray diffraction manipulate that when metal is below the material's yield strength, inter-atomic strains in crystals are absorbed by knowing the material's elastic constants and implying that stress is in fact proportional in regarding to strain, a fair guess for most practical metals and alloys.

3.2.2 Table showing the application of x-ray diffraction technique

Serial number	Author Name & year	Title
1.	Sharma, V., & Pandey, P. M. (2016).	Optimization of the machining and vibration parameters for residual stresses minimization of 4340 hardened steel in ultrasonic assisted transition.
2.	Meng Liu, Jun-ichiro Takagi, Akira Tsukuda (2004)	Impact of tool nose radius and wear of tools on the distribution of residual stress in hard turning of bearing steel
3.	Özel, T., & Ulutan, D. (2012).	Prediction of machining induced residual stresses with experiments and finite element simulations in the turning of titanium and nickel based alloys
4.	Patrik Dahlman, Fredrik Gunnberg, Michael Jacobson	The influence of rake angle, feed cutting and depth cutting on the residual stresses in hard turning.
5.	Philippe Revel , Nabil Jouini b, Guillaume Thoquenne, Fabien Lefebvre	High precision AISI 52100 bearing steel turning heavy.

3.2.3 Advantage of using x-ray diffraction

- Cheapest, most convenient.
- Method widely employed for determining crystal structures.
- Best Phase Analysis Method.
- X-rays are not quite detected by air, so the sample doesn't need to be in an evacuated chamber.

3.2.4Disadvantage of using x-ray diffraction

- X-Rays don't interact with light elements very strongly
- The force is 10 ^ 8 times greater than that of diffraction by electrons.

3.2.5 DIFFERENCE BETWEEN TWO METHOD IN TABULAR FORM

Serial number	x-ray diffraction	Neutron diffraction
1.	x-ray is the cheapest the most convenient and widely used method.	Neutron sources in the world are limited so neutron diffraction is a very special tool and very expensive.
2.	x-ray interact with the spatial distribution of the valence electrons.	Neutron are scattered by the atomic nuclei through the strong nuclear forces. In addition, the magnetic moment of neutrons is non-zero, and they are therefore also scattered by magnetic fields.

3.2.6 Application of x-ray diffraction [21]

- Distance bonding, bond angles and angles of torsion between atoms;
- Determining absolute conformance;
- Solvent molecules found in crystal lattice;
- Description of intra and/or inter-molecular interactions (e.g., bonding with hydrogen).
- Packaging diagrams that show the molecules arrangement within unit cells and may reveal the presence of channels, voids, helices, etc.

3.2.7 Neutron diffraction method

The method of neutron diffractions [22] is very alike to X-ray Process Since it relied heavily on elastic deformations within a crystalline sample which lead to changes in the lattice plane spacing from its stress-free state. Use of diffraction of neutrons in the resolution of important problems in engineering has become rampant in the last two decades. Similar to the X-ray approach, the advantage of the methods of neutron diffraction is its more depth of penetration. In addition, the technique of X-ray diffraction limitations in the calculation of residual stress across a welded structure's thickness.

3.2.8 Barkhausen noise method

It is based on a principle of noise-like inductive signal measurement, created when a magnetic field is done with ferromagnetic specimen. Compressive stresses will reduce Barkhausen intensity of noise whilst stresses related to tensile will raise it.

3.2.9 Hole drilling method

Hole drilling method will calculate residual macroscopic stresses close to surface of the Ingredients. The principle is based upon the drilling into material of a small hole. When the residual stress material is removed the rest of the material reaches a new state of equilibrium.

3.2.10 Ring core method

A mechanical method used here is ring-core technique as a function of depth to compute the main residual stresses. The heart of the ring being based on theory of linear elasticity and consisting of splitting a circular plug with a strain gage. An on-line computer monitors the change in strain as a function of cut profundity.

3.2.11 Deep-hole method

In the deep-hole method, the part thickness is first drilled through a hole. The hole diameter being precisely measured and then a layer of material is trepidated around the hole, releasing the residual stresses in the layer.

3.2.12 Sectioning technique

Sectioning technique is a destructive method that focuses on deformation calculation due to residual stress release upon removal of material from the specimen. The sectioning method consists of cutting of an instrumented plate to remove the residual stresses that reside on the line of cutting.

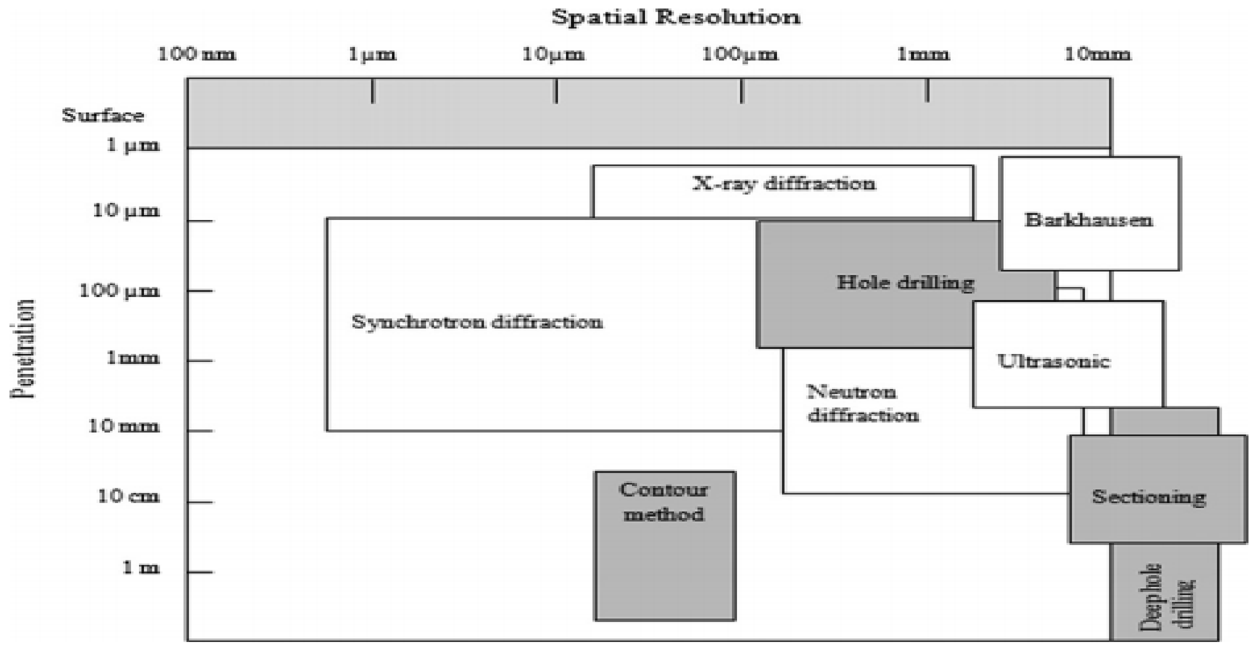


Fig:3.3 Depicting spatial resolution and penetration for different methods. The destructive and semi-destructive methodologies are grayish in color [22]

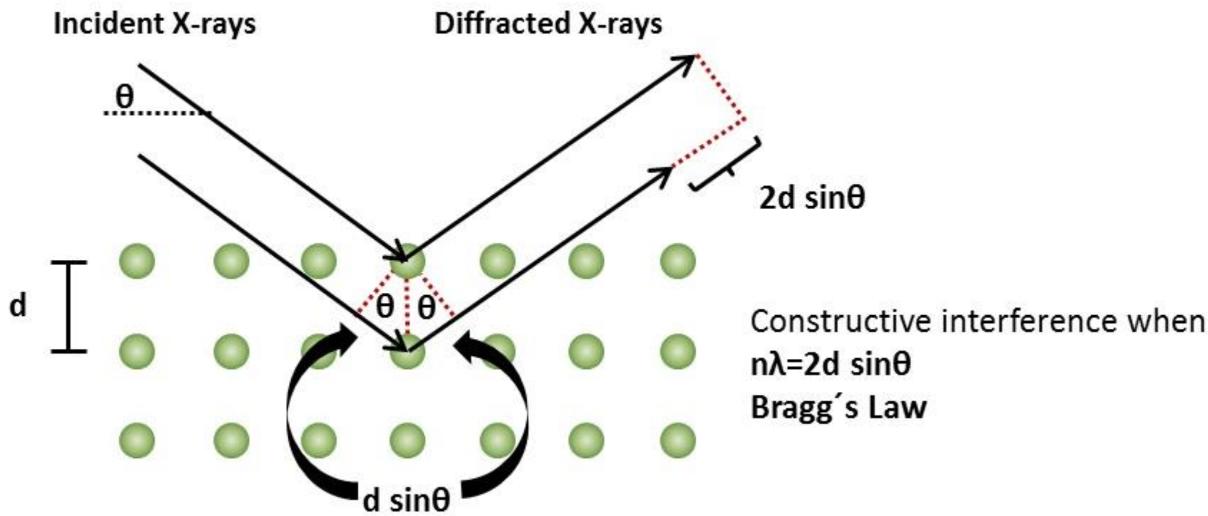


Figure3.4: Structured x-ray diffraction diagram

3.2.13 Cos α Method

The typical Sin2ψ methodology with just a point detector (diffract meter) involves a series of calculations with different sample configurations with regard to a diffract meter to perform the mapping of a strain tensor across the various specific scattering vector configurations, so these instructions being chosen to ease subsequent evaluation.

As each entity with in Debye loop emerges from a unique angle of the resultant matrix for such a given test profile in laboratory places, the whole Debye loop can be used for a separate test by using a 2D detector and a number of propagation matrix configurations are concurrently checked. Use of portable residual stress detectors has now increased, due to its simplicity Due to its ability to detect a whole Debye loop at once from the two-dimensional sensor, the cosα method has arose as a faster and easier method of experimentally evaluating remaining stress while using mobile equipment, so that no different test tilts a*re needed as in the case of* Sin2ψ technique.

3.2.14 Portable X-ray machine with Cos α method to compute residual stress

Pulstec Ltd. is a portable industrial firm. Upon turning of AISI 8620 steel specimen, the remaining stress analyzer (μ-X360) placed on a strong board is used to assess residual stress. Specific marks on the Turning samples being numbered after moving around the tube shaft over the length of the sample. The stress analyzer's detector gun is likely to achieve accurate tests from an angle of 35 ° for ferrous metal. The specimen is placed on the working panel helping the surface to be tested with residual stress producing a red laser position on the spot in which X-ray beam is to be conducted.

3.2.15 The residual stress principle, using the Cos α method

This technique acquires the full Debye-Sherrer circle. A Debye-Scherrer cycle is obtained using an image panel (IP) and the image data as tested to assess the impact of the stress. The conversion of the test scheme (diffractometer scheme) into specimen scheme is significantly more complex because of the study's 2D planar shape. The geometric interpretation of the directions on the Debye ring was shown in figure 3.5.

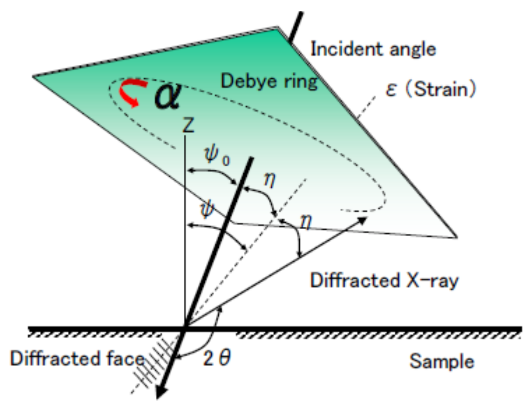


Figure3.5: Geometric display on the Debye ring of the angles α, parallel, π and 2

The expression for the translation of strain,

$\varepsilon_\alpha = n_i n_j \varepsilon_{ij}$

Where n is the diffraction vector, which can be expressed in the form

$$n = \begin{bmatrix} \cos\eta \sin\psi_o + \sin\eta \cos\psi_o \cos\alpha \\ \cos\eta \sin\psi_o sin\emptyset_o + \sin\eta \cos\psi_o \sin\psi_o \cos\alpha + sin\eta cos\emptyset_o \, sin\alpha \\ \cos\eta \cos\psi_o - \sin\eta \sin\psi_o \cos\alpha \end{bmatrix}$$

Now this value of n can be inserted into Hooke's law to form

$$\varepsilon_\alpha = \frac{1+v}{E} n_i n_j \varepsilon_{ij} - \frac{v}{E}\sigma_{kk}$$

The magnitude of strain is determined from the detected position of the Debye-Scherrer ring.

Calculate using the following formula.

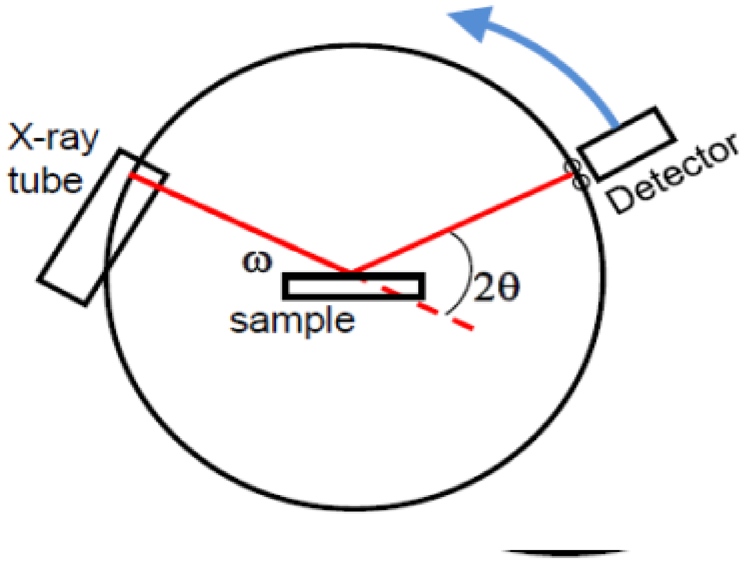
$$\varepsilon_{\alpha 1} = \frac{1}{2}\{(\varepsilon_\alpha - \varepsilon_{\pi+\alpha}) + (\varepsilon_{-\alpha} - \varepsilon_{\pi-\alpha})\}$$

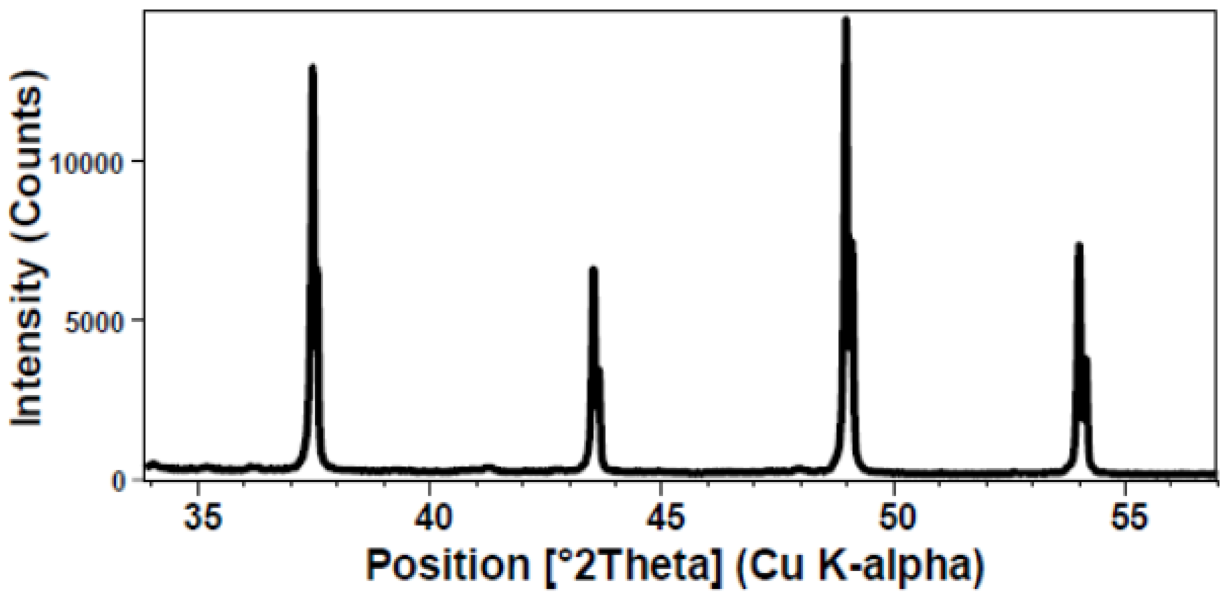
$$\varepsilon_{\alpha 2} = \frac{1}{2}\{(\varepsilon_\alpha - \varepsilon_{\pi+\alpha}) - (\varepsilon_{-\alpha} - \varepsilon_{\pi-\alpha})\}$$

Hence the value of stress is calculated from the strain using proper elastic and other constants.

$$\sigma_x = -\frac{E}{1+v} \cdot \frac{1}{\sin 2\eta} \cdot \frac{1}{\sin 2\psi_o} \cdot \left(\frac{\partial \varepsilon \alpha_1}{\partial \cos\alpha}\right)$$

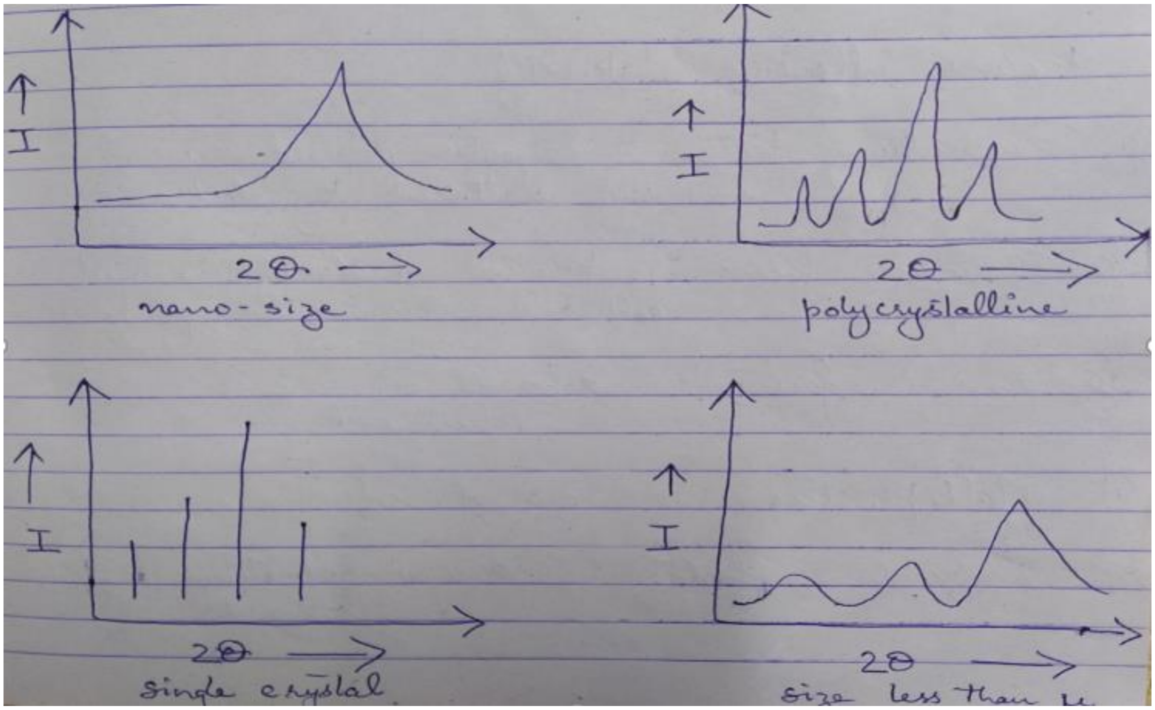
3.3.1 Plot of the intensity of X-rays scattered at different angles by a sample





- The detector rotates around the specimen in a circle.
- The location of the detector is reported as the 2theta (2θ).
- The detector writes down the number of X-rays detected at each angle 2θ.
- The intensity of the X-rays is normally reported as "counts" or "counts per Second".

3.3.2 Width of the peak gives the size of crystal



3.3.3 Factors affecting intensity

- **Polarization factor:** angular dependence of intensity scattered by electron.
- **Structure factor:** Position of atoms in unit cell and their scattering power.
- **Lorentz factor:** Depend on the instrument
- **Absorption factor:** Sample and geometry of instrument.
- **Preferred orientation:** If sample does not have complete random orientation.
- **Multiplicities:** Number of reflection

$$I \propto \frac{1}{2}\left(1+\cos^2 2\theta\right)$$

Where I=scattering intensity,

2θ= angle between direction of incident beam and diffracted beam

- For a given angle 2θ the net intensity decreases with decrease in X-ray wavelength.

Chapter4

4. Design of Experiment

Residual stress optimization in turning process consists of three main parts, namely;

1) CNC Turning Machine.

2) *Taylor Hobson Talysurf*

3)X-Ray Diffraction Machine.

4.1 CNC TURNING MACHINE

CNC Turning is a method of manufacture in which material bars are placed upon chuck and rotated as a tool is fed into the piece to extract material to produce the desired form. CNC Turning produces a distinct end product using computer-controlled machines. The process uses a single-point cutting tool that inserts the material to be cut parallel to. X, Y, Z axis movement is controlled by motor supplying either alternating current or Direct current. Computer movement is accomplished by issuing commands. All operations are performed using codes such as speed, feed, cut depth etc.

The main goal of using CNC Turning machine is to have products at much cheap manufacturing costs, much lower manufacturing times, and to increase life of cutter compared to conventional ones.

CNC Turning machine comprises the following main components:

1) Headstock
2) CNC Lathe Bed
3) Chuck
4) Tailstock
5) Tailstock Quill
6) Foot Switch or Foot Pedal
7) CNC Control Panel
8) Tool Turret

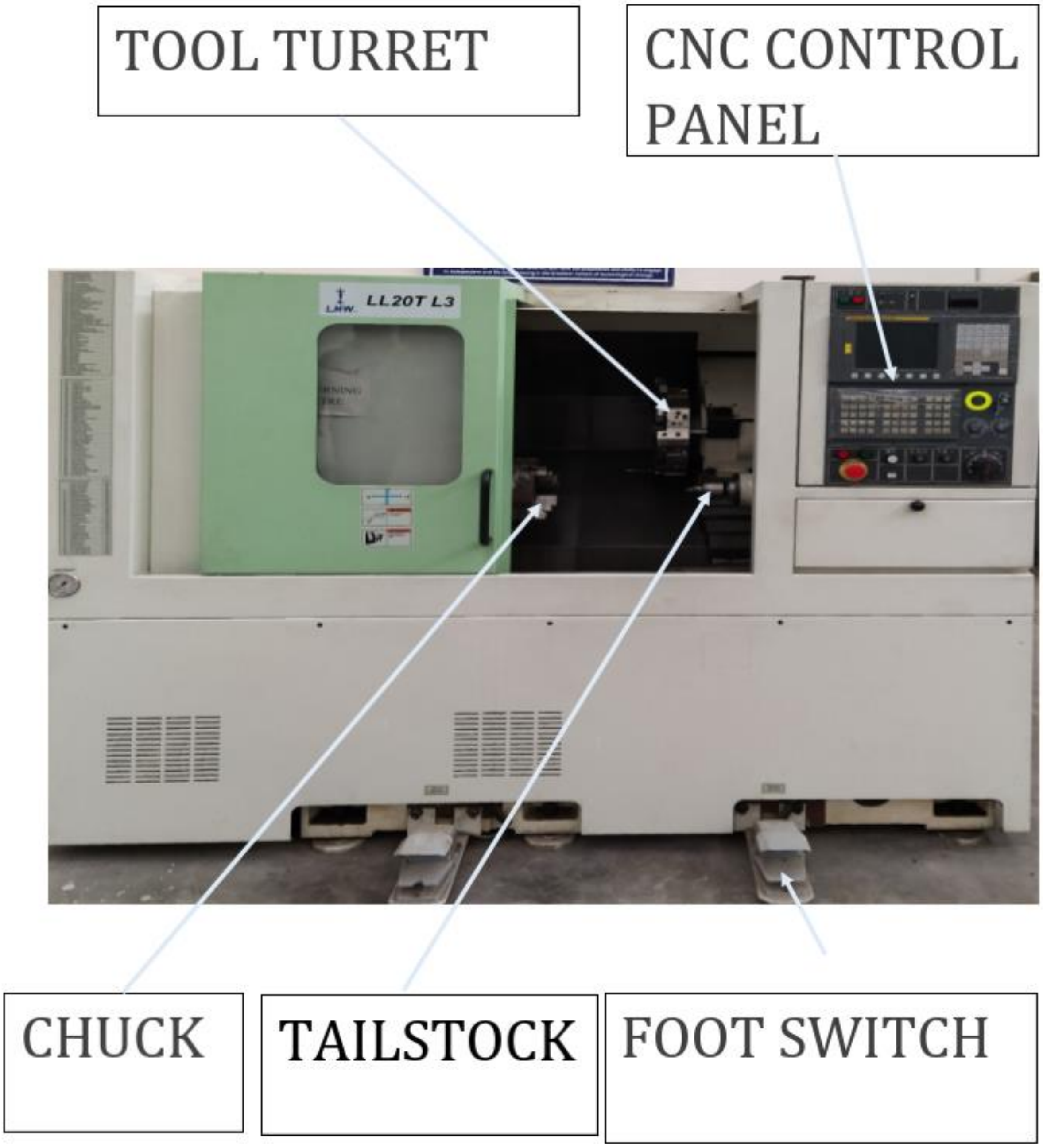


Fig:4.1 CNC lathe machine depicting its main features [62]

Image source: Metal Cutting Lab, Department of Mechanical Engineering, Delhi Technological University; Date: 25/01/2020

4.1.1 HEADSTOCK

Lathe of CNC headstock has the CNC lathe machine 's main motor which trying to move main spindle. On the main spindle is mounted Chuck.

Fig:4.2 CNC lathe headstock

4.1.2 BED OF CNC LATHE

The tool turret travels across the CNC lathe bed, which is specially hardened so that they cannot be affected by any kind of machining.

4.1.3. CHUCK

CNC lathe chuck machine hold the part which we have taken out for machining. There are many parts to Chuck himself. Jaws being put on the chuck to hold the part; CNC Machine Jaws an Introduction for CNC Lathe Machinists might read more about the jaws here.

Fig:4.3 CNC lathe chuck [62]

Image source: Metal Cutting Lab, Department of Mechanical Engineering, Delhi Technological University; Date: 25/01/2020

4.1.4 TAILSTOCK

Tailstock are often used to give the machining of components an extra gripping force. They give added force on the other end for the machining of long components hence machining process being completed easily. In the above picture you can see the component is gripped by the one end chuck and the extra force is provided on the other end tailstock.

Fig. 4.4 Tailstock [62]

Image source: Metal Cutting Lab, Department of Mechanical Engineering, Delhi Technological University; Date: 25/01/2020

4.1.5 TAILSTOCK QUILL

In reality, you push the entire tailstock either forward or backwards, but in this way it is not used to hold the element, but the tailstock is traveled to a point near the part and then it is placed there, after which you trigger the tailstock quill which either travels with hydraulic pressure or pneumatic pressure to hold the part.

4.1.6 SWITCH OF FOOT

Using switches of foot, the chuck and tailstock quill are realized. By opening and closing the chuck to grip the part through these pedals the CNC machinist takes the same manner the tailstock quill is placed reversed or forward by these pedals.

Fig:4.5 foot of CNC late switches [62]

Image source: Metal Cutting Lab, Department of Mechanical Engineering, Delhi Technological University; Date: 25/01/2020

4.1.7 CONTROL PANEL OF CNC

Inside this panel is stored the brain of the CNC machine, all program of CNC, CNC machinists regulate the entire machine through the keys on this panel. CNC machines start / stop the moving axis of the machine by touching various button on this panel.

.

Fig:4.6 CNC control panel [62]

Image source: Metal Cutting Lab, Department of Mechanical Engineering, Delhi Technological University; Date: 25/01/2020

4.1.8 TOOL TURRET

The tools are kept onto the turret of tool that is utilize for machining components. Tool towers differ in shape and tools number to mount on them.

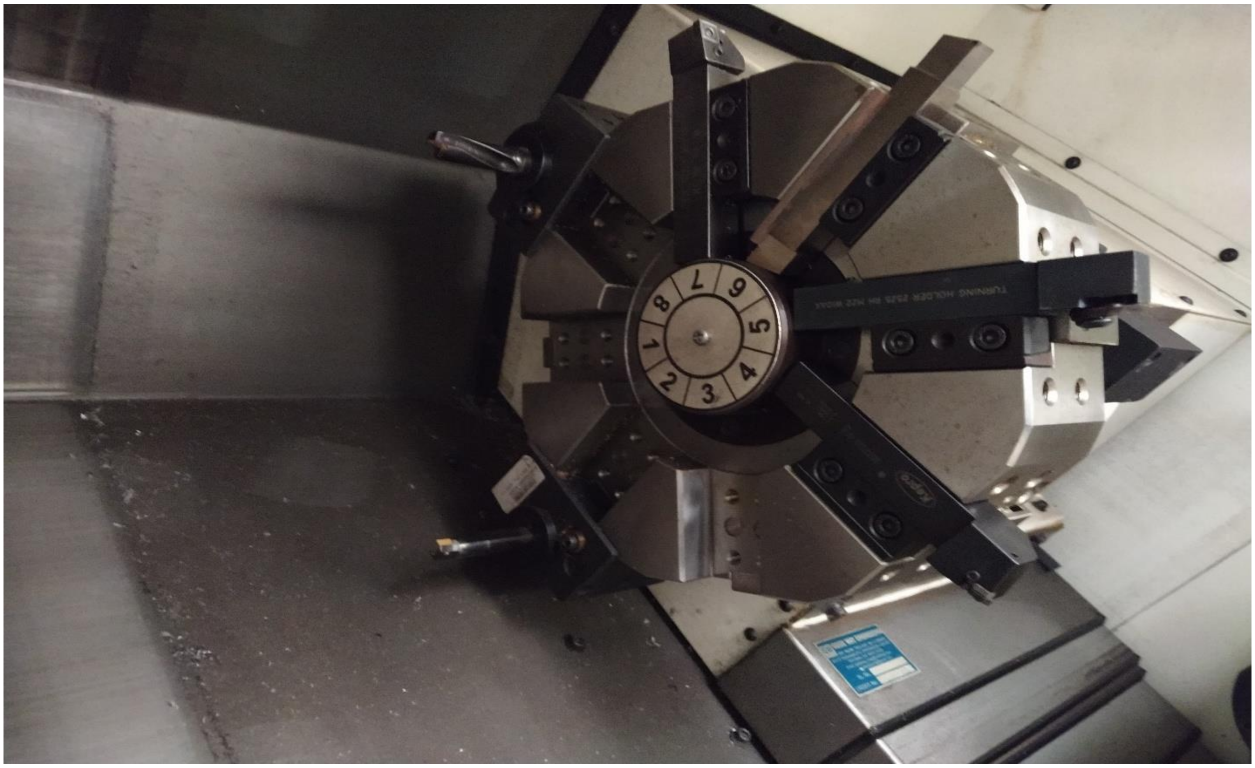


Fig:4.7: Tool turret [62]

Image source: Metal Cutting Lab, Department of Mechanical Engineering, Delhi Technological University; Date: 25/01/2020

4.2Taylor Hobson Talysurf

A skid or shoe sliced across the coating of the workpiece to match the general contours of the grounds as closely as is necessary. The skid also provides the stylus A stylus datum which runs along with the skid over the floor, so its movement is vertically close to the skid. This variable allows to track contours of the stylus

Of surface roughness independent of surface waviness. An amplification to magnify the motions of the stylus A recording machines to create an indication or record of the image on the surface.

The instrument was used in Metrology Lab, DTU. The Taylor Hobson Talysurf instrument of SURTRONIC S-100 SERIES is available in Metrology Lab.

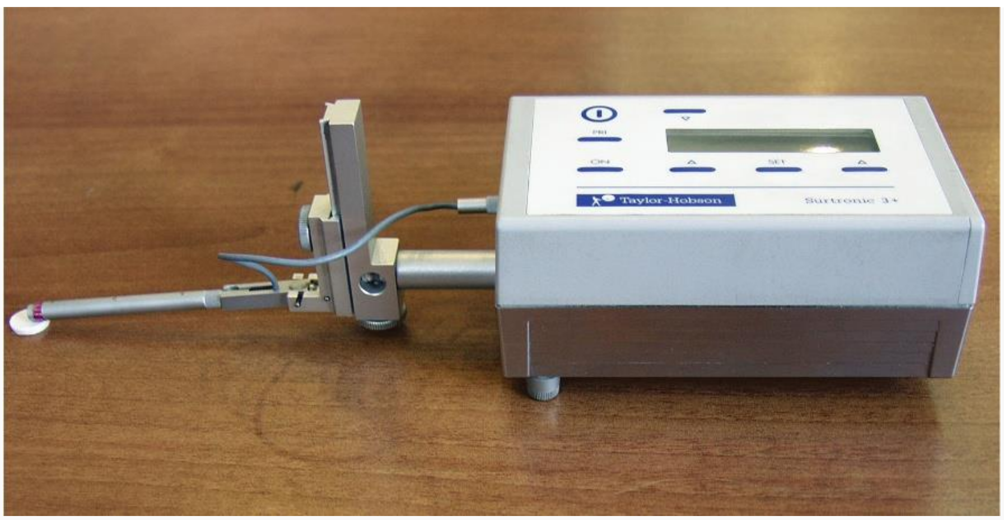


Fig:4.8: Taylor Hobson Talysurf instrument [63]

Image source: Metrology Lab, Department of Mechanical Engineering, Delhi Technological University; Date: 25/01/2020

The SR Measuring Instrument specifications are as follows:

- Measurement capability
- Gauge Range=200 µm / 100 µm / 10 µm
- Resolution=100 nm / 20 nm / 10 nm
- Noise floor (Ra)=250 nm / 150 nm / 100 nm
- Repeatability (Ra)=1 % of value + noise
- Pickup type=Inductive
- Gauge force=150-300 mg
- Stylus tip radius=5 µm (200 µin)
- Measurement type=Skidded
- Calibration Process=Automated software calibration routine
- Standards=Able to calibrate to ISO 4287 roughness standards
- Evaluation length=0.25 mm - 17.5 mm (0.01 in - 0.70 in)
- Measuring speed=1 mm / sec (0.04 in / sec)
- Returning speed=1.5 mm / sec (0.06 in / sec)
- Analysis capability
- Standards=ISO 4287, ISO 13565-1, ISO 13565-2, ASME 46.1, JIS 0601, N31007
- ISO basic=Ra, Rv, Rp, Rz, Rt, Rq, Rsk, Rmr, Rdq, Rpc, RSm, Rz1max
- Units=µm / µin

4.3 X-RAY DIFFRACTION MACHINE

For more than a century, the X-Ray diffraction machine being used to detect the structure of crystals, and the basic method did not change. A crystalline sample is inserted in an X-Ray beam path. X-ray diffracts through detector and through the quartz. The beam and detector are rotated around a number of angles. The angles at which the crystals are diffracting the beam into the detector correspond to crystal planes. Growing crystal has a personality trait pattern of diffraction angles and corresponding diffracted beam strength.

The X-Ray diffractometers are composed of the following parts;

1) X-Ray tube
2) Incident-beam optics
3) The Goniometer
4) Sample and sample holder
5) Receiving-side optics
6) Detector

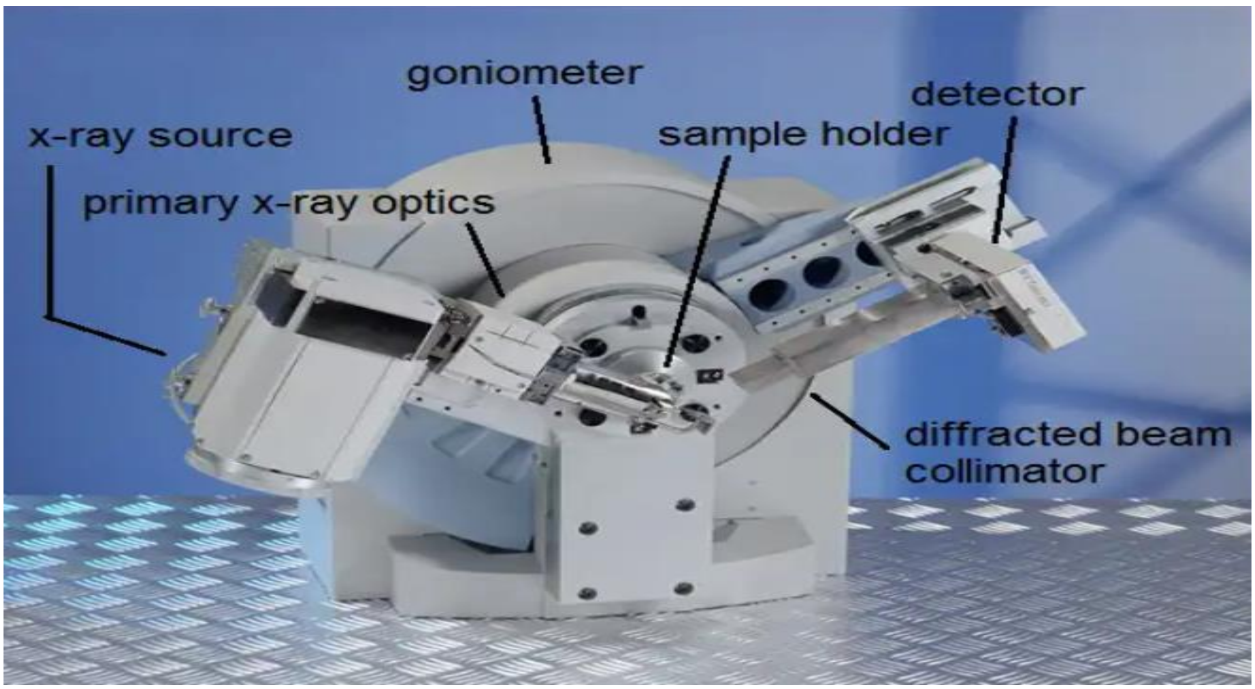


Fig:4.9: Main component of X-Ray diffractometer [64]

Table:4.3.7 Specification of X-ray machine (μ-X360) adopted from lab manual

Parameter	Standardized value
X-RAY TUBE VOLTAGE, Current	30KV, 1.0Ma
X-RAY TARGET MATERIAL	Chromium(Cr)
Beam wavelength(Energy)	λ=2.29 Å (E=5.4KeV)
COLLIMATOR AND BEAM SPOT SIZE	1mm and 2mm diameter
SAMPLE TO DETECT DISTANCE APPROX.	35-40mm
TPICAL DATA ACQUISITION +READOUT TIME	90 seconds

4.4 Experimental Procedure of Surface Roughness

SR was measured by following below steps of experimentation. Steps are described below:

- Taylor Hobson portable tool assess ground roughness. Three marks are marked on the finished layer of each sample.
- Samples are inserted in between the V-blocks for sufficient assistance and stabilization.
- A standard surface sampling system consists of a tiny stylus stage, a gage or transducer, a data crossing and a cpu.
- The floor is evaluated by moving the stylus across the ground traveling in a straight line to and from the surface, the transducer converts this motion into a message which is then conveyed to a computer which converts it into a script and usually a spectral interpretation.
- For correct compilation of information, the gage must keep moving over the substrate in a direct row, while only the point of the stylus hits the layer under study.
- After the exam is closed, the Ra result is collected for each specimen, and the median is collected.

4.5Experimental Procedure of Residual Stress

RS was measured by following below steps of experimentation. Steps are described below:

- RS measurements are made employing X-ray portable machine (μ-X360).

- Four markings are performed on sample surface to determine the RS in the prepared sample.
- Samples are placed under laser on the V-block.
- Collimator concentration is performed on specimens using laser to irradiate the indicated point.
- The position of diffraction peak and the stress values are detected and reported after a specific period.

Several research on CNC Turning has shown that machining factors like Speed, Feed, and DOC etc. have a major impact on mechanical characteristics of manufactured materials. In order to research the influence of individual variables, one may easily choose the conventional experiment design method, in which one factor differs at a time and the other stays identical. This concept involves several cycles of laboratory, and takes time. Furthermore, interaction effects of device parameters are ignored in this process.

The object of the experiment would be to see the effects of the input variables and to generate mathematical model to study the relationship between different parameters.

Following are the steps taken to achieve the above objectives:

1. Detection of essential control factors for processes
2. Deciding the functional scope of the control factors for the procedure, viz. Speed, feed and DOC
3. Creating the design network
4. Performing the assessment according to the design network
5. Record the response viz. Surface Roughness, Residual Stress
6. Constructing numerical models
7. Tests the appropriateness of the models
8. Finding the importance of coefficient
9. Construction of the final Models
10. Diagrammatization and conclusion drawing
11. Debate on the results

4.6.1 Identification of various control factors for processes

Three independently controllable system parameters were identified as particular, cutting speed, feed and DOC, based on the effect on CNC turning machining, ease of design, and desire-level maintenance capability. For this examination, surface roughness and residual stress were parameters of CNC turning geometry.

4.6.2 Considering the range of the process factors

Preliminary flows were generated by differentiating one of the system factors simultaneously, while retaining the steady significance of everything that survives. The working range was set by inspecting the geometry of the Turning process for a smooth appearance and the non-appearance of apparent deformities.

The upper and lower constraints were coded as + 1 and -1 each. We have chosen procedure parameters and their upper and lower restraints are provided along with documentation and units

Table 4.1: Operation control factors and breaking points

S.NO.	FACTORS	Units	Symbols	-1	0	+1
1.	CS	m/min	A	35.20	44.10	52.90
2.	F	mm/rev	B	0.10	0.15	0.20
3.	DOC	mm	C	0.2	0.3	0.4

4.7 Workpiece composition and its properties

The piece of work material taken in the analysis is Inconel 718 super alloy. In order to reduce the non-homogeneity of the test tracks, the first turning operation was conducted with a CNC turning center on the workpiece to minimize the diameter to 55.6 mm for a 230 mm span. The insert tool for cutting cemented carbide approved by ISO, TNMG 160408-MT coated with TiCN -Al_2O_3, is being taken as cutting tool.

Table 4.2: Inconel 718 Chemical composition

Alloy	%	Ni	Cr	Fe	Mo	Nb	Co	C	Mn	Si	S	Cu	Al	Ti
718	Min	49.8	17.2	balance	2.79	4.79							.19	.69
	Max	54.8	21.2		3.29	5.59	1.1	.09	.34	.34	.02	.29	.79	1.13

Table 4.3 Inconel 718 Physical composition

Density	**8.19g/cm3**
Melting point	**1261-1341 ℃**

Table 4.4 Inconel718 Alloy at room temperature with minimal mechanical characteristics

Alloy	Tensile strength Rm N/mm²	Yield strength R P0. 2N/mm²	Elongation A 5 %	Brinell hardness HB
Solution treatment	964	551	29.80	≤363

Inconel718 Characteristics listed below:

1. usability
2. Relatively high tensile power, endurance strength, creep endurance and rupture resilience at 700 ° C.
3. High stainlessness at 1000 ° C
4. Good mechanical accomplishments at lower temperatures.
5. Great performance of welding

Inconel 718 Metallurgical configuration

718alloy structure is austenitic, precipitation hardening generates "γ" which makes exceptional mechanical quality. The generation of the grain boundary “δ “results in great plasticity for treatment of heat

Inconel 718 resistance to Corrosion

718 Alloy with exceptional ability to withstand corrosion crack occurring due to stress and pitting potential under condition of higher or lower temperature settings.

4.8 Horizontal Lathe Specifications

LMW LL20T L3

Figure 4.10: CNC Lathe in Metal Cutting Lab [62]

Image source: Metal Cutting Lab, Department of Mechanical Engineering, Delhi Technological University; Date: 25/01/2020

Figure 4.9: Specimen after the cutting operation performed on the basis of Design Matrix

Table 4.4 Specification of Horizontal CNC Machine adopted by Metal Cutting Lab manual

CAPACITY	
Swing Over bed	510 mm
Chuck dia. Max	210 mm
Max. Turning diameters	320 mm
Max. Turning Length	310 mm
Admit between Centers	420 mm
SPINDLE	
Spindle nose type	A2-6
Hole through spindle	61 mm
Spindle speed	3000 to 3500 RPM
Spindle motor power	11 / 7.5 to 10.5 / 7
FEED	
Cross travel X-axis	185 mm
Longitudinal travel Z-axis	370 mm
Rapid traverse rate X/Z axes	30 m/min
TURRET	
No. of stations nos	8
Tool shank size mm	25 x 25 mm
Max. Boring bar dia	40 mm
Turret Indexing type	Bi-directional
Turret Indexing time	1.0 sec
TAILSTOCK	
Quill dia	75 mm
Quill stroke	100 mm
Quill taper	MT-4
CNC SYSTEM	
Controller	Fanuc / (Siemens)
MACHINE SIZE	
Front x Side	2065 x 1650 x 1920 mm
Weight	3200 Kg

4.10 Recording of responses

Recording of responses occurred after the experiments of Surface Roughness and Residual Stresses.

Table 4.6: Recording of responses

S.NO	Cutting parameter			Output responses	
	Cs	F	D	SR	RS
1	35.20	.10	.20	.980	560
2	35.20	.15	.30	.920	774.50
3	35.20	.20	.40	1.949	902.90
4	44.20	.10	.30	.690	608.90
5	44.20	.15	.40	1.29	1019.80
6	44.20	.20	.20	.94	981.90
7	52.90	.10	.40	.582	850.80
8	52.90	.15	.20	.92	1150.10
9	52.90	.20	.30	.72	1125.10

CHAPTER5

Analysis of Result and discussion

5.1 Experimental and Processing data results

The tests are performed based on Taguchi L9 orthogonal array.

Table 5.1: Experimental Responses and ratios of signal to noise

S.NO	Cutting parameter			Output responses		S/N ratio	Mean
	Cs	F	DOC	Surface roughness	Residual stresses		
1	35.20	.10	.20	.980	560	-51.9535	280.490
2	35.20	.15	.30	.920	774.50	-54.7701	387.710
3	35.20	.20	.40	1.949	902.90	-56.1025	452.424
4	44.20	.10	.30	.690	608.90	-52.6806	304.795
5	44.20	.15	.40	1.29	1019.80	-57.1600	510.545
6	44.20	.20	.20	.94	981.90	-56.8310	491.420
7	52.90	.10	.40	.582	850.80	-55.5863	425.691
8	52.90	.15	.20	.92	1150.10	-58.2044	575.510
9	52.90	.20	.30	.72	1125.10	-58.0135	562.910

Figure:5.1 Main effects of Plot for S/N ratio and Mean

- As our main purpose is to find the minimum surface roughness and residual stresses, so we would consider only those factors from the figure… in which S/N ratios have minimum value therefore we would say that cutting speed has minimum S/N ratios at 52.9m/sec so we take that value as our most optimized value from the three level of responses that we choose while performing the operation.
- And when we look into the feed rate we find out that S/N ratios are lowest at .20mm/sec so we take that value as optimized one and similarly we can that depth of cut is .4mm for smallest S/N ratio so we consider it as most optimized value.

Table 5.2: Analysis of variance(ANOVA) for residual stresses

Source	DOF	Seq.SS	Adj.SS	Adj.MS	F	P	%Cont.
Cutting speed	**2**	**132725**	**132725**	**66363**	**83.03**	**.012**	**37.81%**
Feed	**2**	**204428**	**204428**	**102214**	**127.89**	**.008**	**58.24%**
Depth of cut	**2**	**12282**	**12282**	**6141**	**7.68**	**.115**	**3.50%**
Error	**2**	**1598**	**1598**	**799**			**.455%**
Total	**8**	**351034**					

SS= Aggregate of square, Adj.SS=Adjusted Sum Square, Adj.MS=Adjusted Mean Square

%CONTRIBUTION = (Adj.SS/Total)

If $P<0.05$ then that factor has significant role to play in optimization of a particular process so from the above table, it can be stated that feed being the most important variable to play in optimization of residual process followed by cutting speed while DOC has insignificant importance to play in optimization of residual stresses as its P value being more than 0.05.

Regression Equation

Residual Stresses = 886.00 - 140.2 cutting speed_35.2 - 15.8 cutting speed_44.2
+ 156.0 cutting speed_52.9 - 212.8 feed_0.10 + 95.5 feed_0.15
+ 117.3 feed_0.20 + 11.3 DOC_0.2 - 49.8 DOC_0.3
+ 38.5 DOC_0.4

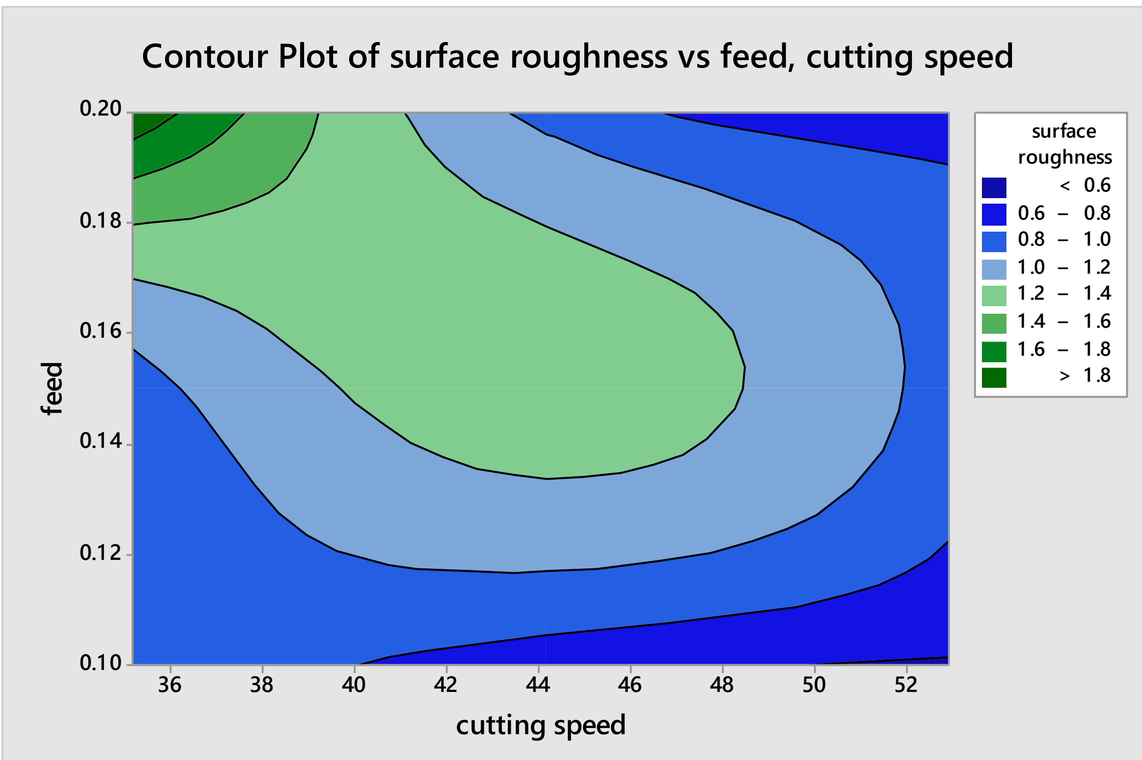


Figure:5.2 Contour plot of SR VS Fd, CS

Figure:5.3 Contour plot of RS VS Fd, CS

- These two above are contour plots for surface roughness and residual stresses which shows the effect of cutting speed and feed rate on surface roughness and residual stresses.
- Every section of surface roughness and residual stresses are marked with different colors to have a clear view and we get to know when and how these factors are going to alter the values of surface roughness and residual stresses.
- Like we can say that most minimum values for both the responses are marked with dark blue color.

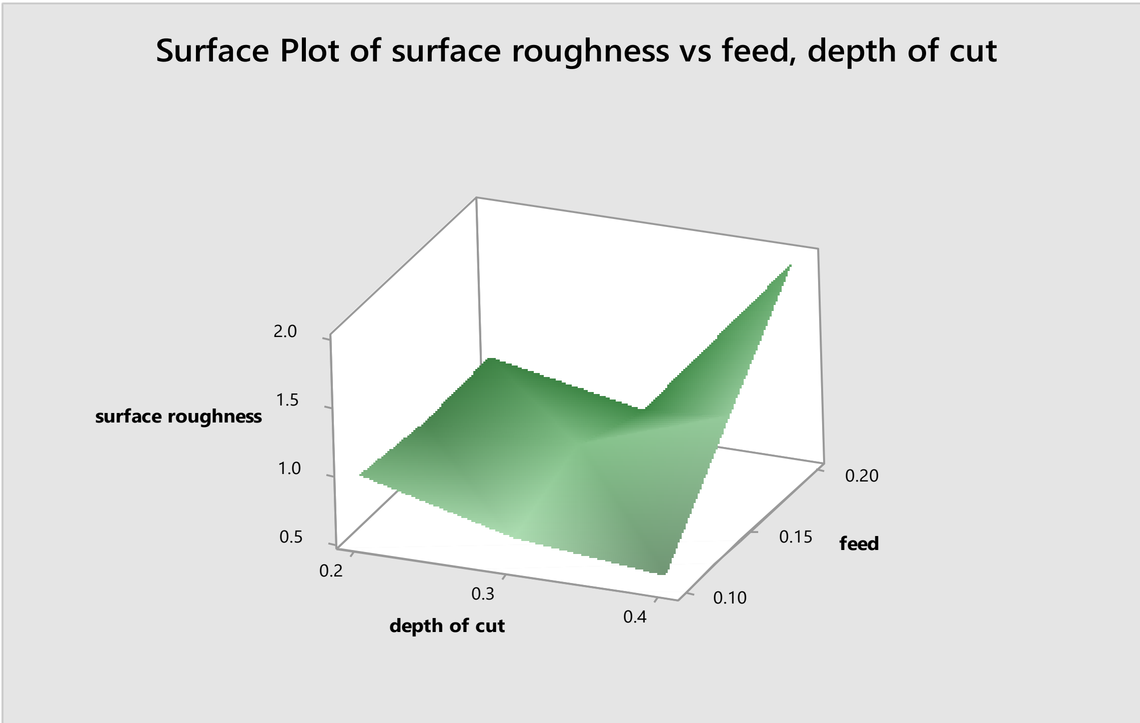


Figure:5.4 3D Representation of SR vs Fd, DOC

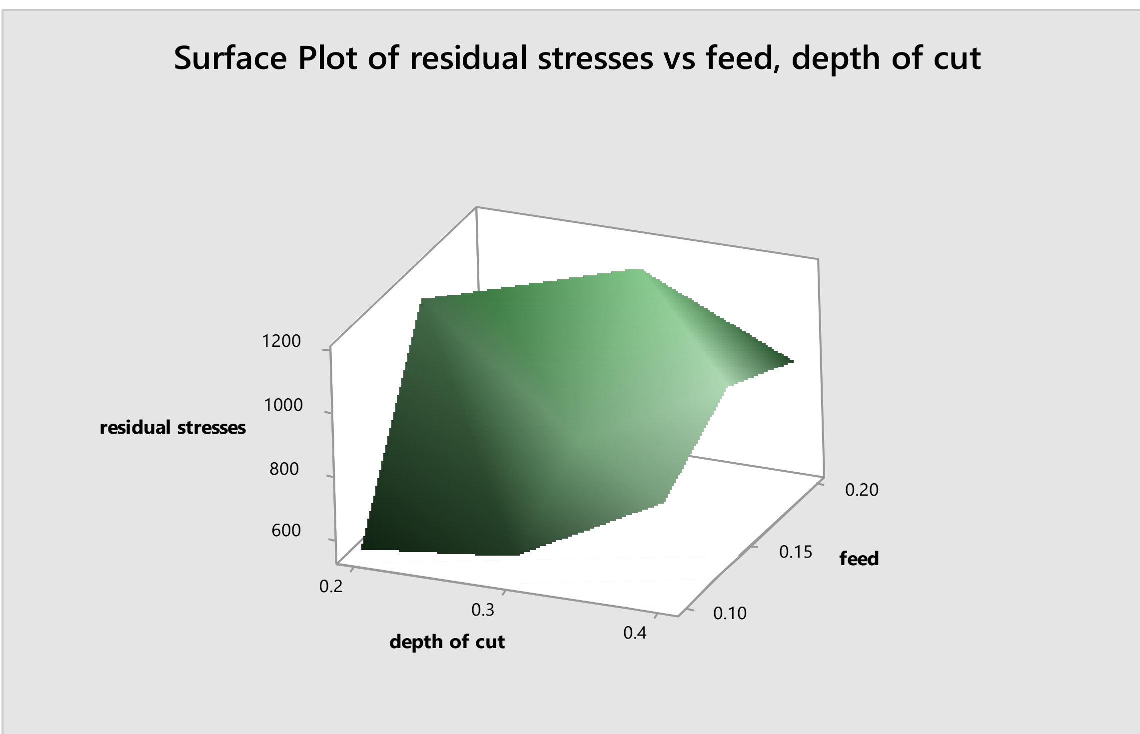


Figure:5.5 3D Representation of RS vs Fd, DOC

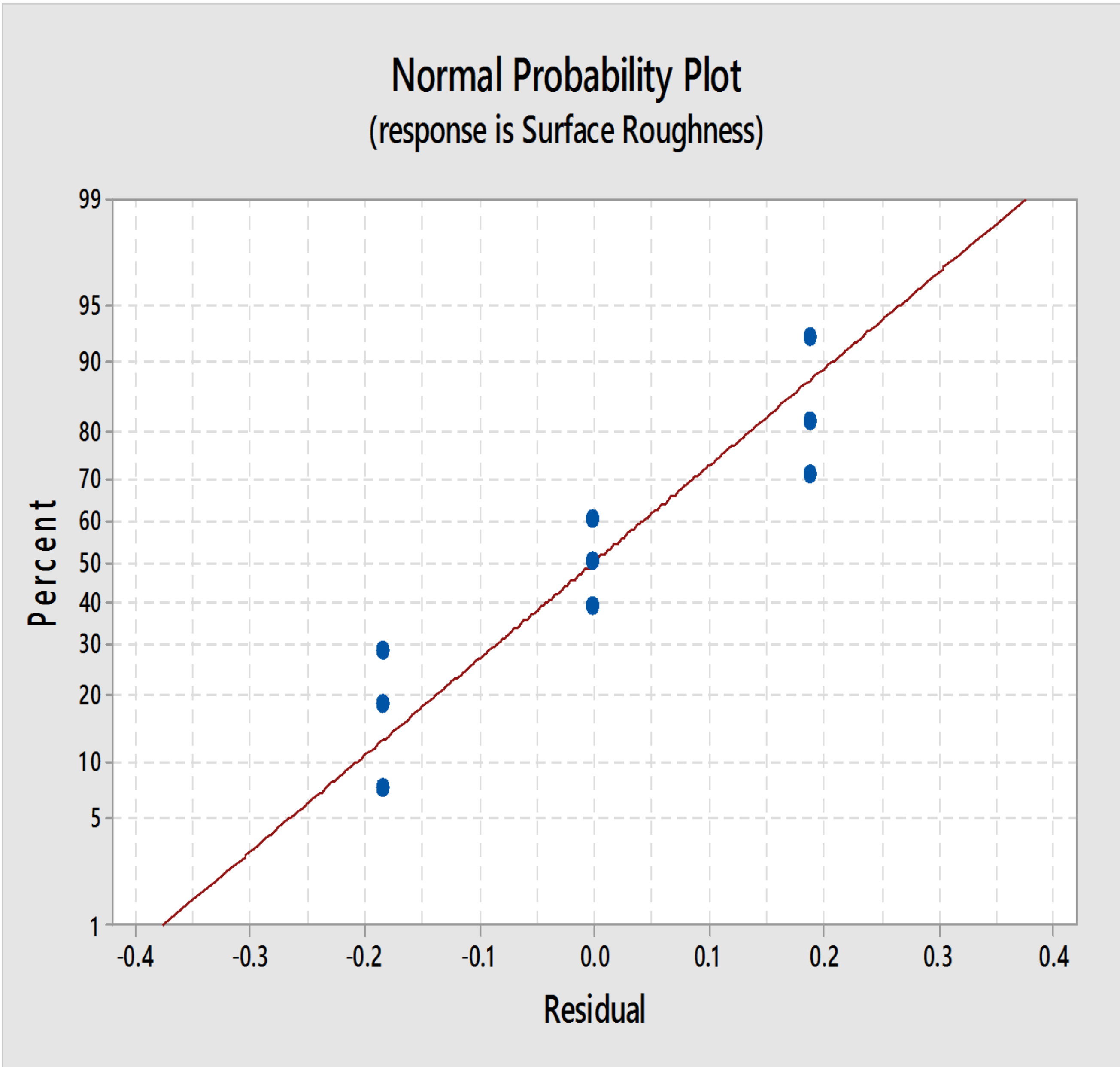


Figure:5.6 Normal probability Plot for SR

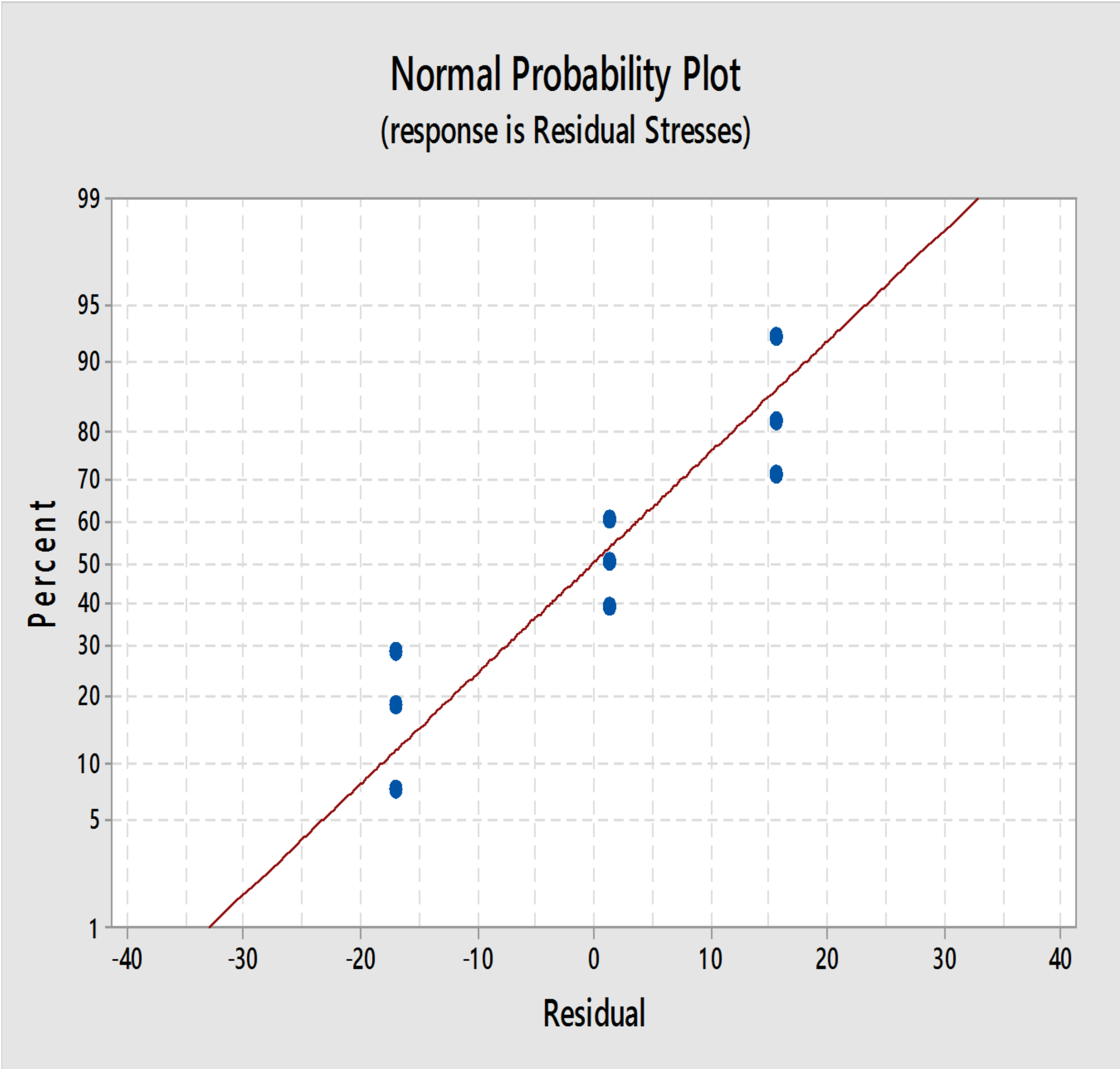


Figure:5.7 Normal probability Plot for RS

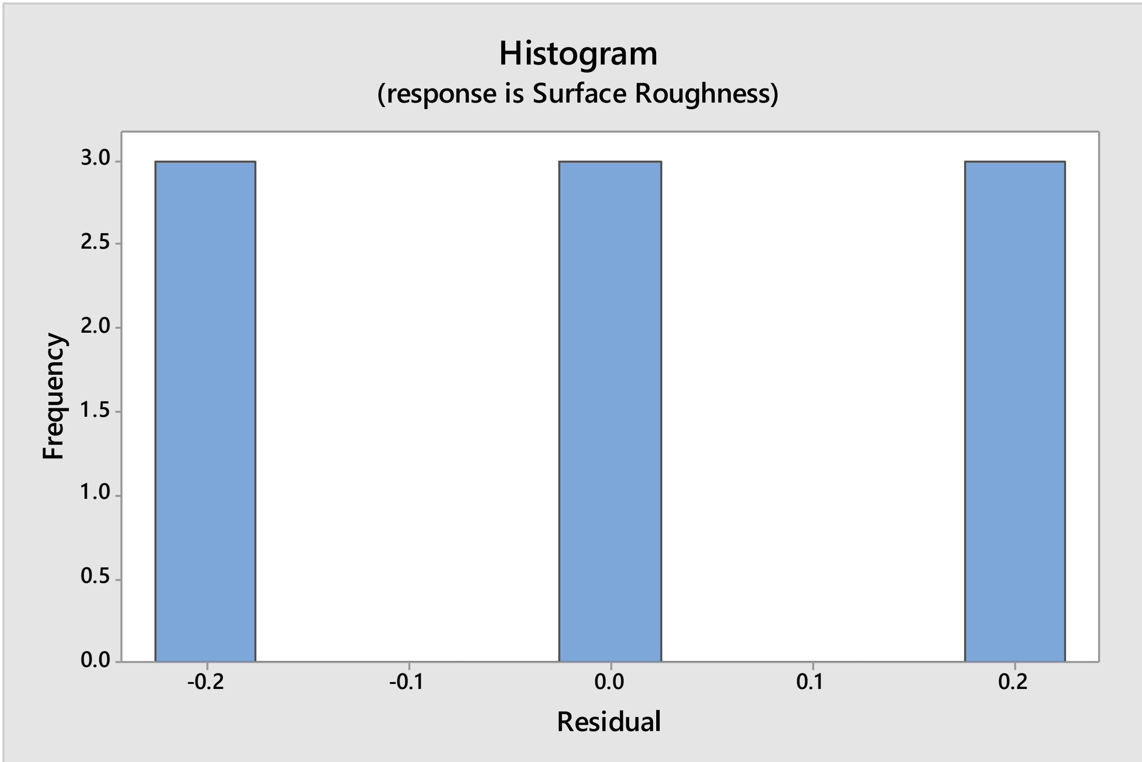


Figure:5.8 HISTOGRAM Representation for SR

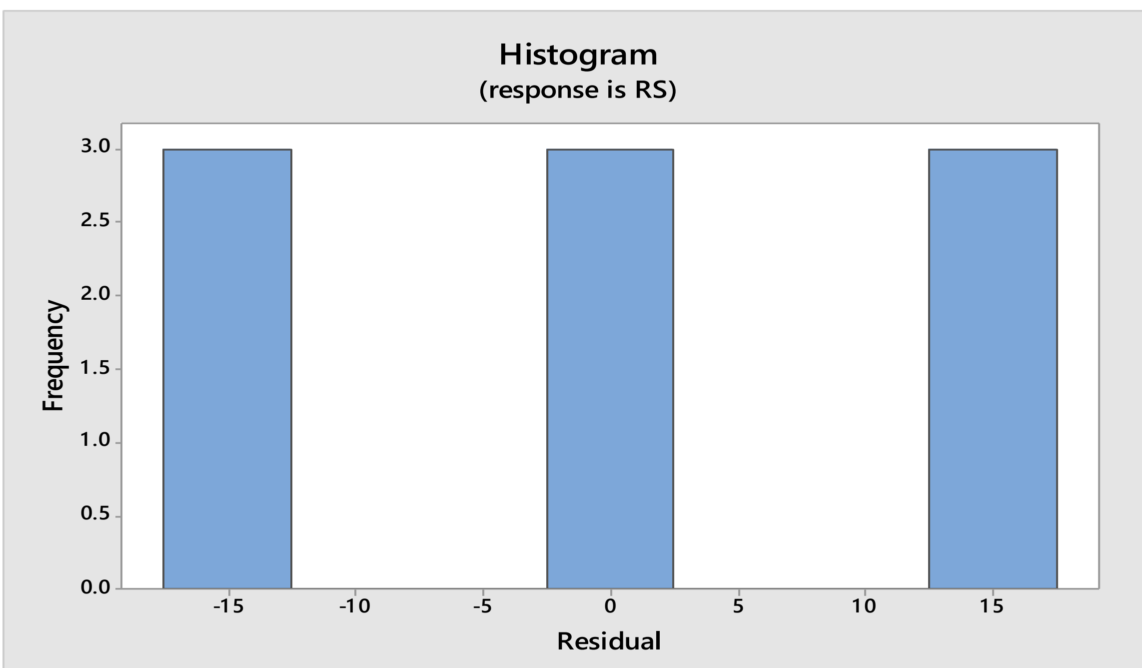


Figure:5.9 HISTOGRAM Representation for RS

5.2 Optimization using genetic algorithm

Genetic Algorithms study optimization techniques, focused on natural selection and genetics dynamics. [65] The strength of such algorithms stems from a really simple heuristic hypothesis that the optimal option would be identified with in areas of solution space having higher probability of viable solution, and that such areas could be found by careful and rigorous testing of solution space. The GAs mechanism is basic, involves binary string duplication and binary string flipping. The three stages are (1) Selection, (2) crossover, and (3) mutation [66]

(1) Selection: In this we select two or more parents from population for crossover. The purpose of doing this is to make sure that whatever filter we did in selecting individual from a population that offspring's have greater fitness function. For example: Roulette wheel selection, tournament selection etc.

(2) Crossover: This is the second stage after reproduction, is largely responsible for the search development. It partially replaces the parent string hence producing offspring. Through this, the length of the string is chosen unsystematically around the network and the parts of the strings are exchanged outside the crossover point. This can be single point or double point crossover.

Single point crossover:

Before 110**|**0110

After one-point crossover 1101001

(3) Mutation: It is coming at the last stage after crossover. This is individually applied to each child after performing crossover. In this, bits are changed like 0 is changed to 1 and 1 is changed to 0 randomly.

For example: string with 1010111 if we perform mutation only one first two bits then string after mutation would be 0110111.

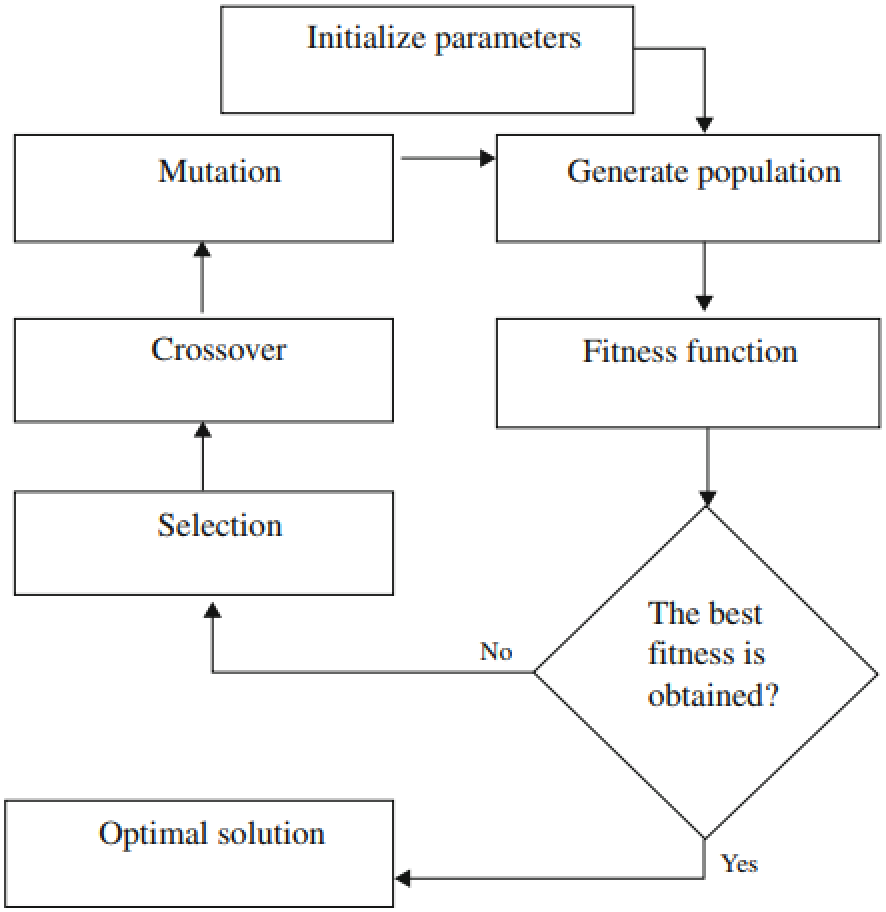


Fig:5.10 The flow of GA for optimization [67]

Explanation of Genetic Algorithm

- In genetic algorithm, we first create initial population of any size suppose N.
- Then we will evaluate the fitness function of each individual.
- Then through decision operation we check the condition for best fitness if condition gets true program terminates and we have the optimal solution else if condition gets false then
- We select a subset from initial population suppose N1 where N1<N
- Then we make pair of the selected population

- And we perform crossover which basically means we are going to transfer best genes of their parents into the offspring
- Then we perform mutation in which 0 is changed to 1 and vice versa, we do this in order to induce better features into the next generation
- And at last we again evaluate the fitness and check with the condition if true terminates their otherwise it keeps moving like that.

5.2.1Fitness function

In this study, the main task is to achieve minimum surface roughness and residual stresses and the fitness function for the given problem is written as:

```
function y = saad(x)

%UNTITLED Summary of this function goes here

%   It is a multi-objective function i.e. more than 1 function

%y (1) ---objective 1 ----equation for SR minimize

%y (2) ---objective 2 ----equation for RS minimize


%x (1) ---cutting speed

%x (2) ---feed

%x (3) ---depth of cut



%SR

y (1) = 1.182192-0.03066*x (1) +4.523333*x (2) +1.635*x (3)
```

%RS

y (2) = -387.102+16.71773*x (1) +3300.667*x (2) +135.8333*x (3)

end

subjected to constraints:

35.20<=x (1) <=52.90

.10<=x (2) <=.20

.20<+x (3) <=.40

Table:5.3 Combining GA parameter levels to have the desired solution

Parameter	Setting value
Population size	50
Mutation rate	0.2
Crossover rate	0.8

5.2.2 MATLAB OPTIMIZATION TOOLBOX

From MATLAB optimization toolbox, this analysis attempted to show the best possible results in many variations of the set values for cutting conditions. The right blend of those qualities will contribute to cutting parameters to a minimum SR and RS.

S.NO	SR	RS	Cs	Fd	DOC	SELECTION
1	.34	854.563	52.9	.1	.2	SELECTED
2	.882	558.691	35.2	.1	.2	
3	.696	667.55	41.492	.101	.201	
4	.368	839.01	51.969	.1	.2	
5	.487	780.49	48.255	.101	.2	
6	.343	853.091	52.811	.1	.2	
7	.6	715.091	44.49	.1	.2	
8	.442	800.345	49.617	.1	.2	
9	.663	681.002	42.434	.1	.2	
10	.467	786.222	48.79	.1	.201	
11	.807	600.791	37.682	.1	.2	
12	.571	731.305	45.434	.1	.2	
13	.632	701.733	43.551	.101	.2	
14	.563	736.522	45.725	.101	.2	
15	.882	558.691	35.2	.1	.2	
16	.78	619.148	38.671	.101	.2	
17	.881	559.478	35.248	.1	.2	
18	.85	576.817	36.276	.1	.2	

CHAPTER 6

CONCLUSION AND FUTURE SCOPE OF STUDY

6.1 Conclusions

This dissertation presented the work for the optimization of CNC turning using super alloy Inconel 718 with multi performance characteristics through TAGUCHI. Results were generated, on account of which following results can be noted as: -

- Results presented that Roughness of surface and Residual Stresses has major influential role primarily from Feed having F value of 127.89, followed by Cutting Speed with F value of 83.03 and finally Depth of Cut having F value of 7.68.
- Results presented that Surface Roughness and Residual Stresses has major influential role primarily from Feed having contribution percentage of 58.24% followed by Cutting Speed having contribution percentage of 37.81% and DOC have insignificant role DURING PROCESS having only 3.50% contribution.
- The optimum result has obtained at maximum value of Cutting Speed, C S =52.90 m/min, maximum value of Fd, f= 0.2 mm/rev and maximum value of DOC, d = 0.4 mm. The best level can be shown as cs3 – f3 – d3.
- As the Speed of cutting and Feed is raised, this is observed that
    - Higher compressive RS are generated.
    - Better SF is obtained.

This dissertation presented the work for the optimization of CNC turning using super alloy Inconel 718 with multi performance characteristics through genetic algorithm. Results were generated, on account of which following results can be noted as: -

Table: 5.4 OPTIMIZATION TOOLBOX PERFORMANCE

	RESULTS
SR	.34
RS	854.563
Cs	52.90
Fd	.1
DOC	.2

- The optimum result has obtained at maximum value of Cutting Speed, C S =52.90 m/min, maximum value of Fd, f= 0.1 mm/rev and maximum value of DOC, d = 0.2mm. The best level can be shown as cs3 – f1 – d1.

It can be concluded that after performing optimization with taguchi and genetic algorithm we would prefer genetic algorithm over taguchi because genetic algorithm give more optimized value and can easily solve more complex problem and can reproduce the best result out of available collection of data and it is based on principle that the best will survive among all and it will always tends to shift towards more fittest among the available population and with operator like crossover it reproduce the best possible result among the population. So with genetic algorithm we get the minimum Ra and most optimized residual stresses. Genetic algorithm uses the features like when two parents mate then child will be going to get the best genes from both parents and hence with every generation this features keeps going on and thus we can say that this way genetic algorithm keeps getting better result.

6.2 Future Scope of Study

Turning process has huge research and development possibilities.

- Research must focus on other parameters such as geometry of the tools, material of the tools, vibration of the machine to calculate its effect on cutting performance.
- In turning method, further analysis can be considered for evaluating tool life and temperature rise.
- Work may also be moved forward by studying the edge condition of the cutting tool and the effect on the angle of the rake, respectively.
- Tool wear can also be noted as one of the enormous possibilities under specific working environment in terms of research field.

Steps were taken to ensure operation with more performance and profitability by irradiating the process's involved difficulties.

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