SIMULATION AND OPTIMIZATION OF GEOMETRIC PARAMETERS OF CUTTING EDGE FOR FINISHING MACHINING OF AISI D3 STEEL

DISSERTATION II

Submitted in partial fulfillment of the requirement for the award of the Degree of

MASTER OF TECHNOLOGY
IN
Manufacturing Engineering

By

Amar Kapoor
(Reg. No. 11209161)

Under the Guidance of

Harpreet Singh
(Assistant Professor)

LOVELY PROFESSIONAL UNIVERSITY

PHAGWARA (DISTT. KAPURTHALA), PUNJAB

(School of Mechanical Engineering)
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CERTIFICATE

I, hereby certify that the work which is being presented in the dissertation entitled **"Simulation and Optimization of Geometric Parameters of Cutting Edge for Finishing Machining of AISI D3 Steel"** in partial fulfillment of the requirement for the award of degree of **Master of Technology (Manufacturing Engineering)** and submitted in Department of Mechanical Engineering, Lovely Professional University, Punjab is an authentic record of my own work carried out during period of Dissertation under the supervision of **Mr. Harpreet Singh**, **Assistant Professor**, Department of Mechanical Engineering, Lovely Professional University, Punjab.

The matter presented in this dissertation has not been submitted by me anywhere for the award of any other degree or to any other institute.

Date: (**Amar Kapoor)**

Reg. No. 11209161

This is to certify that the above statement made by the candidate is correct to best of my knowledge.

Date: **(Harpreet Singh)**

Supervisor

Date: COD (ME)

The M- Tech Dissertation II examination of Amar Kapoor, has been held on__________

_____________________.

Signature of Examiner

LOVELY PROFESSIONAL UNIVERSITY

PHAGWARA, PB, INDIA

CANDIDATE'S DECLARATION

I, Amar Kapoor, Reg. No. 11209161 hereby declare that the work presented entitled **"SIMULATION AND OPTIMIZATION OF GEOMETRIC PARAMETERS OF CUTTING EDGE FOR FINISHING MACHINING OF AISI D3 STEEL"** in partial fulfillment of requirements for the award of Degree of Master of Technology (Manufacturing Engineering) submitted to the Department of Mechanical Engineering at Lovely Professional University, Phagwara is an authentic record of my own work carried out during the period from AUG 2016 to JUNE 2017, under the supervision of Mr. Harpreet Singh (Assistant Professor), Department of Mechanical Engineering. The matter presented in this thesis has not been submitted in any other University/ Institute for the award of Degree of Master of Technology. Furthermore, I also declare that I will not publish this work in any other Journals/ Conferences/ Workshop seminars except the one chosen by supervisor. The presented work is the property of Lovely Professional University, Phagwara. If I found violating any of the above conditions, University has right to cancel my degree.

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ABSTRACT

The present report addresses the simulation and optimization of geometric and cutting parameters of the cutting tool edge with an objective of minimizing the surface roughness. The geometric and cutting parameters that have been considered for optimization are rake angle; nose radius and spindle speed; feed rate; depth of cut respectively. The purpose of the study is to examine the effect of the geometric and cutting parameters of the cutting tool edge during finishing machining of AISI D3 steel. The optimization process is carried out experimentally and as well as with the help of FEM simulation software i.e., Abaqus. The scope of study is to attain good surface finish of AISI D3 as it possess high chromium and carbon content in it which makes it to display excellent compressive strength and good dimensional accuracy. Consequently, it can be concluded that the machining of AISI D3 steel is not easy. Therefore, simulation and optimization of the geometric and cutting parameters is performed in order to attain good results regarding the surface finish and the obtained results are further validated and recommended to industry in order to make the manufacturing unit of industry more efficient. In proposed study, Abaqus is applied to compute the effect of the von Mises stress between the cutting tool and the workpiece. The designing of cutting tool and workpiece is also framed with the help of Abaqus and analysis is investigated on the consideration of less von Mises stress generated in case of different combinations for rake angle and nose radius. Simultaneously, Taguchi Technique and S/N ratio are adopted for optimization of the geometric and cutting parameters experimentally with assistance of Minitab 17. Further, L9 orthogonal array is involved in proposed study for generating different cross-functioning combinations of geometric and cutting parameters on the basis of which experimental is conducted on the CNC lathe. The surface roughness values are experimentally investigated at different combinations of parameters by using SJ-201P surface roughness tester. In this regard, Taguchi design is created on basis of values of surface roughness along with respective combination of parameters and mean; S/N ratio values and graphs are plotted. The graphs for obtaining optimal values of geometric and cutting parameters are developed on the basis of smaller is better signal to noise ratio from which it is concluded that for higher value of rake angle and nose radius, the surface roughness investigated is less and simultaneously, from the simulation results when rake angle and nose radius increase, the value for stresses decreases, which validates that 20° rake angle and 1.2µm nose radius are found to be optimal values for finishing machining

of AISI D3 steel and in case of cutting parameters, S/N ratio and mean plots conclude that 2000 rpm spindle speed, 0.03mm/rev feed rate and 0.03 mm depth of cut are optimal values for finishing machining of AISI D3 steel. The optimized parameters are then validated with the help of ANOVA on the basis of the rank generated by ANOVA and response table for mean. Further, it is observed that when ANOVA and response table for mean are generated for cutting parameters, therefore, it is analyzed that rank one is provided to feed rate followed by spindle speed and depth of cut because of maximum contribution of feed rate i.e., 69.41% and when ANOVA and response table for mean are generated in case of geometric parameters, therefore, it is analyzed that nose radius is provided with rank one followed by rake angle because of maximum contribution of nose radius i.e., 52.09%. Thus it is analyzed that the results generated by ANOVA and response table for mean are same. Therefore, the proposed model finds as validated and model can be implemented in industry for attaining finishing machining of AISI D3 steel. Also, the optimization of geometric and cutting parameters have been conducted separately which makes it easier to perform and understand. Thus, the variance in the optimization values shows the effectiveness of the proposed optimization model.

ACKNOWLEDGEMENT

Nothing can be achieved without an optimal combination of inspiration and perspiration. The real spirit of achieving a goal is through the way of excellence and discipline. I would have never succeeded in completing my task without the cooperation, encouragement and help provided to me by various personalities.

I owe my special thanks to Mr. Harpreet Singh, Assistant Professor, Department of Mechanical Engineering, Lovely Professional University, Phagwara, who helped and guided me for this work. His encouraging remarks from time to time greatly helped me in improving my skills.

I am also thankful to Mr. Gurpreet Singh Phull, HOS, Department of Mechanical Engineering, Lovely Professional University, Phagwara. I wish to place on record my gratitude for all those who have been instrument in bringing my work to this stage.

I do not find enough words with which I can express my feeling of thanks to all my family members and friends for their help, inspiration and moral support which went a long way in completion of my thesis.

Above all I render my gratitude to the ALMIGHTY and MY PARENTS who bestowed me self-confidence, ability and strength to complete this work.

Amar Kapoor

Reg. No. 11209161

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NOMENCLATURE

AISI	American Iron and Steel Institute
ALE	Arbitrary Lagrangian-Eulerian
ANN	Artificial Neural Network
AWJM	Abrasive Water Jet Machining
CAD	Computer Aided design
CAM	Computer Aided Manufacturing
CAPP	Computer aided Process Planning
CBN	Cubic Boron Nitride
CHM	Chemical Machining
CNC	Computer Numerical Control
CNC	Computer Numerical Control
CRITIC	Inter criterion correlation
DNC	Direct Numerical Control
EBM	Electron Beam Machining
ECEA	End Cutting Edge Angel
ECM	Electro Chemical Machining
EDM	Electrical Discharge Machining
FE	Finite Element
FEM	Finite Element Method
GA	Genetic Algorithm
HMMC	Hybrid Metal Matrix Composite
HPC	High Performance Cutting
LBM	Laser Beam Machining
MRR	Material Removal Rate
NC	Numerical Control
PBM	Plasma Beam Machining

PCM	Photo Chemical Machining
PSO	Particle Swarm Optimization
RSM	Response Surface Methodology
S/N Ratio	Signal to Noise Ratio
SCEA	Side Cutting Edge Angel
SEM	Scanning Electron Microscopy
TM	Taguchi Method
USM	Ultra Sonic Machining
WJM	Water Jet Machining
n	Number of Observation
y	Respective Characteristic
$\bar{y}^2$	Mean
σ^2	Variance

CONTENTS

CHAPTER 1: INTRODUCTION

1.1 MACHNING

Casting, forming, and various shaping processes are often used for manufacturing of various parts and the parts produce by this process require further operation with due stock known as machining. Parts have to be interchangeable according to required application, thus we have to control dimensional accuracy and surface finishing and this can be done by machining. Thus machining is defined as removal of non-required material from the work piece in order to get surface quality and definite degree of accuracy.

1.1.1 History of Machining

In earliest of times, human used to make tools of bone, stone and wood which they used for cutting of materials. Later over a period if one million years' these tools were made up of metals like copper and iron. Later with the discovery of electricity as useful source of energy manual tools were replaced by tools which used electricity and other source of energy in various applications. Based on the need of more accuracy in the field of metallurgy an industry started in nineteenth century. Wilkinson (1774) manufactured a precision machine for boring engine cylinders. About Twenty-three years later, Maudslay made a development in machining era by manufacturing a screw-cutting engine lathe. Whitney (1818) presented the primary milling machine to machine grooves, dovetails, and T-slots as well as flat surfaces. Brown (1862) constructed first universal milling machine to cut helical flutes of twist drills. Another significant advancement came when Fellows (1896) made a machine that could manufacture every type of gear. In the later part of the nineteenth century and in the twentieth century machinery used electricity instead of steam as fuel. McGeough (1988) introduced multiple-station vertical lathes, production millers, special-purpose machines, and gang drills. Later with the introduction of NC (Numerical Control), computer numerical control (CNC) and direct numerical control (DNC) machining was done with great accuracy and uniformity. In modern era machining harder, stronger, and more tough material that are not easy to machine are used more rapidly and for that non-conventional machining processes came into practice as an alternative. Further advancement in machining led Hybrid Machining came into practice which uses combined more advantageous and kept away from the opposed effects of the constituent processes produced. With the introduction of micromachining McGeough (2002) proposed Machines such as precision grinders can manufacture product with accuracy up to ±0.01 μm which can be measured with the help of laser instruments.

1.1.2 Machining Processes

Machining processes are those process which helps in removal of unrequired material from the work piece. Following are the different material removal processes which are mentioned below as:-

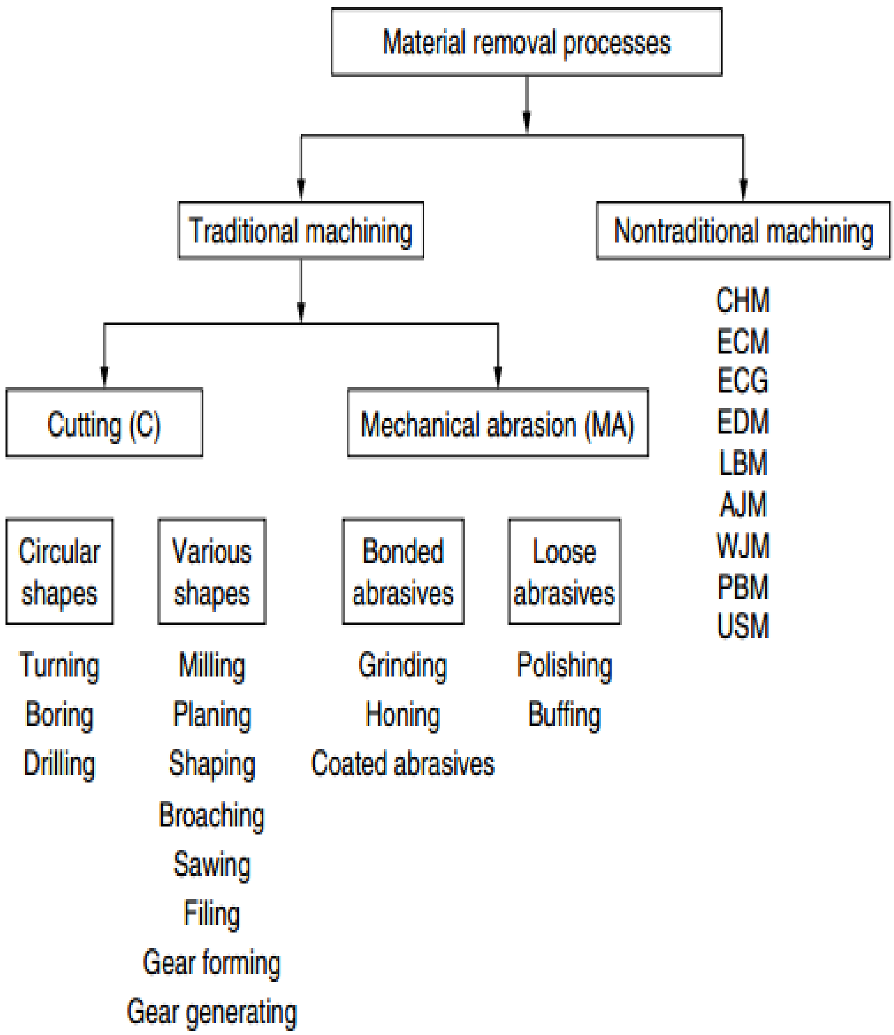

Figure 1.1: Classification of Metal Removal Processes (Hassan, 2005)

(i) Traditional Machining

Traditional machining also termed as conventional machining. During traditional machining presence of tool is required in order to machine work piece and it is to be kept in mind that the tool which is used to machine work piece must be harder.

(a) Machining by cutting

It involves penetration of in the work piece to the depth of cut. In order to determine the work piece geometry required a relative feed motion is to be given.

Turning, Boring, Drilling are used to machine circular shapes. Whereas Milling, Planning, Shaping, Broaching, Sawing, Filing, Gear forming, gear generating is used for machining various shapes.

(b) Machining by abrasion

Abrasion machining is a process in which the material is removed with the help of multitude of hard, angular abrasive particles or grains, which might be the integral part of tool of definite geometry or not. In this the orientation of cutting edge is random and the depth of penetration is small and penetration is not equal for all grains that are simultaneously in contact with work piece. Grinding and honing uses bonded abrasive. Moreover, in processes like lapping, polishing, and buffing, slurry of abrasive particles and some liquids base is used.

(ii) Non Traditional Machining

It came into existence in case of the work material is too hard or work piece is not able to withstand the cutting forces or shape ordered by customer has too complex contours or requirement for surface finish and tolerance is high or temperature and residual stresses are undesirable or unacceptable. On the other hand nontraditional processes uses electrical, chemical and other optical source of energy for machining. Following are the types of non-traditional machining which are mentioned below as:

(a) Mechanical machining.

(b) Thermal machining.

(c) Chemical and electrochemical machining.

(a) Mechanical machining.

In this type of machining the material removal is due to motion of abrasive particles material is removed. Examples are Ultrasonic machining and water jet machining.

(b)Thermal machining

By melting or vaporizing the work piece material thermal machining process removes the machining allowance. EDM, EBM, LBM are some examples of thermal machining.

(c) Chemical and electrochemical machining

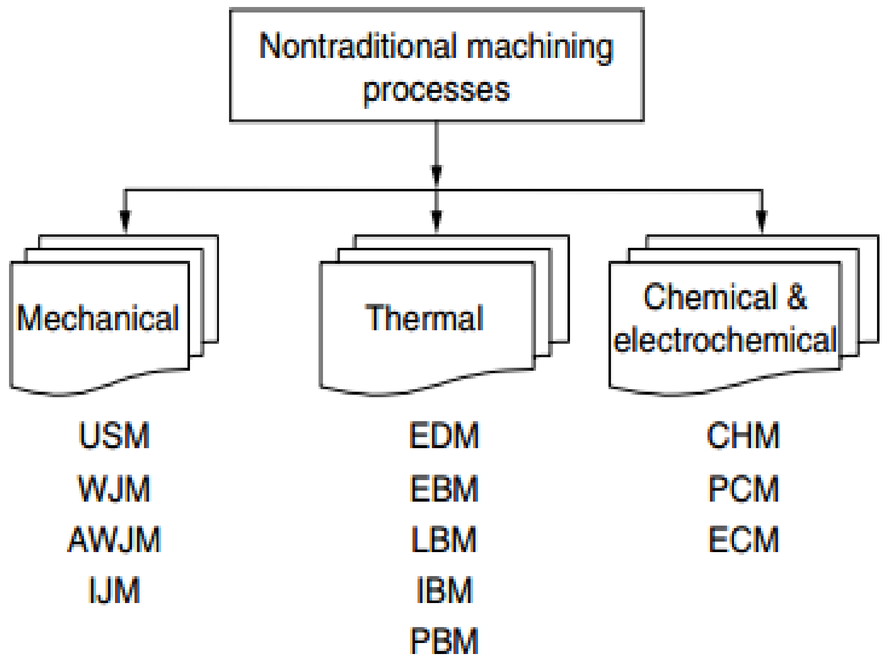

Figure 1.2: Classification of Non-Traditional Processes (Hassan, 2005)

In this type of nontraditional machining material removal is due to the chemical action caused by the ions in the etchant whereas electrochemical dissolution uses ion transfer in an electrolytic cell to remove machining allowance. Chemical milling (CHM) and photochemical machining (PCM) are examples.

(iii) Hybrid machining

Hybrid machining is also one of the modern technique evolving now days. Hybrid machining is used in removal of material by combining the various machining action or phases. When mechanical conventional single cutting process is combined with electro discharge machining it reduces the adverse effect of both process and thus the outcome is very good in comparison of the individual process.

1.2 CUTTING TOOL EDGE

Cutting tools are made up of material harder than the work material and has sharp cutting edges. The cutting edge helps to cut chip from the work material. There are two surfaces connected to cutting edge which are described below as:

(a) Rake face is the surface of tool on which the chip flows at a distinct angle known as rake angle.

(b) Flank provides clearance between the tool and the machined work material, hence preventing the surface of the work material from bad surface finish.

Shinozuka et al. (1999) studied the chip forming analysis by optimizing the cutting tool geometry with the help of thermo-elastic plastic FEM and come to know that the simulated results are similar to experimental results for different cutting conditions and different tool geometries. Sikdar and Chen (2002) focused on the relation of flank wear area and cutting forces in turning process on a CNC machine with no use of coolant and it is found that due to increment in flank wear surface cutting forces also increases. Yen et al. (2004) Estimate wearing of tool in orthogonal cutting using the FEM. The predominant focus is on the adjustments made to the industrial FEM code in order to estimate wearing of tool. Leo et al. (2014) studied the influence of tool on the contact phenomenon of tool-based micromachining. This paper presents investigation of friction between the tool and work piece and flow stagnation phenomenon with the evolutions of contact length and contact stress distributions, and to relate the material deformation and contact length due to influence of tool edge radius was studied and the effect of Cutting Edge on Deformation Induced Hardening when Cryogenic Turning of Metastable Austenitic Stainless Steel and it is found that with a variation in the geometry of the cutting edge, especially the cutting edge radius, mechanical loads and thus the amount of marten site formed were adjustable. Chen et al. (2014) studied the genetic algorithm-based optimization of cutting parametric values in cutting of ceramics and found that increase in cutting speed, cutting depth and feed speed will tend to increase material removal rate and cutting speed. Denkena et al. (2015) proposed development of cutting edge geometries for hard milling operations and it is found that the flank face adjustments enable to enhance the life of tool and the production of reduced tensile stresses in the work pieces.

1.2.1 Various Cutting Edge Angles

Following are the various cutting edge angles that are involved in cutting operation:

(i) Rake Angle (Back and Side)

It can be positive, zero or negative. Larger rake angle give rise to lower cutting force and power. However, increasing to very high value decreases the strength of the tool tip. Smaller rake angles are used for hard materials whereas larger rake angle for soft and ductile. Dahlman, F Gunnberg, M Jacobson studied the above effect of rake angle.

(ii) Side Cutting Edge Angle

It helps in prevention of sudden engagement of entire depth of cut when the tool enters work material due to which life of tool and work surface finish get affected. It varies from 0º to 90º. It is used in the production of square shoulders. The chip produced with this is thinner and wider with the increase in SCEA. It also helps in distributing the produced heat over a large cutting edge.

(iii) End Cutting Edge Angle

The purpose of this is to relieve the trailing end of the cutting edge to prevent the rubbing the machined surface. Only small angle is sufficient for this purpose. According to various studies the satisfactory ECEA for boring and turning tool is 8º to 15º.

(iv) Relief Angle (Side and End)

It prevents rubbing of flank of the tool with the machined surface. It ranges from 5º to 15º.Small relief angles give strength to cutting edge when machining hard and strong materials, whereas increased values of relief angle allows to penetrate and cut the work piece material more efficiently reducing the cutting forces and vice versa in case of large relief angles.

1.3 OPTIMIZATION OF CUTTING TOOL PARAMETERS

It is finding an alternative by optimizing desired factors and reducing unwanted ones economically or highest achievable performance under the given constraints. Traditionally the machine operator decides the cutting conditions for metal cutting. In such cases, major role is played by the operator, but also for skilled worker it is not easy to get optimum values every time. Cutting speed, feed rate and depth of cut, nose radius, rake angle, cutting edge are machining and geometric parameters in turning process. Taylor pushes the envelope and study his tool life equation helped in investigating analytic and experimental approach for the best of cutting parameters. Gilbert (1950) studied how to optimize the machining parameters in turning based on maximum production rate and minimum production cost as criteria. Brewer and Allgeier (1966) purposed to utilize Lagrangian multipliers to optimize unit cost. Walvekar and Lambert (1970) discussed how to carry out geometric programming for the optimization approach. Ermer and Kromodiharajo (1981) developed a multi-step mathematical optimization to resolve a confined multi-pass machining quandary. Tsai (1986) presented the notion of a break-even point through finding out the relations between the multi-pass and single-pass machining. Agapiou (1992) formulated single-pass and multi-pass machining operations to scale back the creation price and time taken. Prasad et al. (1997) pronounced the progress of an optimization module for picking process parameters for operations as a part of a computer based generative CAPP method. Korkut et al. (2004) studied the cutting speed of tool on wearing of tool and surface roughness and come to know that with the rise in cutting speed the wearing of tool and surface roughness decreases. Hua et al. (2006) proposed a newly hardness-based flow stress model, which is used in the FEM simulation of AISI 52100 steel for hard turning using various cutting conditions. Albu and Bolo (2014) made a program to optimize the inclination angle of cutter and eccentricity. Kalyan and Samuel (2015) founded that with rise in cutting edge radius surface finish increases while shearing in cutting and vice- versa.

1.3.1 Different Optimization Techniques

Following are the approaches to optimize that are used now a day very frequently, which are explained below as:

(i) Fuzzy Logic: Fuzzy logic has satisfactory capacity to seize more than a few features of human commonsense like reasoning, decision-making and so forth. Klir and Yuan (1998) fuzzy logic includes an engine known as fuzzy interference and a fuzzification-defuzzification module. Where fuzzification expresses the input parameters which are based on various membership functions and defuzzified expresses the membership values which are obtained using different approaches to f true value.

(ii) Genetic Algorithms: GA algorithms are founded on mechanics of natural choice and ordinary genetics, that are more effective and more likely to locate global surest. It doesn’t start from a single point due to the feature that it goes through solution space. In this method a suite of genes is mixed collectively to type chromosomes, used to perform the elemental mechanisms in GA, like crossover and mutation. The function of crossover is to alternate some a part of two chromosomes to generate new offspring and performance of mutation is to furnish a small randomness to the new chromosomes after crossover. In order to determine single chromosome, the encoded cutting conditions are decoded from the chromosomes and are used to foretell machining performance measures. For the implementation of GA first all the parameters are encoded as n-bit binary numbers assigned in a line as chromosome strings. For constraining in GA, penalties are given to individual of constraint. If an individual is out of constrain its fitness will be given zero. The GA is initialized via randomly making a choice on individuals within the full variety of parameters. According to their fitness value Individuals are chosen to become parent of the coming generation. For being chosen as parents there should be possibility of choosing the higher fitness value. Kuo and Yen (2002) had used a genetic algorithm established parameter tuning algorithm for multidimensional motion control of a CNC machine. Wang and Jawahir (2004) had used this process to optimize milling machine variables.

(iii) Taguchi Techniques: In late 1940s a Japanese engineer Genichi Taguchi constructed this technique. Many Japanese industries have earned allot by utilizing this method It was also found that ten thousands of tests have been performed thousands of engineers using the same method. Sullivan (1987) reported that the term "Taguchi methods" (TM) uses orthogonal arrays which refer to the different methodology being used to determine measuring systems. Pignatiello (1988) identified the plan of Taguchi and the tactics of Taguchi as a two different aspects of the Taguchi methods. Collecting of specific methods and approaches used by Genichi Taguchi refers to Taguchi tactics whereas structure for planning a product or process design experiment is Taguchi strategy and the Quality is measurement of the deviation of a functional characters from its ordered value. Due to Noises these deviations results in degradation of quality. Taguchi methods remove the influence of noises which is proved to be very useful during optimization processes.

(iv) Response Surface Methodologies (RSM): The two features of general scientific methodology Experimentation and making inferences. Inferences can be made by making strategic plans for experiment, which helps in making accurate result from experimental readings. The methodology for making inferences had three main aspects. First, it found methods for extracting inferences from readings. Second, it includes methods for gathering suitable data. Lastly, method for proper explanation of consequences is devised.

1.4 SIMULATION OF CUTTING TOOL AND WORKPIECE

Simulation is defined as the imitation of real world-process operations. The act of simulation needs that the miniature should be made first and this miniature portray the key features or behavior of the chosen physical process, whereas the simulation portray the operation of the system over span of time and model portray the arrangement itself. Simulation in our work context helps in optimizing the various parameters that are to be considered during the study or experiment and the software that is being commonly used for the optimization of the cutting edge is ANSYS. With the help of this software we can optimize parameters of cutting edge by inputting the different values of cutting edge parameter like rake angle, nose radius etc. and after the design process we get some values which are to be further compared with the experimental work to get the desired result. In thus way optimization process is done in optimizing the parameters of the cutting edge. Further, it can be investigated that how rake angle got affected and its effect on the work material during a precision cutting and with regard to this, simulations were evaluated under different tool rake angles in order to find the effect on various cutting variables and geometric variables and studied how FEM is helpful while doing orthogonal cutting. Further FEM simulation is combined with the friction law of coulomb in which tool rake angle varies within optimized range along with coefficient of friction and came to know rake angle and friction coefficient are nonlinear. Yen et al. (2004) focused on how temperature, stress, strain will affect the cutting edge of the tool which further influence the formation of chip and tool geometry. All these process variables that influence geometry of tool and chip formation can easily be determined by using FEM in comparison to experimental approach. Majumdar et al. (2005) investigated how the heat generated at the interface of the tool and work piece affects the tool life and cutting variables. So, in order to get reliable result FEM is used to determine the temperature distribution between the tool and the work material. Fang and Fang (2007) investigated the effect of round edged tool on experimental and theoretical result derived after performing machining. It was found that during machining process friction decreases with increase in the cutting parameters which can also be explained by using FEM. Hairudin et al. (2011) studied how FEM model is useful for simulating the orthogonal cutting. For simulation two different rake angles and tool edge radius are taken. Lagrangian-Eulerian method was used for thermo mechanical modelling. The result shows that with the increase in the rake angle stresses on the work piece decreases and it was experimentally investigated that the outcome on the cutting variables and work material surface due to variation of speed during cutting, feed and depth of cut and it is found that feed rate and cutting speed strongly influence work material surface. Wan et al. (2015), studied the effect of different cutting tool edge geometries by using finite element simulation method. In this Lagrangian-Eulerian (ALE) approach was used for simulation in ABAQUS. The result shows that tool edge geometry gets influence on chip removal process.

1.5 WORK MATERIAL D3 STEEL FOR ORTHOGONAL CUTTING

D3 steel is also known as 1.2080 (Werkstoff) is a high carbon, high chromium and air hardening steel. It poses excellent abrasion or wears resistance with high compressive strength and good dimensional stability. After performing a heat treatment, it will offer a nice range of hardness between 58-64 HRC. D2, D3, D4, D5, and D7 are cold work tool steels consisting of high-carbon and high-chromium.

1.5.1 Chemical Composition of D3 Steel

D3 steel consists of high composition of the chromium and carbon due to which it poses high compressive strength and excellent wear or abrasion properties. The following table shows the chemical composition of the D3 steel:

Table 1.1: Chemical Composition of D3 Steel

Element	Composition (Percentage)
C	2.00-2.35
Mn	0.60
Si	0.60
Cr	11.00–13.50
Ni	0.30
W	1.00
V	1.00
P	0.03
S	0.03
CU	0.25

1.5.2 Physical Properties of D3 Steel

D3 steel poses good density, modulus of elasticity, electrical resistivity, Machinability and melting point, which are discussed in the following table.

Table 1.2: Composition of Physical Properties of D3 Steel

Properties	Imperial
Density	0.284 lb/in3
Modulus of Elasticity	30 x 106 psi
Electrical Resistivity	54.8 µOhm-cm at 70ºF
Machinability	45-50% of a 1% carbon steel
Melting point	2590°F

1.5.3 Fabrication and Heat Treatment of D3 Steel

(i) Heat Treatment: For achieving maximum properties D3 steel requires hardening and tempering. For achieving maximum accuracy, the parts of the D3 tool steel should be stress relieved after roughing operations. Stress should be relieved for one hour at a temperature of 648°C (1200°F) and cooled slowly.

(ii) Annealing: Annealing of D3 steel has to be done in a controlled atmosphere furnace. D3 should be heated at a temperature of 871°C (1600°F) and cooled slowly at a rate of not more than -6°C (20°F) per hour, until the furnace is black and afterwards material should be removed and air cooled.

(iii) Tempering: In case of tempering D3 steel should be cooled to room temperature and to be tempered immediately. The parts should be placed in the tempering furnace and increased slowly to the desired tempering temperature. One hour per inch of thickness is required for tempering.

(iv) Hardening: For achieving maximum hardness D3 steel should be heated properly as it is very sensitive to overheating. The work should be directly placed in a furnace and preheated to 954°C (1750°F) and soaked for 20-25 minutes, plus 5 minutes per inch of thickness, and afterwards oil-quenched to harden it.

1.6 CUTTING CEMENTED CARBIDE TOOL FOR MACHINING OF D3 STEEL

Cemented carbide has demanding application for rare combination of strength, hardness and toughness. An important feature of cemented carbide tool is that we can change its composition in order to ensure maximum resistance to wear, deformation, fracture, corrosion, and oxidation by changing its physical and chemical properties.

1.6.1 Carbide Tool Composition

Cemented carbide acts as metal matrix composites and carbide particles act as aggregate whereas metallic binder acts as matrix. We imagine carbide tool structure is similar to grinding wheel, only one thing is different that are abrasive particles which are smaller. The process which helps to combine the carbide particles with the binders is referred to as sintering. As a result of this process metal matrix composite of distinct properties are created by embedding the carbide grains.

1.6.2 Carbide Tool Applications

Following are the applications where carbide tools where it is used: -

(i) It is used to make components of automotive.

(ii) It is used to make Canning tools for deep drawing of two-piece cans.

(iii) It is used to make Rotary cutters.

(iv) It is used to make Rings and bushings.

(v) It is used to make Roof and tail tools.

(vi) It is used to make ball bearings balls and ball point pen.

(vi) It is used to make Bridal Jewelry.

CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

This chapter revised the contributions made in the field of machining by optimizing the cutting parameters and cutting edge geometry. Machining is a process in which not required material is to be cut by controlled material removal process. The significance of reviewing problems related to machining is important due to the diversity in optimizing of cutting parameters in machining process. Each review describes the approach, method, technique and software used to solve the problems with their specified objectives and how the method works in order to produce results and the software used to optimize the cutting parameters. Following research papers has been studied for knowing the various methods used for optimization of cutting tool parameters.

2.2 REVIEW MODELS

Bouzakis et al. (2000) studied how to optimize the radius of the cutting edge by using film fatigue failure mechanism of Physical Vapor Deposition carbide insert during milling operation. The fatigue and wear behavior are investigated experimentally and analytically through Finite Elements Method. Examination of different cutting inserts with different cutting edge radii at various fed rate was done. Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray micro spectral investigations were used to depict the tool failure. Therefore, impact test was considered to determine the fatigue stress. The experimental and computational results effect the tool radius and feed rate on the coating fatigue failure and was found that by increasing the cutting edge radius premature failure of the coating is prevented and also by increasing the feed rate at an optimum value leads to be beneficial for the tool service life.

Kim et al. (2002) investigated how cutting speed can be optimized for ball end milling by using precision machining. The main purpose of this study is to make program for optimizing the cutting speed, which was developed to improve tool life. NC code is to be generated from CAD/CAM as per the cutting velocity optimization program. Which further goes through a reverse post process and cutting simulation and afterwards and the effective tool diameter of the ball end mill is obtained. With the help of optimization program, the suitable range of critical cutting speed for the work piece is selected and spindle revolution is changed according to the effective tool diameter within the range of the critical cutting speed and therefore it results in making the tool deflection and the cutting force stable and it can get a fine surface shape without leaving cutting traces on the machined surface.

Yu and Lee (2003) proposed which cutting parameters are to be selected to affect the production cost while doing High Speed Milling of SKD6 steel tool. This study pays emphasis on minimizing production cost by optimizing the cutting parameter during high speed milling operation. Machining model is created by polynomial network. Whereas self-organizing technique helps polynomial network to learn the relationships between cutting variables such as cutting velocity, feed and life of tool. Once the material removal volume of machined part and the required time and cost components for high speed milling operations are given, it is founded that production coat get decreased while performing High Speed Milling.

Yen et al. (2004) proposed how finite element analysis is being used for the estimation of wear in tool by using orthogonal cutting. In metal cutting temperature, contact stresses and relative sliding velocity strongly influence frictional wear of tool on the tool-chip and tool-work piece interfaces. Whereas FEM simulation helps in predicting the temperature and it stresses on tool face. In order to achieve the required goal a methodology is proposed in which first we have to create a model for frictional wear of tool for the defined work piece and tool by combining the set of frictional wear of tool cutting tests with cutting simulations. In the second part some changes are made in commercial code of FEM used for updating tool geometry and tool wear calculation and the third part include confirmation of experiment of the developed methodology. Thus this paper pay attention toward making a reasonable tool frictional wears estimates.

Tsai et al. (2005) proposed how to increase the machining performance while machining of Inconel 718 by analyzing the cutting edge parameters. The main concern of this manuscript is to develop manufacturing technique which ensured flight safety by producing highly reliable aircraft component. Further Taguchi L9 layout is used to enquire various optimum cutting variables by using planar-type conical ball end, the S-type cutter, and the conventional conical ball-end milling cutter for machining purpose of Inconel 718. Different values are obtaining of cutting parameters like: shaft speed, feed rate, cutting speed for different cutter. Therefore, it was found that S-type cutting tool is suitable with fast feed rate for high speed cutting and at the same time it was determined that it can reduce time and cost for the machining process.

Zong et al. (2007) studied diamond tool geometry optimization and various cutting parameters which are dependent on residual stresses of the work piece. In this research article Lagrangian formulation is use to imitate diamond turning, which is based on FE mold. Rezoning technology is combined with FE based model to observe the effect of diamond tool edge radius. The simulated results help in indicating that the rake angle and the clearance angle are to be 10° and 6° respectively for the most favorable geometry for diamond tool to machine ductile materials. Also smaller the cutting edge radius lower will be the tensile residual stress or compressive residual stresses and it was founded that the residual stresses are reduced to the smallest level, when depth of cut is equal to the critical threshold.

Oktem (2008) studied how to improve the surface finish by modeling and cutting parameters by optimizing during end milling. In this research work, for determining surface roughness analysis of variance is conducted. Back-propagation learning algorithm is a foundation artificial neural network to build the surface roughness model. To obtain best combinations of cutting parameters, Genetic algorithm was combined with the tested ANN, this leads to optimizing the roughness to the lower surface. The surface roughness value and machining time get decreased based on the cutting parameters before and after optimization process using the analytical formulas. While performing the final measurement experiment to verify the surface roughness value resulted from GA with 3.278% error. It can be easily realized from the results that this study is more reliable and suitable for others problem encountered in the metal cutting operations.

Nalbant and Muammer (2009) investigated the effect of cutting parameters, uncoated physical vapor deposition and coated cemented carbide insert on surface roughness, while turning with CNC and using artificial neural network for prediction. In this paper machining of steel is done by physical vapor deposition and coated cemented carbide insert with different cutting parameters like: feed rates, cutting speed and constant depth of cut without using cooling liquid. It was founded that friction of coefficient and thermal conductivity get influenced by coating material type, number of coating layer and coating method. There is negative association between coated cemented carbide cutting tools and the average surface roughness. Further, it was founded that average surface roughness gets influenced with increase in the feed rate.

Pytlak and Bogusław (2010) proposed different criteria for optimizing turning operation, while turning hardened 18HGT steel. For carrying out the multiple criteria optimization, cubical boron nitride was used to machine the steel with the use of Wiper geometry inserts. Parameters that are to be optimized are: cutting speed, depth of cut, feed, time per unit, production cost and resultant cutting force. Thus multi criteria optimization results in increase in production and reduction in the cost of production as well as resultant cutting force. But one of the greatest disadvantages of the Pareto set is to provide additional information to make decision for selecting the single solution from the set. Which is to be obtained by complying some limited cutting parameters with the selected surface roughness parameters.

Thakur et al. (2010) investigated to optimize the parameters by providing lubrication, while doing high speed turning of super alloy Inconel 718. In this study, semi-dry operations employ very small amount of cutting fluids and are used to improve surface finish excellence, and severe cutting conditions because all these requirements are not fulfilled in case of dry machining for obtaining higher machining efficiency. The cutting fluid that is used in dry machining is known as minimum quantity lubrication which plays a significant role in a number of practical applications. Parameters and the technique that are used in this study are feed rate, cutting speed, quantity of lubricant, delivery pressure at the nozzle, frequency of pulses and TAGUCHI respectively. Results indicated that lower the analysis of variance better the S/N ratio. The parameters used after the effective optimization for high speed machining of super alloy Inconel 718. Found improvement in cutting parameters, flank wear and temperature during cutting to the optimal cutting parameters to greater extent.

Wang et al. (2011) studied the association between chip flow and cutting edge ratio length. Turning is performed with sharp corner tools which are derived using cutting power equilibrium equation with a new chip flow angle. In this study, RATIO is defined as the ratio of minor cutting edge length combined with set of variable on the basis of the constant identical cutting area. Different values of RATIO corresponding to the chip flow angle is predicted by the current model which shows good relation with the experimental measurement and FEM simulation helps in getting various results for different cutting conditions. The chip generated by cutting edge engaged in cutting, affect the chip flow direction.

Paiva et al. (2012) proposed robust parameter design approach for optimizing the AISI 5200 hardened steel during turning operation with wiper mixed tool. Noise and controllable are considered to be new characteristic for this new optimization approach which are to be considered for the hard turning to determine. The parameters levels helps in minimizing the distance of each response and variance caused by the noise variables. Where mean, variance and mean square error for surface roughness parameters helps in generating the experimental arrangement. Further principal component analysis was employed to extract the information and founds out that a robust solution could be found by adopting the Multivariate Mean Square Error as optimization criteria.

Witty et al. (2012) proposed optimizing technique in order to optimize the cutting tool edge geometry for stainless steel during plunge milling process. In this paper performance and the stability of the plunge milling is investigated. Where micro geometry and the process parameters are analyzed for the engagement conditions of the tool and found that machining of hard to access geometrical features is done by plunge milling process, if the main focus is on achieving a large tool aspect ratio in order to achieve stable machining processes process parameters. So, in order to maintain that large tool aspect ratio, small feed rate is combined with small corner radii to machine hard to access materials.

Chen et al. (2013) studied what are the various variables that will affect the cutting stability while doing turning of thin walled circular cylindrical shell. In this study a model of cutting dynamics relates both work piece degradation and tool vibration because thin walled circular cylinders is prone to vibration during the cutting process. Further mathematical model for optimization on the basis of cutting parameters were proposed which was further acquired by adding critical cutting width. In accordance to the orthogonal experimental design orthogonal table was adopted showing maximum value of MRR with the help of Particle Swarm Optimization (PSO) program, thus stability of optimal results verified by the stability of dynamic test of cutting forces.

Chang and Zen (2013) proposed how finite element and genetic algorithm are used for optimizing the oblique turning operation. Turning operation is optimized by optimizing the cutting parameters and temperature, whereas power required for cutting and material removal are the constraint being applied on the temperature for better optimization result. For simulation of cutting force, temperature, stress distribution and chip morphology developed version of FE model is used, in which tool is considered to be a rigid body and the work piece is observed to be elastic thermoplastic with sensitivity in strain rate and thermal softening effect and thus, results in increase in inclination angle with increase in chip flow angle, higher mises stress at primary zone and lower in secondary zone and also found that high temperature region was found to be reduced as chip moves away from the tool face rake.

Bin Li (2014) examined machining of grey cast iron as work piece along with carbide coating tool during dry cutting environment. In this research least square method was used for experimental data to make regression analysis. Further abrasion modality, geometry of the tool and the effect of cutting force on cutting parameter were analyzed. It was found that when cutting force increases gradually, depth of cut also increases. Rise in cutting temperature leads to decrement in cutting forces with the increment in the cutting speed and also at the same time increasing the cutting speed and decreasing the cutting depth with leads to good cutting effect.

Umer et al. (2014) investigated the use of optimization technique FEM and genetic algorithm during oblique turning operation. In this manuscript barriers are being applied on material removal rate and cutting power during turning operation. While optimizing cutting force and temperature and FE model is used for simulation purpose. Where work material is considered as elastic and tool is considered to be rigid body due to which thermal softening effect is produced. Further effect of cutting speed, rake angle, feed rate and inclination angle are modeled and compared with findings of different experiments. As a result, the chip flow angle is increased by increasing the inclination angle. Furthermore, von Mises stress are higher at primary zone and lower at secondary zone and RSMs based on radial basis functions are found to be more accurate than polynomial and neural network models.

Abaini and Ouelaa (2015) experimentally studied how the geometric parameters of the tool will affect the cutting forces and vibration of tool. For the design of different cutting tool geometries with various tool angles are produced with high speed steel material with a high tungsten alloy grade. It was founded that when rake angle moves from negative to positive value, average cutting force component decreases due to the changes in tool vibrations, cutting force components, and surface roughness. Due to variation in cutting edge angle with major cutting edge and positive cutting edge inclination angle variation on the axial and radial force component were observed, whereas tangential force remained constant. Further decrease in the surface roughness was seen by lowering the major cutting edge angle and a small variation was observed when inclination cutting edge angle is increased. As a conclusion a good tool geometry optimization was observed with neutral angle 0, +5, _5 and cutting edge inclination angle 3°and the minor cutting edge angle is 75°.

Cheng et al. (2015) studied how to optimize the various geometric parameters of the cutting tool, while performing rough machining on stainless steel. In this study 2D finite element method AdvantEdge is used for the optimizing the geometric parameters and the effect of temperature and stress is studied. It was found that with rise in cutting edge radius and the rake angle, tool stress decreases and optimizing parameters get less influenced by the cutting parameters while machining of steel. As a result, by keeping equal removal rate, smaller feed rate and larger cutting speed obviously reduces the stress and temperature. On the other hand, with the increase in rake angle coefficient deformation of work piece get diminished. On the other hand cutting edge radius disappears with the evolved result.

Hashmi et al. (2015) studied how response surface methodology is being applied in optimizing the process parameters for machining of Ti-6Al-4V. Titanium and its alloys are mostly used in aviation industry like in aerospace for its good strength and corrosion as well as heat resistance. But at the same time it came to know that alloys of titanium are difficult to machine because of its bad thermal conductivity which cause very high temperature at the cutting tool and work piece interface and also it leads to the formation of buildup edge at the tool and work piece junction. Further high speed machining of alloys of titanium is done, which is one of the challenge to prevail it. So, in this paper a model is developed known as average roughness model for milling of titanium alloy using carbide tool inserts. A series of experiment are practiced by using response surface methodology and found that surface roughness is affected by depth of cut.

Meddour et al. (2015) proposed to optimize the cutting conditions by considering surface roughness and cutting force during turning of AISI 52100 steel. This investigation is performed for the requirement of hard materials and there increasing demand in industries with their wide range of application required to improve the machinability process. Turning is performed by varying cutting parameters, for doing so central composite design was adopted which includes 30 test. Where surface response methodology is used for modeling cutting conditions and surface roughness. ANNOVA and response surface graphics were used for analyzing the effect of input parameters on output response. This study shows that force components get affected by depth of cut and followed by feed rate with lower degree. Likewise, with large nose radius chip thickness on surface roughness was less.

Santos et al. (2015) proposed usage of genetic algorithm for optimizing while turning the of aluminum alloy. In this study the central composite design of the experiment was used for the generation of second order parameters such as: cutting temperature, machining force components, power consumption, tool wear, surface integrity, and chip thickness ratio. Where surface response model and level curves utilize the effect of cutting conditions on the output parameters. Genetic algorithm method is used to set limits for cutting conditions for minimizing the machining force. This resulted in decrease in output parameters when cutting parameters increases.

Benlahmidi et al. (2016) proposed how to get optimized results while turning AISI H11 hardened steel with CBN720 tool. In this validity of quadratic regression model is checked by response surface methodology and ANOVA, in order to determine significant parameters which are getting affected by the output response. Box–Behnken design was used for developing mathematical models for output parameters. The results shows that the surface roughness conditions get affected by feed rate and the hardened work piece while negative effect on feed rate but not on depth of cut. Also, the result shows work piece hardness and depth of cut gets powerfully affected by the cutting pressure. In addition, cutting speed and feed rate influence the life of the tool by 91.68 % and 3.83 % respectively

Cheng et al. (2016) studied how to improve the geometric parameter of the chamfered edge during machining of the stainless steel. In this study a method is proposed to measure the chip curl radius. Numerical simulation is used for optimizing the chamfered edge tool. It was founded that by keeping the constant removal rate and most favorable geometry parameters of Fe–Cr–Ni stainless steel for rough machining. Furthermore it was found that if small rake angle is engaged with small chamfer length than tool stress is reduced to reasonable point and the radius of chip curl increases when the rake angle is increasing continuously upto certain value also having length of land less than 200µm. When the rake angle is larger, chip curl radius was found to be minimum.

Liao et al. (2016) proposed how to get most favorable geometry for cutting edge for finishing machining of stainless steel. To resolve the chip deformation coefficient and tool stress favorable geometric parameters are to be considered. 2D finite element model was used for orthogonal cutting of the work material. Tool cutting edge had an adverse effect on stress than temperature while machining of stainless steel. Comprehensive criterion and multiple sets of validation experiments are used for the correctness of optimizing results. The coefficient of chip deformation is decreasing but on the other hand stress increases with increase in rake angle and Stress changes with increase in radius of cutting edge while the chip deformation coefficient has no obvious changes. It is also found that with the rise of the feed rate cutting edge radius increase when stress reaches to high point.

Mia et al. (2016) studied usage of Taguchi technique for improving the surface roughness and cutting temperature by providing coolant during hard turning .Taguchi L36 orthogonal array is used to evaluate surface finish and cutting temperature during machining operation. In this experiment three different types of hardened steel are used with hardness number 40, 48 and 56 HRC and were turned by cemented carbide using dry and high pressure coolant jet where depth of cut was kept fixed. High-pressure coolant jet successfully reduced the cutting temperature, surface roughness, and tool wear and the machinability of the hardened steel get improves by the application of HPC due to reduction in surface roughness, cutting temperature and tool wear as compared to the dry cutting and is also having minimum temperature and surface roughness.

Nataraj et al. (2016) investigated what are the parameters are to be considered for CNC turning of Hybrid metal matrix composite. In order to evaluate characteristic of composite a mathematical model was evolved to state responses like: surface finish, intensity of vibration and work-tool interface temperature. Further experimental approach was used to conduct the experimental trials, whereas mathematical model was formulated by using response surface methodology. As a result, it was found that fabricated HMMCs density was reduced as compared to metal ML6 aluminum alloy density also lead to increase in mechanical properties. It is also clear from the response analysis that feed rate and depth of cut and the cutting speed would affect the surface roughness, temperature and vibration and it assures that the surface roughness decreases with increase in depth of cut.

Negrete et al. (2016) studied robust technique to minimize the consumption of the energy during turning of steel at constant material removal rate. The main focus of this paper is to reduce the electrical energy consumption required by the tool in order to perform various cutting operations. Further MRR was set to be constant in order to analyze the effect that the cutting parameters on the energy consumption. To know the effect of depth of cut, feed rate, and cutting speed on the energy required by the machine is designed with the help of robust design. Thus, concluded that third level of feed rate, first level of depth of cut and first level of cutting velocity leads to less consumption energy.

Rashid and Bin (2016) studied the turning of AISI 2340 steel is done by CBN cutting tool for which Taguchi orthogonal array came into existence by using some set of the cutting parameters and on the other hand vertical turning trails were executed with well-designed Taguchi matrix. Furthermore multiple regression analysis, S/N ratio analysis and ANNOVA were carried out. As, a result roughness of surface is improved by lowering the feed rate and at the same time it also influences the tool life because of time engagement with the work piece and increased track length.

Rocha and Souza (2016) proposed optimization of AISI H13 steel during turning. Robust criteria was to be executed to opt for the most favorable optimal point. The response surface methodology was used to model cutting force, tool life, surface roughness parameter and the ratio between MRR and cutting force. Simultaneously normal boundary intersection method along with the mixture design of experiments is used to optimize the above discussed responses. An entropic was used to select favorable Pareto optimal point as the final solution. Thus, the study was able to demonstrate that the variances of obtained response get influenced by the weights used in multi objective optimization process. Furthermore, robustness process was hired to reduce forecast error.

Wan et al. (2016) proposed how to optimize the mechanical properties by using CRITIC method. In this study first high speed turning experiment is carried to seek the effect of various properties of the tool used in order to know the effect of tool life period and after that exponential model was built to increase the tool life period. Secondly Analytic Hierarchy Process method was associated with Criteria Importance with the help of Inter criteria

Correlation method in order to optimize the mechanical properties to increase the tool period. It was also found that when cutting speed is between 100 and 200 m/min. ceramic tool poses longer tool life and it also came into know that the main reason for the failure of the tool during high speed cutting is due to the crater wear and flank wear.

Zerti et al. (2016) proposed usage of Taguchi method for optimizing the parameters during dry turning. In this study an optimizing approach is used by selecting input variables such as: cutting edge angle, nose radius, cutting speed, feed rate, and depth of cut. A Taguchi L18 orthogonal array helps in optimizing of the input variables and ANNOVA is used to examine the foremost effect on the output variables. The result indicates that the roughness of surface gets effected by the feed rate and the cutting radius. While the tangential and specific cutting forces are get effected by depth of cut carried out by feed rate. Whereas cutting speed and feed rate are the major parameters affecting the cutting power. Further "the smaller-the-better" approach is used to calculate signal to noise ratio which are calculated using predicted technological outputs.

Varghesea et al. (2017) proposed multi objective optimization of cutting parameters throughout dry turning operation of 11SMn30 free cutting steel by using grey relational analysis. The main aim of this study is to observe the effect of the machining parameters such as spindle speed, feed rate and depth of cut on the surface roughness and material removal rate. L27 orthogonal array was used for obtaining the combination of process factors, on the basis of which experimental work is to be conducted. After the experimental work was over surface roughness is measured with the help of surface roughness tester. Which leads to found out the optimized machining parameters on which the value of surface roughness is low.

CHAPTER 3: PRESENTWORK

3.1 INTRODUCTION

The reason for selecting simulation and optimization of cutting edge geometry is due to the diversity in the field of machining. As, machining includes to work on various parameters in which some parameters are considered and some not, which indicates that more of the work can be done on this field. Additionally, majority of scholars published their work in optimizing of cutting parameters by using optimization technique. Yang and Tarng (1998) proposed usage of Taguchi technique to optimize the cutting variables during turning operation (Asilturk and Akkus, 2011) optimized the cutting variables based on the Taguchi method to reduce surface roughness caused after machining. Chen et al. (2013) studied what are the various variables that will affect the cutting stability while doing turning of thin walled circular cylindrical shell. Hashmi et al. (2015) studied how response surface methodology is being applied in optimizing the process parameters for machining of Ti-6Al-4V. Further, it was found that work piece and too life get affected by optimizing cutting edge geometry like the tool wear decreases which lead to increases in the tool life and on the other hand surface of the work piece also get improved by optimizing the major angle like rake angle, side rake angle and relief angle. Liao et al. (2016) proposed how to get most favorable geometry for cutting edge for finishing machining of stainless steel (Cheng et al. 2016) studied how to improve the geometric parameter of the chamfered edge during machining of the stainless steel. So, in order to get the most effected results, optimization of the cutting parameters along the cutting edge geometry is done. Now a day's more advancement is made in the field of optimization, like usage of software, which was not earlier used. With the help of software we can design and optimize the required parameters and after wards we can compare our software result with experimental work, which further helps in obtaining the improved results from the results that is to be got after performing experiment. Therefore, the results that are obtained after performing experiment and usage of software are more reliable and can be further used in industries for machining purpose.

3.2 PROBLEM FORMULATION

It is commonly observed that optimization of cutting edge parameters is widely done by performing experiments in which experiments are to be performed many times and after performing the experiment number of time the outcome may or may not be reliable. Therefore, in order to get more reliable result different types of techniques and software are used. The recent techniques that are used now days are Fuzzy Logic, Genetic Algorithms, Taguchi Techniques, Comprehensive Criteria and Response Surface Methodologies, where Fuzzy Logic helps in decision making, Genetic Algorithm is based on mechanics of natural selection and natural genetics, Taguchi Technique provides an array, with the help of which experiments are to be performed in less number according to the array to get the required result by not being performing the experiment number of times, Response Surface Methodologies helps in deriving clear and accurate conclusions from the experimental observations. On the other hand software that is used for designing and simulation is ABAQUS. So, it is primarily selected that the Taguchi is to be used for optimization from one of the above discussed technique.

3.2.1 Assumptions

Before machining is being performed to get the desirable output some assumption are made.

Following are the assumptions that are to be kept in consideration while performing machining process:-

(i) Machining process is assumed to be stable.

(ii) All the experiments are to be performed on a single machine.

(iii) The process is limited to specific type of tool and work material and also adaption is to be mainly focused on finishing of work piece.

(iv) The proposed analysis is to be derived from this study may or may not be applicable to other machining operation which will be substantially different but the general approach may be applied.

(v) It is also assumed that the Taguchi Design is to be used for optimizing the cutting edge parameters.

(vi) Simulation results are to be taken for studying the effect of cutting edge parameters on type of chip formed and stresses produced.

(vii) Different scope of cutting edge radius with single rake angle is to be considered.

(viii) Optimal scope of rake angle and cutting edge radius are to be considered.

3.2.2 Considerations

In proposed problem, optimization of cutting edge parameters is considered and the work piece is to be machined by tool in such a way that the resultant is to increase in surface finish. In order to achieve reliable and optimized result, the following constraints need to be optimized which are mentioned below as:-

(i) Optimum scope of nose radius is to be considered.

(ii) Optimum scope of rake angle is to be considered.

(iii)Optimum scope for cutting parameters.

3.3 RESEARCH GAPS

After a comprehensive study conducted on the existing literature, some of the following limitations are to be found in optimization of the cutting edge parameters:

(i) In the recent years, during metal cutting process cutting parameters such as cutting speed, feed rate, depth of cut, cutting temperature are found exhaustive in comparison to geometric parameters such as rake angle and nose radius for achieving good surface finish.

(ii) Less of the study has conducted on the combined and cross-functioning effects of geometric and cutting parameters for metal machining process to reduce surface roughness, which signify machining surface quality and the life of the tool.

(iii) Less work has been devoted on optimizing the geometric parameters, which have great influence on work piece material for achieving good surface finish.

(iv) Comprehensive criterion has been implemented to optimize different parameters in different fields, which is found to be difficult and complex in comparison to the other optimization techniques such as Taguchi, Genetic Algorithm, Response Surface Methodology, which are been into play for a longer time.

(v) Less of the work has been devoted on studying work piece deformation depending on rake angle and nose radius of the tool, by combining simulation and experimental approach.

(vi) The researchers face difficulty in selecting and understanding the new techniques such as Comprehensive Criterion, for the optimization of the machining parameters under the specified considerations.

3.4 OBECTIVES

It is observed from the exhaustive literature review and after the identification of research gaps that there is still need for studying the combined effect of cutting and geometric parameters for achieving good surface finish during turning of D3 steel by using cemented carbide tools. Therefore, in order to reduce surface roughness, the following objectives have been proposed:

(i) To study the effect on work piece deformation depending upon geometric parameters such as nose radius and rake angle.

(ii) To study combined and cross-functioning effects of geometric and cutting parameters for metal machining process to reduce surface roughness, which signify machining surface quality and the life of the tool.

(iii) To optimize the cutting parameters such as spindle speed, feed and depth of cut along the geometric parameters such as nose radius and rake angle by using L9 orthogonal array for three factor and two factor respectively.

(iv) To propose criterion on the basis of which optimization has to be performed is Taguchi. It is a technique which works on the basis of orthogonal array, in which we have to input different level of parameter, resulting in different combination of levels of parameters. Further, the experimental work has to be conducted on the basis of these produced levels of parameters.

(v) To simulate the effect of considered geometrical parameters on the performance of the cutting tool during machining using Abaqus which is an analysis software which examines structural analysis, heat transfer rate and finite element analysis. The effect of geometric parameters of cutting tool can be virtually studied and modified as per requirements.

3.5 METHDOLOGY/PLANNING OF PROPOSED WORK

In the present research work, Taguchi is to be used for the optimization of the of the cutting edge geometry and cutting parameters to get reliable result and simulation parts helps in understanding the effect of von Mises stress on geometric parameters. The step-by-step methodology proposed for the present research work is explained in further sub-sections.

3.5.1 Design and Simulation for Metal Cutting Process

FEM simulation software which is to be used for studying the effect of geometric parameters is ABAQUS. The part design approximate size is 0.02. Therefore, all the dimensions for work piece and the tool are set according the approximate size given in part design window. The following steps for the design and simulation necessary for metal cutting process are mentioned as:

3.5.1.1 Part designing of workpiece and tool

Work piece and tool are generated as per the required dimensions as shown in Figure 3.1 and 3.2 for performing metal cutting process.

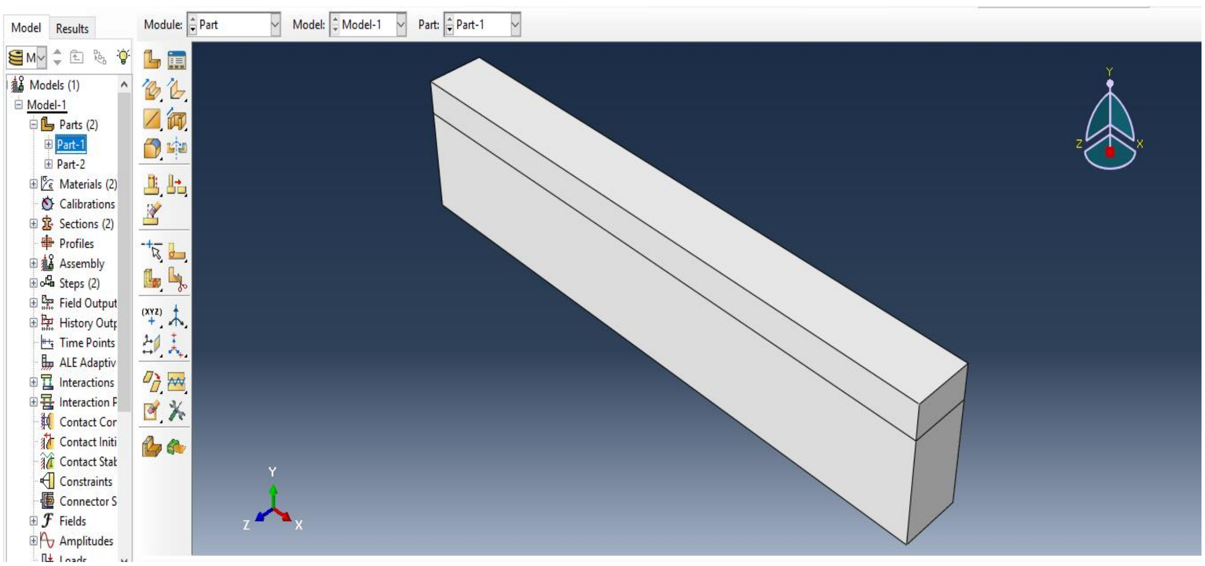

Figure 3.1: Part Design for Workpiece (ABAQUS Dialogue Window, Version 6.13.1)

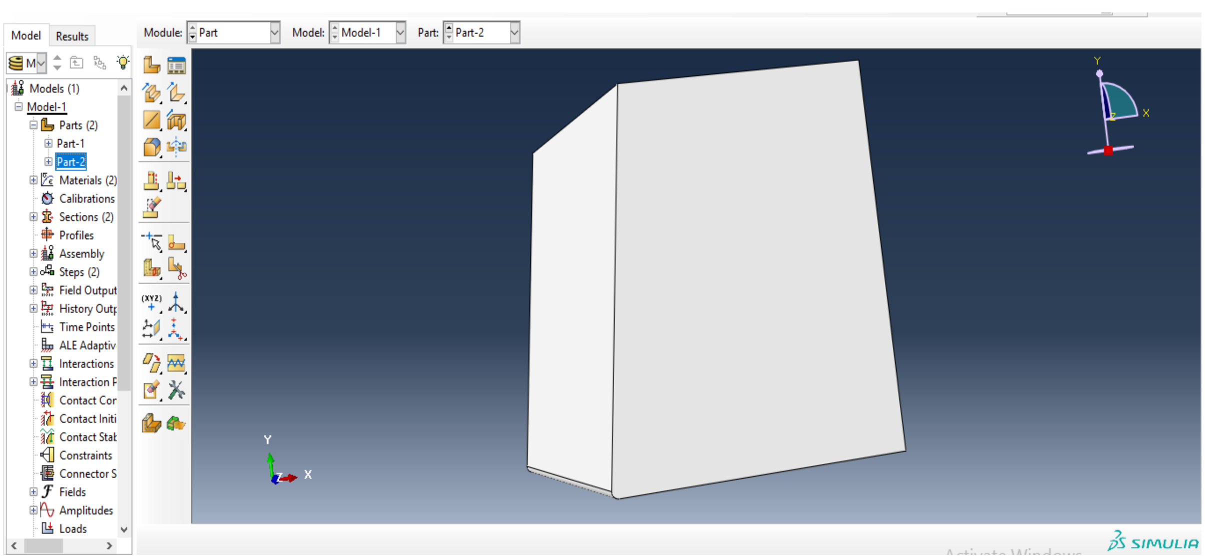

Figure 3.2: Part Design for Tool (ABAQUS Dialogue Window, Version 6.13.1)

The next step is to give materials properties such as Density, Poisson ratio, Elastic modulus etc. to the workpiece and the tool and afterwards we have to assign the properties to the workpiece and the tool like in this case the tool is assigned the properties of the carbide and the workpiece is assigned with the properties of the steel.

3.5.1.2 Assembly of tool and work piece

As the assignment of properties is done the next step is to assemble the tool and the workpiece for which first we have to go to instances and click of the part1 and after that click on part2 and the click on apply to see the assembly, which is to be shown in Figure 3.3.

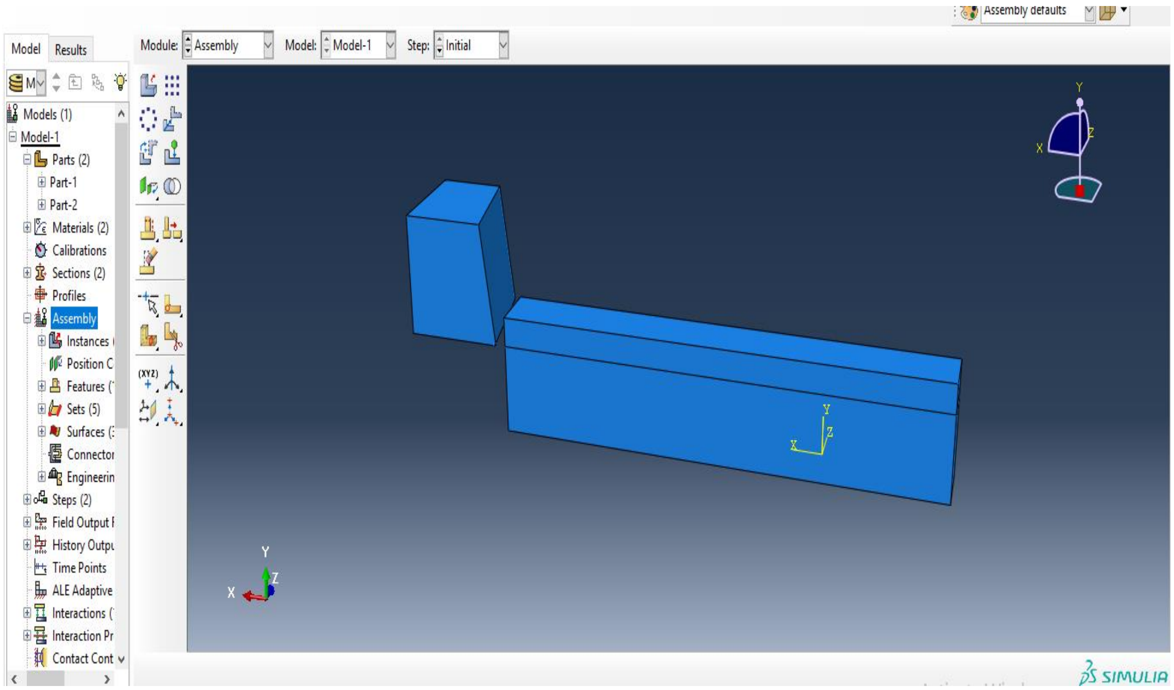

Figure 3.3: Assembly of Tool and Workpiece

3.5.1.3 Boundary conditions on tool and work piece

After assembly, we have to create a step in which we have to define that the procedure that we are following is Dynamic, Explicit. The next step is to create surfaces in which we have to select the surfaces which will perform the cutting process. Now, most of the work is done the next step is applying boundary conditions to the workpiece and the tool and the tool will only move in linear motion and the workpiece is considered to be fixed as shown in the Figure 3.4.

3.5.1.4 Meshing of work piece and Tool

The next step is to perform meshing of the workpiece and the tool, for workpiece the global size is set be 0.002 and for the tool 0.0005 as shown in Figure 3.5 and Figure 3.6. While meshing of workpiece we have to specify element type in which choose explicit option and then click on yes for element deletion for removal of material from the workpiece.

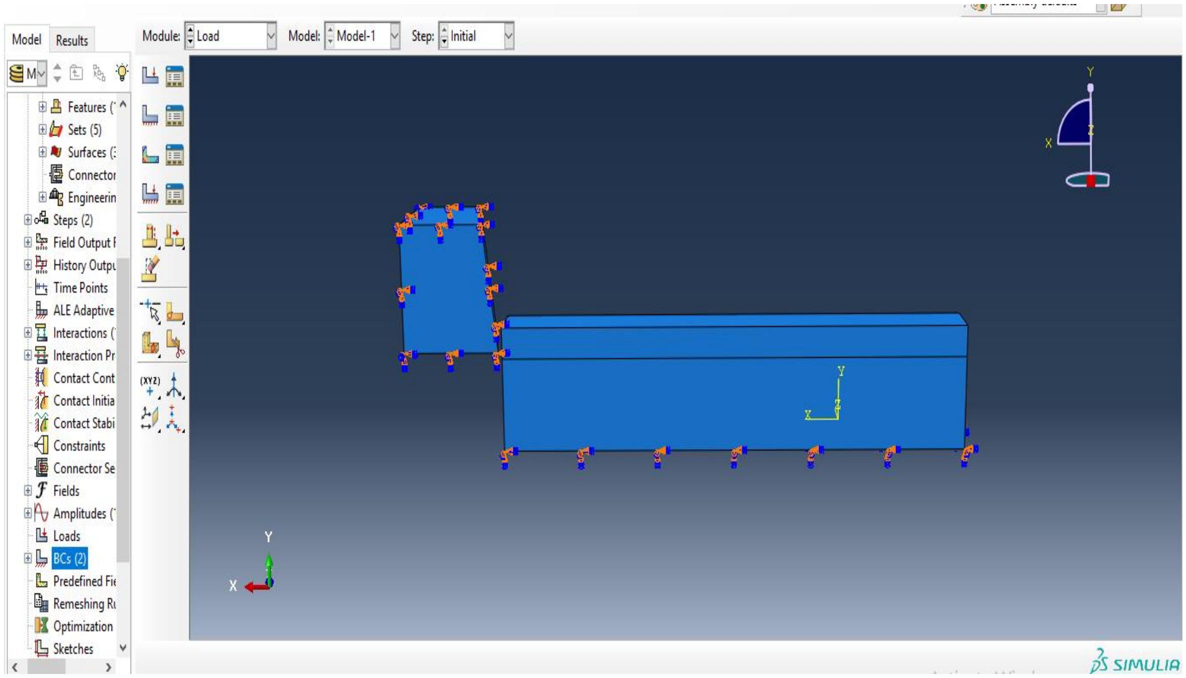

Figure 3.4: Boundary Conditions Applied on Tool and Workpiece

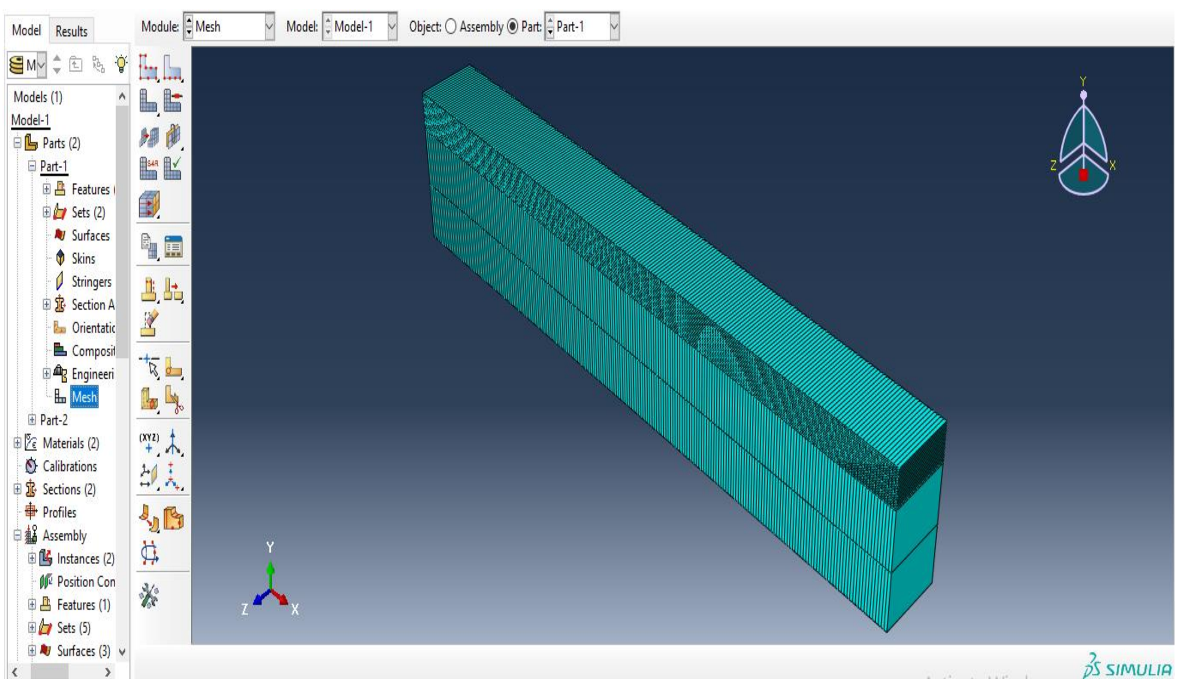

Figure 3.5: Meshing of Workpiece

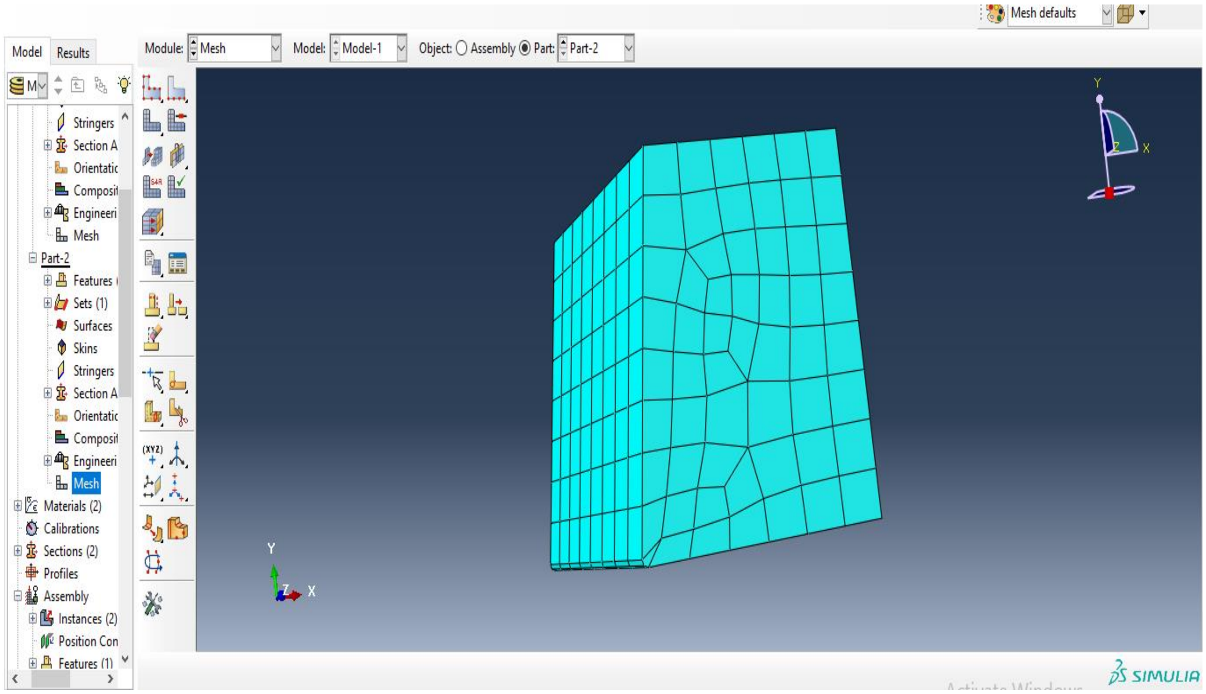

Figure 3.6: Meshing of Tool

3.5.1.5 Stress analysis for cutting tool

After meshing is performed the next step is to create status file by clicking on edit, a field output response window was generated for checking the status of simulation.

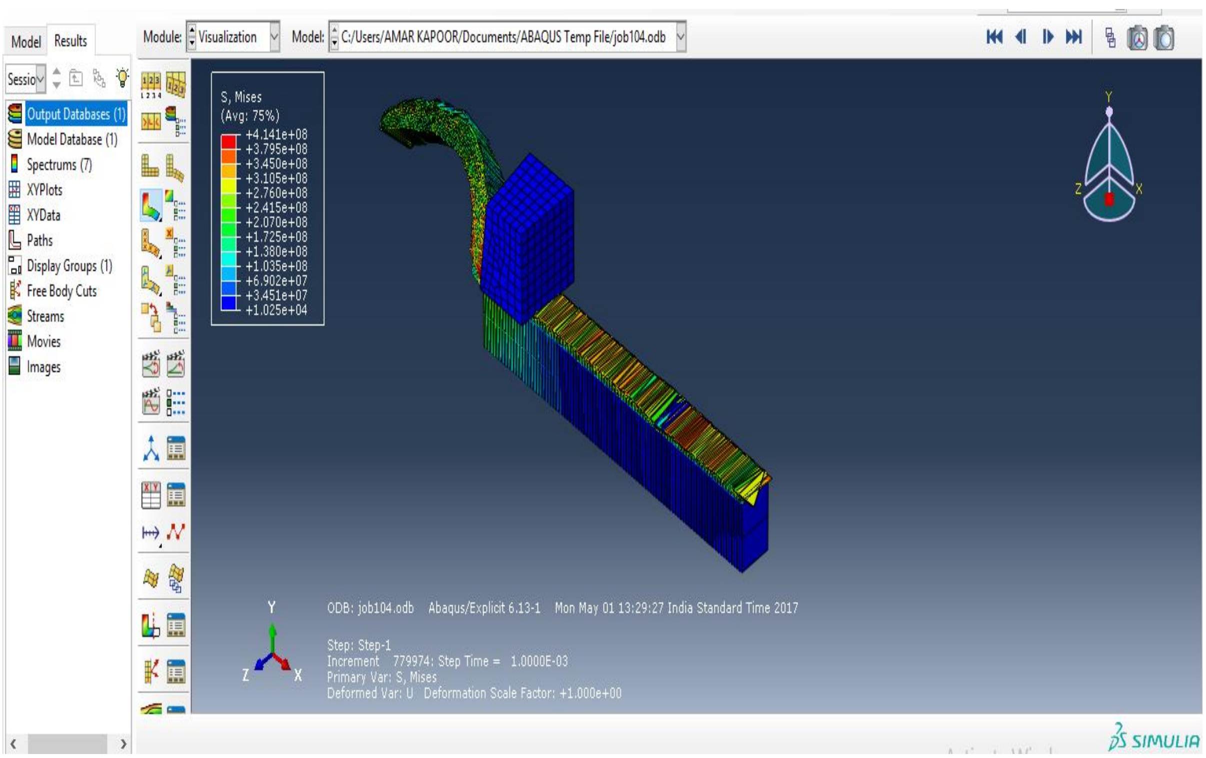

Figure 3.7: Simulation Result for Stresses

Afterwards name the file and then submit the file, as the file is submitted, check the status of the file and after job is completed click on results to get result window as shown in Figure 3.7. Figure 3.7 shows what will be the overall von Mises stress for that particular geometry and what type of chip is to be formed whether it is continuous or not continuous.

3.5.2 Minitab Software

Minitab is a statistical software developed in 1972 at the Pennsylvania state university by researchers Barbara F. Ryan, Thomas A. Ryan, Jr., and Brian L. Joiner. It began as light version of OMNITAB, which is a statistical analysis program. The documentation for OMNITAB was published in 1986. Minitab is distributed by Minitab Inc. It is a privately owned company headquartered in state college, Pennsylvania Minitab Inc. It is the first eLearning package that teaches statistical tools and concept in the context of quality improvement. Bouzakis et al. (2000) studied how to optimize the radius of the cutting edge by using film fatigue failure mechanism of Physical Vapor Deposition carbide insert during milling operation. Different combinations for cutting edge radius is done with the help of MINITAB software. Yu et al. (2003) proposed which cutting parameters are to be selected and different combination of levels of parameters are done with the help of MINITAB software, in order to affect the production cost while doing High Speed Milling of SKD6 steel tool. Tsai et al. (2005) uses Taguchi L9 by using MINTAB software, to increase the machining performance while machining of Inconel 718 by analyzing the cutting edge parameters. Janardhan and Krishna (2012) in this study multi objective optimization of cutting parameters was done by using MINITAB and Response Surface Methodology for surface roughness and metal removal rate during surface grinding. Yahya et al. (2015) optimize the machining parameters using Response Surface Methodology and MINITAB software for improving the surface roughness for AA6061. Abbas (2016) optimize the cutting parameters during turning operation using MINITAB software and Taguchi technique for improving the surface finish for AL1070. Mia and Dhar (2016) studied usage of Taguchi technique by using MINITAB software for improving the surface roughness and cutting temperature by providing coolant during hard turning .Taguchi L36 orthogonal array is used to evaluate surface finish and cutting temperature during machining operation. In this study, Taguchi and ANOVA are used by using MINITAB software, which are discussed as follow.

3.5.2.1 Taguchi parameter design for array formation

Taguchi is a technique which gives much reduced "Variance" for different sets of experiments with optimum settings of control parameters based on "ORTHOGONAL ARRAY". Where orthogonal array helps in achieving a set of well-balanced experiments and on the other side signal to noise ratio are the log functions of the output, which helps in analysis of data and forecasting of optimum results. The Procedure for applying Taguchi technique is mentioned below in form of steps as:

(i) Problem identification and formulation for Taguchi Parameters

In order to optimize the desired parameters we have to first formulate the problem. For which a detailed knowledge is required in order to examine the subject. So, first an objective is set which is to be achieved at the end of the study by this design of experiments. The process variables are found out after setting the objectives, which are also known as controllable factors or signals. The performance of whole process gets affected by two factors known as controllable and uncontrollable factors, where uncontrollable factor is also known as Noise. For example in any precision machining, different environmental factors such as vibrations, temperature, humidity etc. affects the whole process. Combination of different levels of parameters are made for performing experimentation work to get the optimized parameters.

(ii) Experimental design for Arrays

Orthogonal array is used for making an experimental design. The selection for required orthogonal array depends on the number of parameters and number of variables selected for the study. In this study L9 array is used for design of experiment as there are three parameters and three levels on which whole experimental work is performed. 27 combinations of different parameters forms from three parameters and three levels. The Taguchi orthogonal array helps in selecting the most affecting nine parameter combinations. About 99.5% accuracy can be achieved by conducting the nine experiments instead of twenty seven experiments. This somehow reduces the time required for experimentation work.

(iii) Analysis of results

After performing the experimental work on the basis of the combination of the different levels of parameters, we have to analyze the result and for analyzing the result Signal to Noise ratio is used to process parameters. Where these process parameters gets affected by two factors known as controllable and uncontrollable also known as signal and noise respectively. Thus with the help of S/N ratio we can found which are the parameters which are less affected by noise.

3.5.2.2 Signal to noise ratio

By Taguchi methods, uncontrollable factors such as noise can be minimized to identify the control factors, which are the one that decreases the liability of the product. Control factors are process variables that can be controlled by minimizing the noise factor. Where uncontrollable factors can be controlled while performing experimental processes. In this method, the noise factors are manipulated for variability to take place and from the results, the control factor settings are identified and optimized in order to obtain a robust product. The effects of noise factors are minimized by the Control factor settings, which can be identified with the help of higher signal-to-noise (S/N) values obtained from the Taguchi process. The whole process depends upon:

Step 1: In order to identify the optimal control factors signal-to-noise (S/N) ratio are used in order to reduce variability.

Step 2: Signal-to-Noise (S/N) ratio helps in identifying the least affecting factor. Which helps in bringing the mean values closer to the target. Different signal-to-noise ratios can be chosen according to the target of the experiment.

For the static experiments three different S/N ratios (Qureshi, 2015) are generally used.

(i)Larger is better:

This signal-to-noise ratio is used to maximize the response.

$$S/N = -10 * \log(\Sigma(1/Y^2/n) \quad (3.1)$$

(ii)Nominal is best (default):

This signal-to-noise ratio is used to target the response and the ratio is based on both standard deviations and mean.

$$S/N = 10 * \log((\bar{y}^2 \div \sigma^2) \quad (3.2)$$

(iii)Smaller is better:

This signal-to-noise ratio is used when the response is to be minimized.

$$S/N = -10 * \log(\Sigma(Y^2)/n)) \quad (3.3)$$

3.5.2.3 ANOVA (Analysis of Variance) to validation of Taguchi results

The ANOVA (Analysis of Variance) is used for validating the results obtained by Taguchi technique. In this study is two way ANOVA is used because the experiment is having two or more different variables with quantitative results and can be used under various conditions. Since in this method two or more independent variables are used due to which the outcome of one variable may or may not affect the outcome of the others. The structure of Two way ANOVA is that each of the categorical variables has its own population mean. This Interaction model usually has no restrictions on its patterns. On the other hand, the non-interaction (additive) model has a restriction on population mean. The restriction is that the effect on the outcome of one explanatory variable is the same for every other explanatory variable. It does not depend on each other. This is known as Additive model. While the level change of one variable depends on the levels of other variables in the Interaction model. Following steps help in interpreting the key results for two-way ANOVA.

Step 1: To determine whether each main effect and the interaction effect is statistically significant, compare the p-value for each term to your significance level to assess the null hypothesis. Usually, a significance level (denoted as α or alpha) of 0.05 works well. A significance level of 0.05, which indicates a 5% risk difference exist when there is no actual difference.

(i) The null hypothesis for a main effect is that the response mean for all factor levels are equal.

(ii) The null hypothesis for an interaction effect is that the response mean for the level of one factor does not depend on the value of the other factor level.

The statistical significance of the effect depends on the p-value, as follows:

(i) If the p-value is larger than the significance level you selected, the effect is not statistically significant.

(ii) If the p-value is less than or equal to the significance level you selected, then the effect for the term is statistically significant.

The following shows how to interpret significant main effects and interaction effects.

(i) If the main effect of a factor is significant, the difference between some of the factor level means are statistically significant.

(ii) If an interaction term is statistically significant, the relationship between a factor and the response differs by the level of the other factor. In this case, you should not interpret the main effects without considering the interaction effect.

Step 2: To assess the means, if the p-value in the ANOVA table indicates a statistically significant main effect or interaction effect, use the means table to understand the group differences.

For main effects, the table displays the groups within each factor and their fitted means. For interaction effects, the table displays all possible combinations of groups across both factors.

Step 3: To determine how well the model fits your data, examine the goodness-of-fit statistics in the model summary table.

(i) S: Use S to assess how well the model describes the response. S is measured in the units of the response variable and represents the standard deviation of how far the data values fall from the fitted values. The lower the value of S, the better the model describes the response. If you compare different models, the model that has the lowest S value indicates the best fit.

(ii) R-sq: R2 is the percentage of variation in the response that is explained by the model. The higher the R2 value, the better the model fits your data. R2 is always between 0% and 100%. R2 always increases when you add additional predictors to a model. For example, the best five-predictor model will always have an R2 that is at least as high the best four-predictor model. Therefore, R2 is most useful when you compare models of the same size. A high R2 value does not indicate that the model meets the model assumptions. You should check the residual plots to verify the assumptions.

(iii) R-sq (adj): Use adjusted R2 when you want to compare models that have different numbers of predictors. R2 always increases when you add a predictor to the model, even when there is no real improvement to the model. The adjusted R2 value incorporates the number of predictors in the model to help you choose the correct model.

(iv) R-sq (pred): Use predicted R2 to determine how well your model predicts the response for new observations. Models that have larger predicted R2 values have better predictive ability. A predicted R2 that is substantially less than R2 may indicate that the model is over-fit. An over-fit model occurs when you add terms for effects that are not important in the population, although they may appear important in the sample data. The model becomes tailored to the sample data and therefore, may not be useful for making predictions about the population. Predicted R2 can also be more useful than adjusted R2 for comparing models because it is calculated with observations that are not included in the model calculation.

3.5.3 Optimization of Geometric and Cutting Parameters by Taguchi

Figure 3.8 depicts the proposed criterion for optimization of geometric and cutting parameters for attaining good surface finish. Following steps are to be followed for optimizing the required parameters for achieving good surface finish.

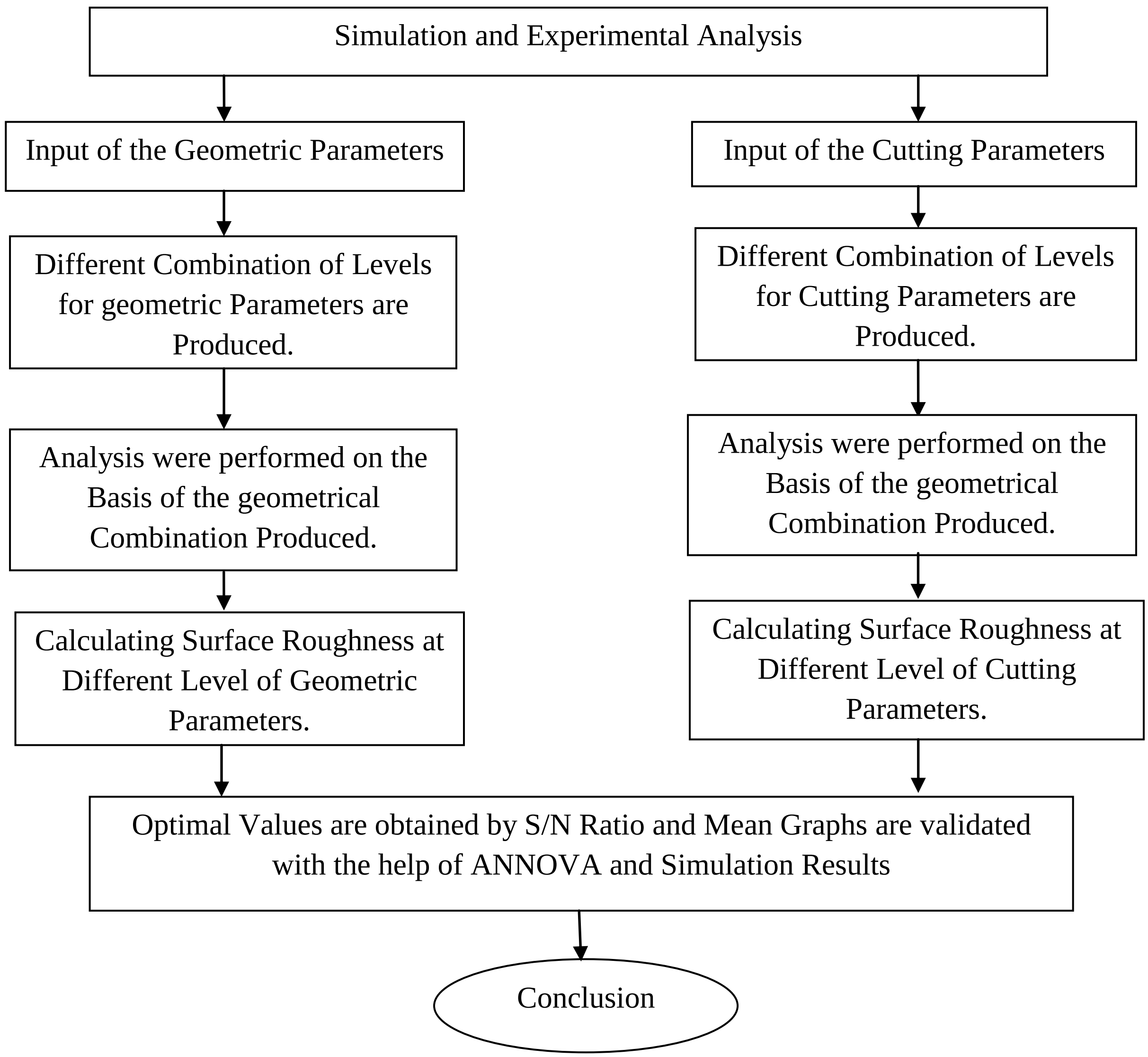

Figure 3.8: Proposed Criterion for Optimizing of Geometric and cutting Parameters for Good Surface Finish

Step 1: The optimization process is divided into two parts; one is the optimization of the cutting parameters and other optimization of geometric parameters. The two are, respectively, independent and not related to each other.

Step 2: For optimizing the cutting parameters and the geometric parameters different combination of parameters are obtained by using L9 orthogonal array.

Step 3: The next step is to perform experiment on the basis of the combinations obtained by the Taguchi Design and experimentally calculate the value for surface roughness with the help of surface roughness tester.

Step 4: In order to obtain the optimal values for cutting parameters and geometric parameters S/N ratio plots and Mean plots are used. With the help of these plots we can attain what will be the optimal value for spindle speed, feed, depth of cut, rake angle and nose radius.

Step 5: After obtaining the optimal parameters, our next step and last step is to validate the results means the result we are getting is valid or not by applying ANNOVA.

3.6 EXPERIMENTAL SETUP AND MACHINING PROCEDURE

The surface integrity is influenced to a large extent by cutting parameters such as cutting speed, feed and depth of cut as well as the geometric parameters such as rake angle and nose radius. In order to minimize the machining time and hence the cost of machining in an industrial environment there is a need for optimization of cutting parameters. However, due to lack of reliability of suitable models relating machining variables with cutting parameters, these models have not found proper implementation in industry. Many researchers have developed theoretical models. However, machine tool structure and cutting process dynamics are so complex that these theoretical models cannot be completely relied upon. Therefore, to achieve reliable outcome proper experimental procedure along with suitable model had to be employed.

3.6.1 Considered Variables

Both cutting parameters and geometric parameters such as cutting speed, feed rate, depth of cut, rake angle and nose radius are considered while performing the experiment and are shown in Table 3.1. To improve the surface finish, coolant was applied at specific interval of time which somehow helps in increasing tool life.

3.6.2 Material, Machine and Equipment

AISI D3 bar is used as a work material. The chemical composition and the physical properties are discussed in Table 1.1 and Table 1.2. The work piece (bars) has been pre-cut with grooves to simulate the orthogonal cutting. Orthogonal metal cutting experiments have been conducted in a CNC machining center.

Table 3.1: Scope of Cutting and Geometric Parameters

Parameters	Values
Depth of Cut	0.03-0.09 mm
Feed Rate	0.03 to 0.07 mm/rev
Spindle Speed	1000 to 2000 rpm
Nose Radius	0.4 to 1.2 mm
Rake Angle	10º to 20º

A cemented carbide tool bit of different rake angle and nose radius has been selected as the cutting tool. Further surface roughness tester is used for measuring the surface roughness at different levels of selected parameters, which will help us in attaining the optimal parameters for finishing machining of D3 steel.

3.6.3 Experimental Setup

Experimental setup used for performing the turning operation is CNC lathe machine. The abbreviation of CNC is Computer Numeric Control. Its works when the machining command is given in the form of programmable logic control. Numerical control program is created for directing the CNC machine tool for machining process. They are also called as part program and can be stored in memory of CNC lathe. Part program contains two types of codes. They are G-codes and m-codes. G-codes are used to specify the direction and rate of movement of the machine tool. M-codes stands for miscellaneous functions of the machine like coolant on and off, spindle start and stop etc. CNC lathe tool can move in three dimensional axes, it helps in easy and fast machining. CNC machines are very high precision machines and very high degree of accuracy can be obtained in machining. Accuracy of the machine depends on the part program made to run the machine. The proper selection of tool and rate of movement is necessary to attain accuracy. Since, the machining time in CNC machine is less and is mostly used for batch production. During machining many decisions has to be made by the machine tool operator like of feeds rate, cutting speed, mathematics and sometimes even selection of cutting tool in order to get desired product with high accuracy. The decisions made by the worker depend on the number of work to be produce and the environment he is working in. The accuracy and tolerance limit is set by the organization the operator working for. In keeping all these factors in mind the operator should take decisions for machining. Therefore, LEADWELL T6 CNC Lathe will be used for performing the turning operation as shown in Figure 3.9. Following Table 3.2 shows the different specification of CNC lathe, which proves to be helpful during turning operation. Table 3.2 shows the specifications of LEADWELL T6 CNC Lathe.

3.6.4 CNC Part Program for Turning Operation

```
G71 G95 G90
M03 S1000
M06 T1 D1
G00 X35 Z10
G01 X32.46 Z5 F0.07
G01 Z-70 F 0.09
G00 X35 Z-5
G01 X32.43 Z5 F0.07
G01 Z70 F0.07
G00 X35 Z5
G01 X32.40 Z5 F0.07
G01 Z-70 F0.09
G00 X35 Z-5
M05
M30
```

This part program is used for turning the work piece. The machining parametric quantities user are:

Spindle speed = 1000 rpm, Feed rate = 0.07 mm/rev and depth of cut = 0.09 mm. The above part program can edited accordingly to use for performing facing operation with all the nine parametric combinations that has been selected by Taguchi method.

3.6.5 Contact Mechanical Profiler

Surface roughness is measured with the help of Contact Mechanical Profiler. It consist of a conical diamond tip stylus which helps in measuring the surface roughness by tracing the surface, which is to be examined by an examiner. The diamond tip provided in stylus has a cone angle of 60˚ or 90˚ and the radius of the tip varies from 1-10 µm.

Table 3.2: Specifications of the LEADWELL T6 CNC Lathe

Parameters	Specifications
Capacity	450 mm
Bar Capacity	51 mm
Chuck size	6 inch
X axis travel	230
Z axis travel	105+20 MM
Spindle speed	45-4500 RPM
Spindle nose	A2-5
Through hole spindle	62 mm
Number of tool position	12
Turret indexing time	1 sec
X rapid traverse	20 m/min
Z rapid traverse	24m/min
Spindle motor	15 HP

Figure 3.9: LEADWELL T6 CNC Lathe

The stylus moves in perpendicular to the direction of machining in order to records variation in surface of work piece. There should be no disturbance or any external force acting on the stylus while mounting the profiler on the workpiece. So, it is to be kept in mind that profiler should be firmly placed on workpiece. It slides on the surface of workpiece at regulated speed. The transducer reads the vertical variation of the stylus and converts the mechanical signals to electrical signals. Amplification of these electrical signal is done to undergo conversion of Analog to Digital. The obtained digital profile is loaded in the computer and can be used for checking the surface waviness and roughness. This mechanical profiles provides high accuracy. It is potable and very easy to use. For this thesis work, Mitutoyo SJ-201P is used as depicted in Figure 3.10.

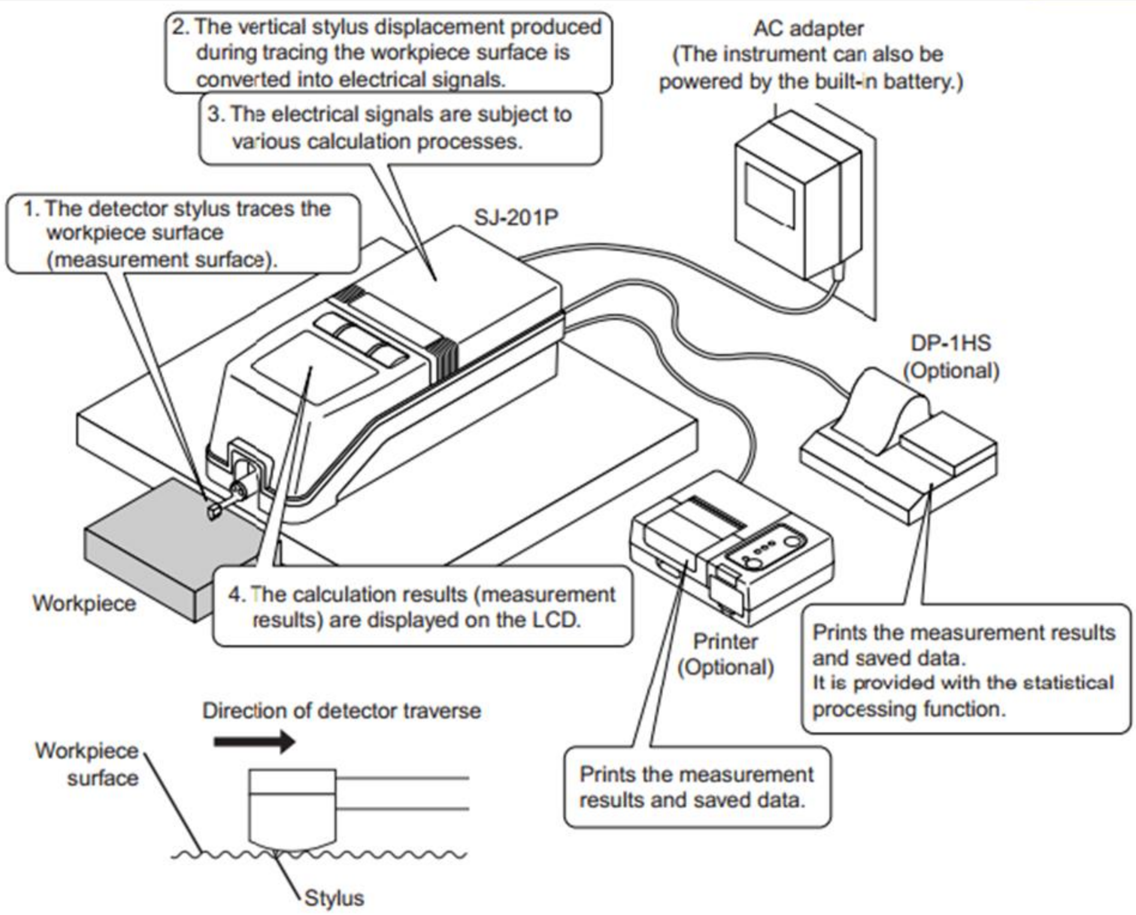

Figure 3.10: SJ-201P Surface Roughness Tester

CHAPTER 4: RESULTS AND DISCUSSIONS

4.1 INTRODUCTION

This chapter addresses about the results obtained, by following the sequence of system architecture algorithm for result analysis as design, simulation, optimization and validation as shown in Figure 4.1. Accordingly, the first step is to generate a design and simulation model for analysis of von Mises stress on cutting tool as discussed in Section 4.2.2 and the software which is to be used for performing the design and simulation part is ABAQUS. The next step after the simulation part is to perform experimental work in order to attain good surface finish, for which Taguchi method has been used, which is quite successfully in several industrial applications to optimize manufacturing processes and in the design of electrical and mechanical components. Taguchi's method helps to find the best set of specified process parameter level combinations which include the discrete setting values of the process parameters. Further, mean and S/N ratio plots are used to find the optimal values for cutting and the geometric parameters as shown in Figure 4.7, Figure 4.8, Figure 4.12 and Figure 4.13 respectively. S/N ratio consists of two variables known as controllable and uncontrollable also known as signal and noise respectively. In order to find optimal parameters, the value of S/N ratio should be high for which there must be reduction in uncontrollable factors. A table of response is developed, which helps in studying the most contributing factor or impact factor. Analysis of Variance (ANOVA) is used to validate on the basis of the significant factor, by comparing the results for the contributing factor.

4.2 RESULT ANALYSIS

In this section of this chapter, the results for finishing machining i.e. Surface roughness is being discussed. As discussed in Chapter 3, the experiments are performed by varying the cutting and geometrical parameters such as spindle speed , depth of cut, feed rate, rake angle and nose radius respectively in order to machine D3 steel by using carbide tool to obtain good surface finish. The experiments are performed on the basis of Taguchi design. The results obtained from the experimental investigation for Surface Roughness (Ra) are shown in Section 4.2.2.1. These results obtained are then used to develop a relationship between the surface roughness and process variables on the basis of plots of means and of signal to noise ratio.

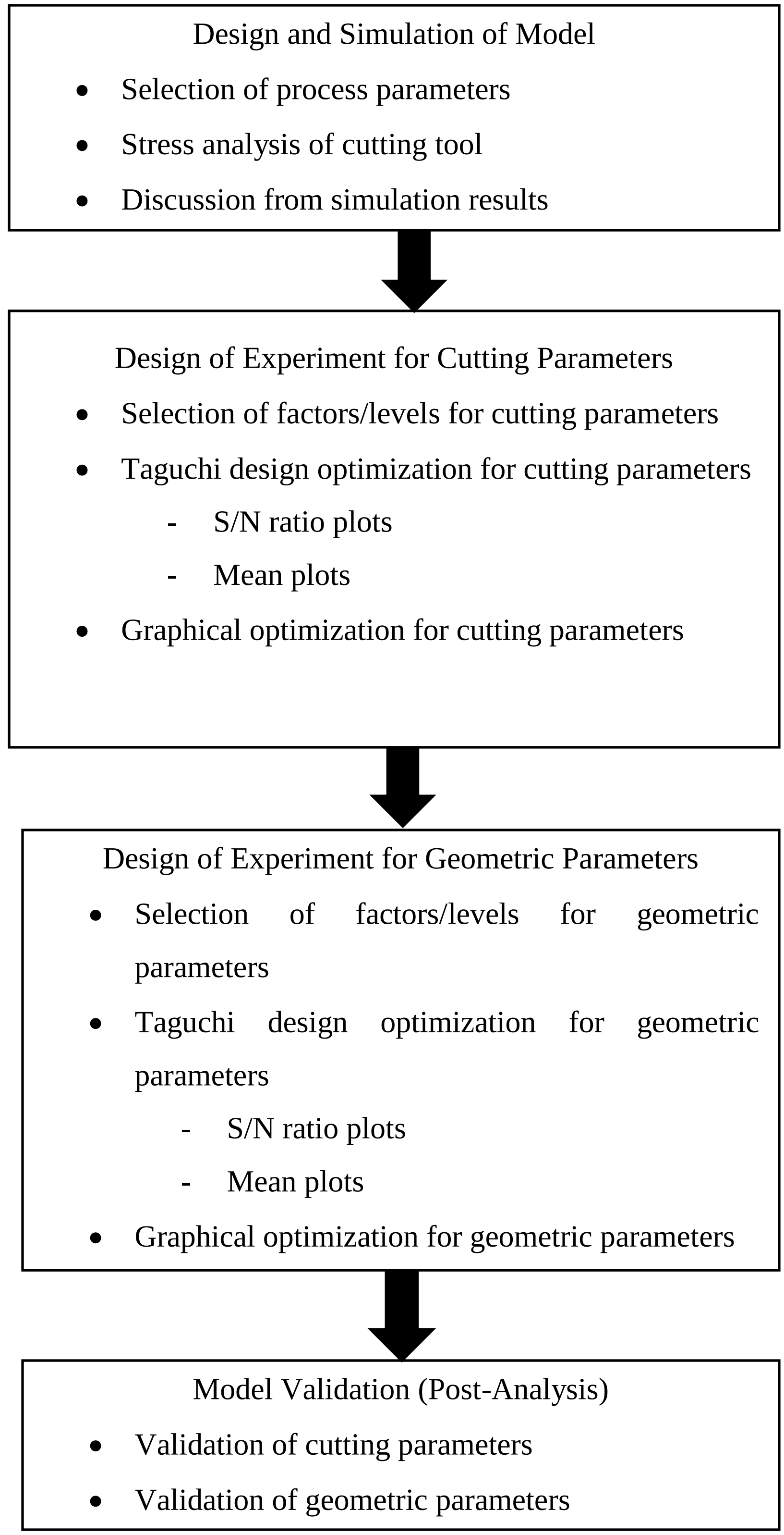

Figure 4.1: System Architecture Algorithm for Result Analysis, Simulation, Optimization and Validation

Figure 4.1 shows the step by step design; analysis; simulation; optimization and validation of the model.

4.2.1 Design and Simulation of Model

The FEM simulation software that is used for performing metal cutting simulation is ABAQUS. In this study, ABAQUS is used to understand the effect of the geometric parameters of tool on the work piece, this type of simulation came under ABAQUS/Explicit, in which it can employ explicit integration to solve highly nonlinear system under transient loads with many complex contacts. This section is divided into three parts as first is designing part, second is processing or FEM analysis of work and third is post processing part under ABAQUS/Explicit. In case of designing part, first it is desired create the parts after which it is asked to provide the material properties for the designed part as the materials properties are input, then we have to create sections in which we have to assign the these material properties to designed part. The next step is to create an assembly for the designed parts, as soon as assembly part is over, our next step is to provide the boundary conditions for the designed parts, in this case, work piece is considered to be fixed and tool is considered as moveable part, for which some displacement is being provided to the cutting tool, which allows tool to move in the desired direction and the cutting operations are to be performed by the cutting tool. As soon as, it can performed with applying boundary conditions. The next step is to perform meshing for the designed parts i.e., the tool and work piece. After the meshing part is over, our assembly is ready for analysis, for which we have to name the job which we are going to submit. As, the job is being submitted, click for the status of the job, which shows what is the status of the analysis as the job is being completed, our next step came into play i.e., analysing or processing in present step. The FEM simulation software processes the information that we have already given as input during the designing part and we check this step by confirming for the status of file by choosing monitor option. After the second step, our third step is to post processing or generating output file, which shows the results that we get after the designing part. In this step, we have to analyse on the basis of the von Mises stresses produced during the metal cutting process and this can done by comparing the results of the stresses which is being produced under the effect of geometric parameters. In this case, rake angle and nose radius are the considered parameters which are to be varied, in order to study the effect of stress produced and found optimal values for rake angle and nose radius during the metal cutting simulation.

4.2.1.1 Selection of process parameters

The parameters which are to be selected on the basis of analysis of stress in simulation are rake angle and nose radius. Different ranges of parameters for rake angle and nose radius are selected on the basis of the literature survey conducted in chapter 2. The following Table 4.1 depicts the range for the selected process parameters.

Table 4.1: Selected Process Factors/Levels for analysing Geometric Parameters

Factors/Levels	Units	I	II	III
Rake angle	Degrees	10	15	20
Nose radius	mm	0.4	0.8	1.2

Therefore, our next step is to make different combinations of the selected factors on the basis of which we will perform our simulation work, which is to be further analysed on the basis of stress generated on cutting tool. Table 4.2 shows different combinations for the rake and nose radius selected for this study.

Table 4.2: Selected Process Factors with Respective Levels for Design

S.no	Rake Angle (Degrees)	Nose Radius (mm)
1	10	0.4
2	10	0.8
3	10	1.2
4	15	0.4
5	15	0.8
6	15	1.2
7	20	0.4
8	20	0.8
9	20	1.2

4.2.1.2 Stress analysis of cutting tool

In this sub-section, the simulation is being performed to understand the metal cutting processes. The whole simulation process is divided into three steps. First is pre-processing, in this step model is created inside the ABAQUS software, followed by processing stage in which the software processes our inputs and the last step is post processing or generating report as discussed in section 4.2.1. The following steps helps in analysing the von Mises stress produced during metal cutting simulation on cutting tool by varying rake angle and nose radius of tool.

(i) When rake is 10° and nose radius is variable

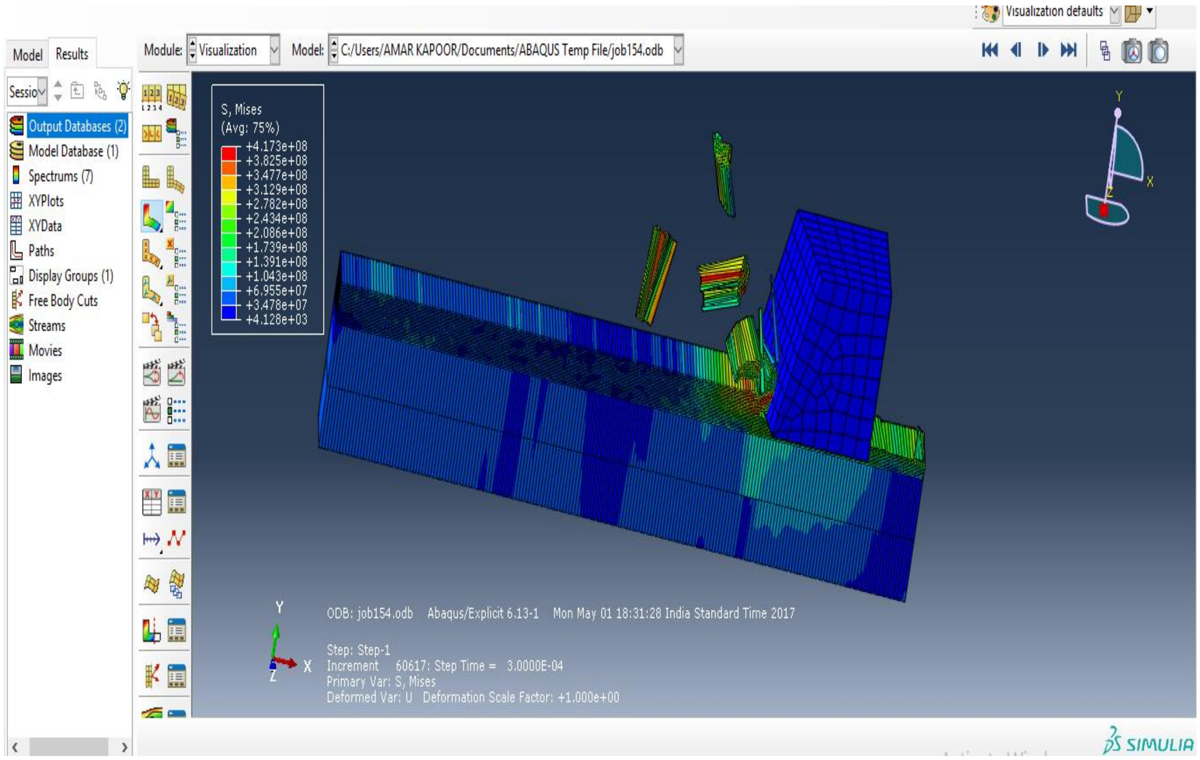

Figure 4.2: Simulation Dialogue Window at Rake Angle 10° and Variable Nose Radius

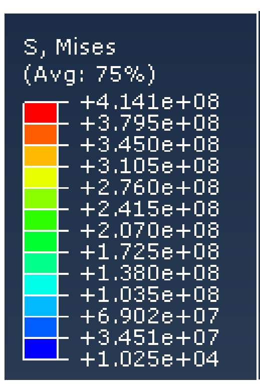

Figure 4.2 (a)

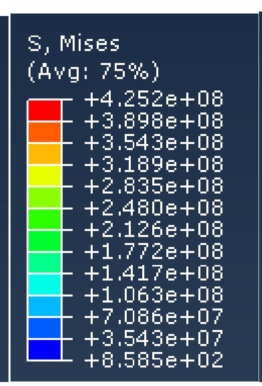

Figure 4.2 (b)

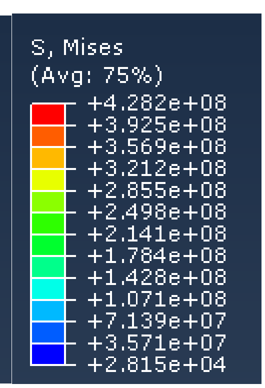

Figure 4.3 (c)

The Figure 4.2 shows the simulation results for stresses at constant rake angle i.e., 10° and variable nose radius. Figure 4.2(a), 4.2(b) and 4.2(c) show the values of stresses at 10° rake angle and 1.2mm, 0.8mm and 0.4mm nose radius respectively. As per the simulation results, it is seen that the value of stresses getting increased as the nose radius decreases, means less of stress is being produced as there is more area of contact between the tool and work piece as nose radius increases.

(ii) When rake angle is 15° and nose radius is Variable

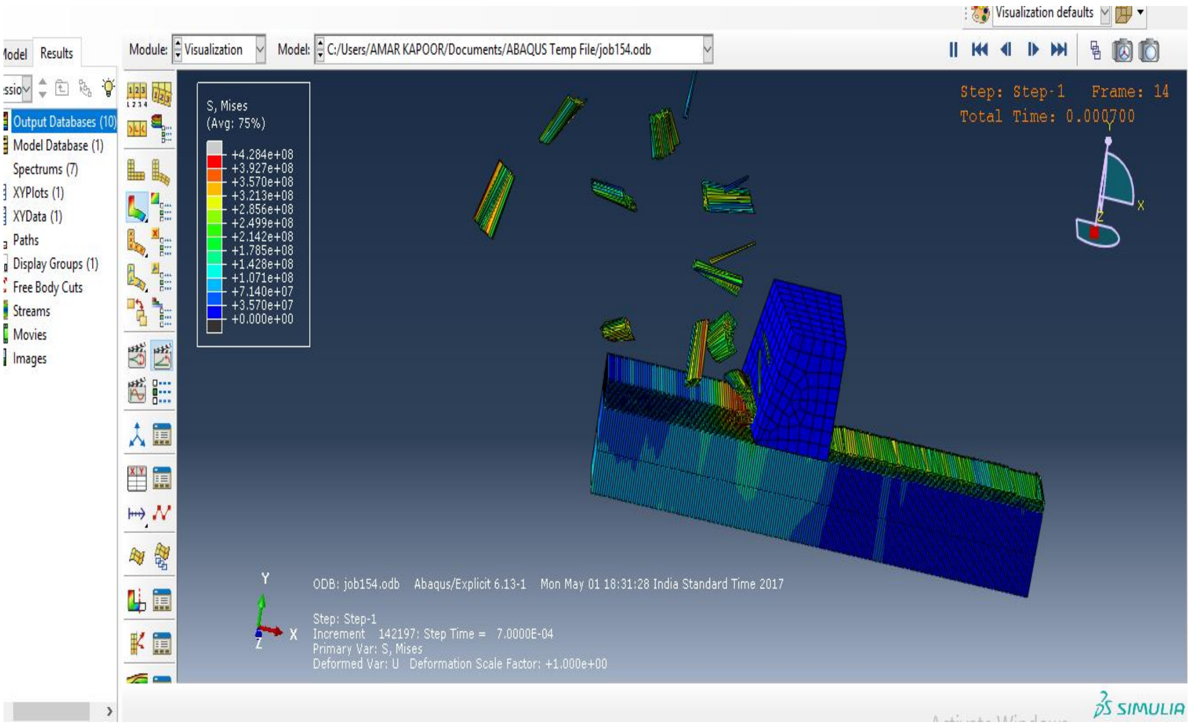

Figure 4.3: Simulation Dialogue Window at Rake Angle 15° and Variable Nose Radius

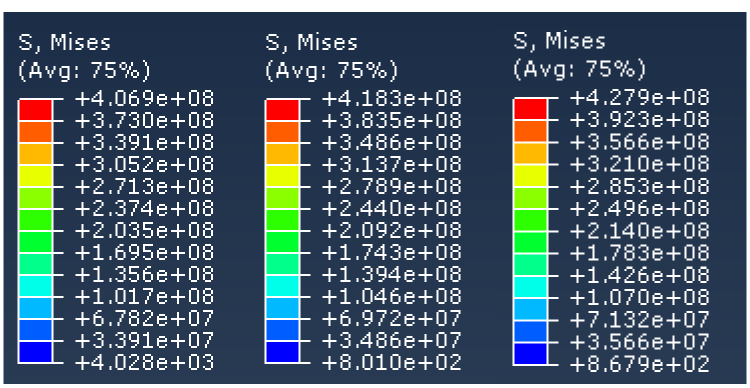

Figure 4.3 (a) **Figure 4.3 (b)** **Figure 4.3 (c)**

Figure 4.3 shows the simulation results for stresses at constant rake angle i.e. 15° and variable nose radius. Figure 4.3(a), 4.3(b) and 4.3(c) show the values of stresses at 15° rake angle and 1.2mm, 0.8mm and 0.4mm nose radius respectively. As per the simulation results, it is seen that the value of stresses getting increases as the nose radius decreases, means less of stress is being produced as there is more area of contact between the tool and workpiece as the nose radius increases.

(iii) When rake angle is 20° and nose radius is Variable

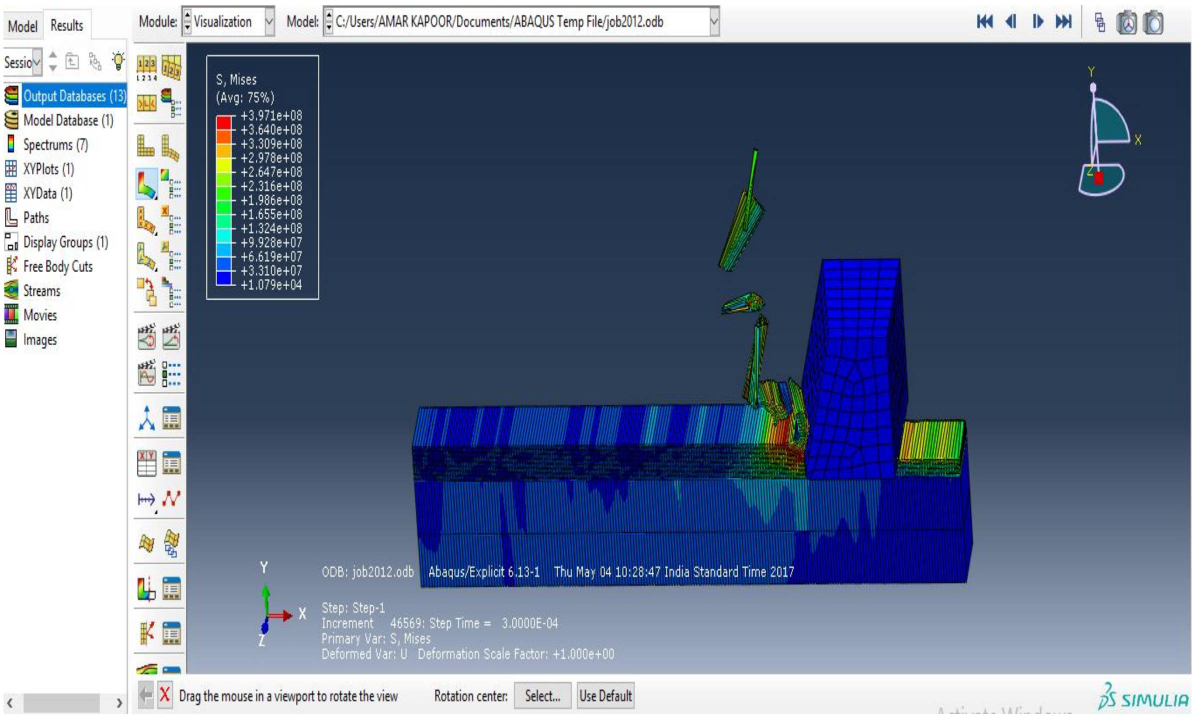

Figure 4.4: Simulation Dialogue Window at Rake Angle 20° and Variable Nose Radius

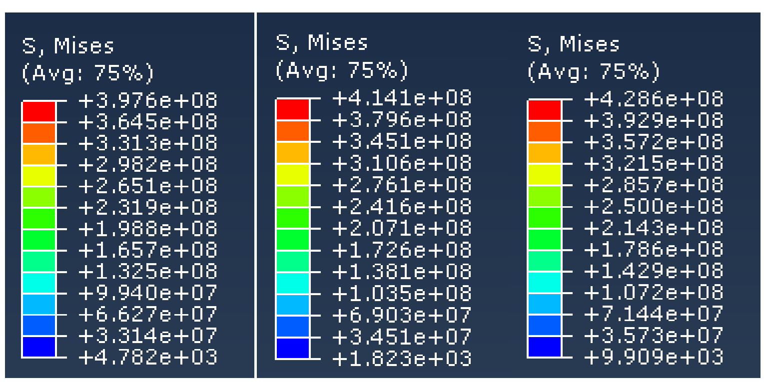

Figure4.4 (a) **Figure4.4 (b)** **Figure4.4 (c)**

Figure 4.4 shows the simulation results for stresses at constant rake angle i.e., 20° and variable nose radius. Figure 4.4(a), 4.4(b) and 4.4(c) show the values of stresses at 20° rake angle and 1.2mm, 0.8mm and 0.4mm nose radius respectively. As per the simulation results, it is seen that the value of stresses getting increased as the nose radius decreases, means less of stress is being produced as there is more area of contact between the tool and work piece as the nose radius increases.

4.2.1.3 Discussion from simulation results

After studying the effect of von Mises stresses on different tool geometry, it is found that the value for the stresses decreases as the nose radius increases and on the other hand, rake angle also has effects on stress value and it is observed that with the increase in value of rake angle, value for stress tends to decrease. Thus, it is observe that larger the value of nose radius and rake angle, smaller will be the value for stresses which are further explained and discussed with the help of Figure 4.5 and Figure 4.6.

(i) Nose radius vs. avg. von Mises stress

Table 4.3 shows value for average von Mises stress which is obtained from the simulation results and Nose Radius, which are considered in this study after going through exhaustive literature survey.

Table 4.3: Table for Avg. Stress and Nose Radius

Avg. von Mises Stress (N/mm^2)	4.282	4.192	4.062
Nose Radius (mm)	0.4	0.8	1.2

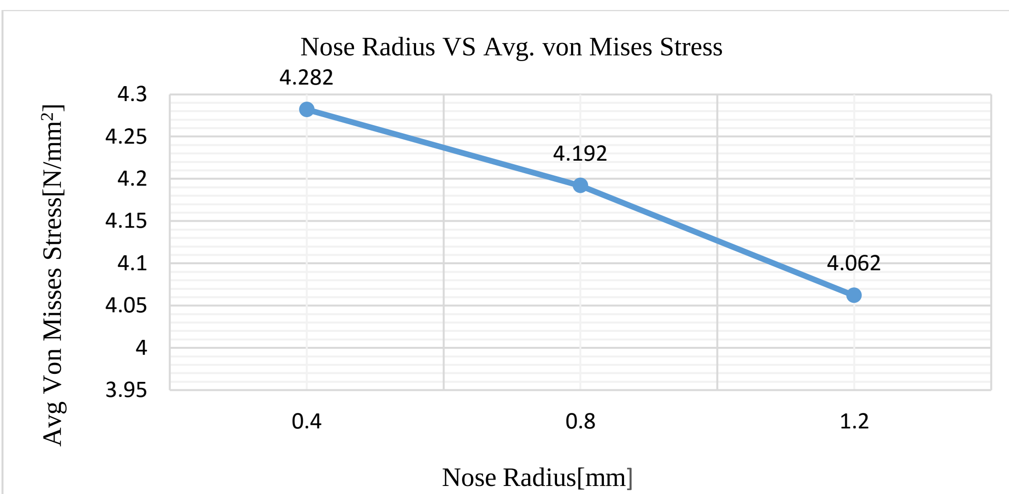

Figure 4.5: Optimal Value for Nose Radius under Von Misses Stress

Figure 4.5 shows a relation between the von Mises stress produced after simulation and nose radius and it can be easily concluded with the help of Figure 4.5 that the value for stresses decreases as the value for nose radius increases. Thus, it is observed that when nose radius is 1.2mm less of stress is found in comparison to value of stress at 0.4mm and 0.8mm.

(ii) Rake angle vs. avg. von Mises stress

Table 4.4 shows value for average von Mises stress which is obtained from the simulation results and Rake Angle, which are considered in this study after going through literature survey.

Table 4.4: Table for Avg. Stress and Rake Angle

Avg. von Mises Stress (N/mm^2)	4.282	4.192	4.062
Rake Angle (Degrees)	10	15	20

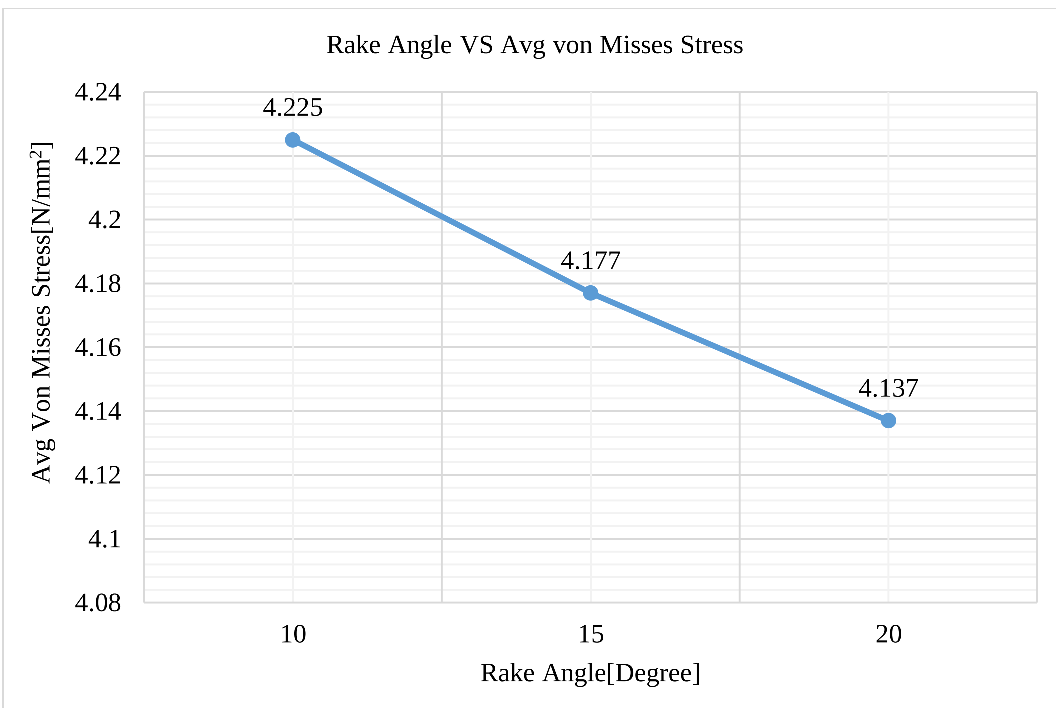

Figure 4.6: Optimal Value for Rake Angle under Von Misses Stress

Figure 4.6 shows a relation between the von Mises stress produced after simulation and Rake Angle. It can be easily concluded with the help of Figure 4.6 that the value of stresses decreases as the value for Rake Angle increases. In this case it is found that, when rake angle is 20° less of stress is being generated in comparison to the value of stress at 10° and 15°.

Thus, it is observed that the optimal values for rake angle and nose radius are 20° and 1.2mm by keeping von Mises stress in consideration.

4.2.2 Design of Experiment for Cutting Parameters

In order to optimize the cutting tool geometry experimentally, first we have to optimize the cutting parameters experimentally. For which the following procedure will give you detailed information on how to optimize cutting parameter and geometric parameter, to obtain optimized parameters for achieving good surface finish.

4.2.2.1 Selection of factors/levels for cutting parameters

After going through exhaustive literature survey, different levels of parameters are studied to get most optimized result to decrease surface roughness. Qureshi (2015) optimized the cutting parameters, in order to achieve good surface finish of P20 steel, while performing turning operation on CNC Lathe and further L9 orthogonal array and S/N ratio is being applied to get better results. Galanis et al. (2014) uses Finite Element Analysis to optimize the cutting parameters, during turning of AISI 36L steel. So, different levels for process parameters are considered during turning operation on CNC as discussed in Table 4.5.

Table 4.5: Selected Process Factors/Levels for Optimizing Cutting Parameters

Factors/Levels	Units	I	II	III
Feed	mm/rev	0.07	0.05	0.03
Depth of cut	mm	0.09	0.06	0.03
Spindle Speed	rpm	1000	1500	2000

As, the different levels of process parameters are selected from literature survey which are discussed in chapter 2. These selected process parameters are further processed by using L9 orthogonal array, which results in providing different levels for performing the experimental work as discussed in Table 4.6. After getting the desired level of combinations of considered parameters, we have to perform our experimental work according to the value that are generated with the help of Taguchi L9 as discussed in Table 4.6. Our experiment is to perform turning operation on CNC lathe. Therefore, in order to perform turning operation on CNC we have to make a program for turning operation on the basis of which the CNC lathe will work. So, in order to get better results for surface finish three different values for surface roughness is calculated for each one level by using surface roughness tester as shown in Table 4.7.

Table 4.6: Selected Process Factors with Respective Levels

S.no	Spindle Speed (rpm)	Feed Rate (mm/rev)	Depth of Cut (mm)
1	1000	0.07	0.09
2	1000	0.05	0.06
3	1000	0.03	0.03
4	1500	0.07	0.06
5	1500	0.05	0.03
6	1500	0.03	0.09
7	2000	0.07	0.03
8	2000	0.05	0.09
9	2000	0.03	0.06

Table 4.7: Experimentally Calculated Results

S.no	Spindle speed (rpm)	Feed Rate (mm/rev)	Depth of Cut (mm)	Ra 1 (µm)	Ra 2 (µm)	Ra 3 (µm)
1	1000	0.07	0.09	0.68	0.70	0.66
2	1000	0.05	0.06	0.57	0.59	0.55
3	1000	0.03	0.03	0.45	0.46	0.47
4	1500	0.07	0.06	0.67	0.61	0.58
5	1500	0.05	0.03	0.54	0.55	0.51
6	1500	0.03	0.09	0.48	0.45	0.46
7	2000	0.07	0.03	0.56	0.51	0.57
8	2000	0.05	0.09	0.42	0.46	0.47
9	2000	0.03	0.06	0.51	0.48	0.49

After performing the whole experiment according to the Taguchi L9 array next step is to optimize the parameters for achieving the good surface finish, which is discussed in sub-section 4.2.2.2.

4.2.2.2 Taguchi design optimization for cutting parameters

In order to get best result for surface finish, the results have to be analysed for which signal to noise ratio is being used, which works on the basis of L9 orthogonal array. Where S/N ratio gets affected by two factors controllable and uncontrollable. Controllable factors are also known as signal and can be controlled easily, whereas uncontrollable are known as noise which are to be minimized in order to identify control factors that decreases the variability in the products. In this way, signal to noise ratio identifies the optimal factors means these are the factors which has less effect on S/N ratio in order to reduce variability means bringing values closer to the target. The following Table 4.8 shows values for mean and S/N ratio for surface roughness, which is achieved experimentally by conducting turning operation on different levels of parameters.

Table 4.8: Table for S/N Ratio and Mean

S.no	Spindle Speed (rpm)	Feed Rate (mm/rev)	Depth of Cut (mm)	Ra 1 (µm)	Ra 2 (µm)	Ra 3 (µm)	Mean (µm)	S/N Ratio
1	1000	0.07	0.09	0.68	0.70	0.68	0.68	3.34732
2	1000	0.05	0.06	0.57	0.59	0.55	0.57	4.87894
3	1000	0.03	0.03	0.45	0.46	0.47	0.46	6.74348
4	1500	0.07	0.06	0.67	0.61	0.58	0.62	4.13638
5	1500	0.05	0.03	0.54	0.55	0.51	0.53	5.45562
6	1500	0.03	0.09	0.48	0.45	0.46	0.46	6.67898
7	2000	0.07	0.03	0.56	0.51	0.57	0.55	5.23555
8	2000	0.05	0.09	0.42	0.46	0.47	0.45	6.92575
9	2000	0.03	0.06	0.51	0.47	0.49	0.49	6.19126

Surface roughness is calculated at different levels of input factor. In order to get optimal factors for attaining the good surface finish, Minitab 17 software is used, which helps in getting optimal results. At different combinations of spindle speed, depth of cut and feed rate value of surface roughness (Ra) is checked. For every combination three different values of Ra is calculated. Now, by inputting all these values in Minitab 17, we have calculated what will be the mean of surface roughness and values for signal to noise ratio. The approach smaller is better is to be used for calculating the optimized values and graphs for mean. S/N ratio is calculated using $-10\log 1/n\ (\sum Yi^2)$. It is to be noted only that factor is considered as optimal factor for which S/N ratio value is high and this can only be achieved, if value of signal is greater than noise means by lowering the effect of the noise we can control the controllable factor also known as signal. On, the basis of these values of mean and S/N ratio graphs are being generated by Minitab 17 as shown in Figure 4.7 and Figure 4.8, which shows that what are the optimal parameters for achieving good surface finish while machining of D3 steel.

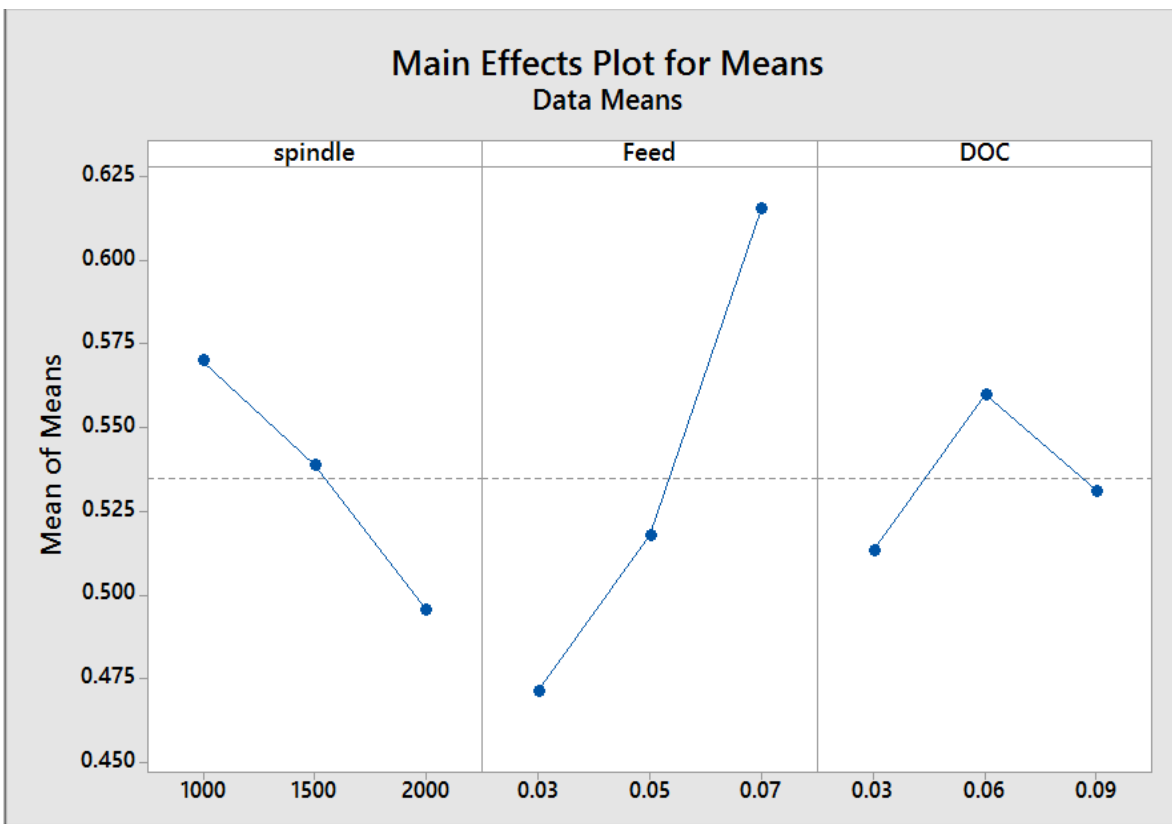

Figure 4.7: Graph for Main Effects Plot for Mean (Minitab, V17)

The Figure 4.7 depicts the mean plot in which the horizontal line is the value of the total mean of the means. Smaller the value of mean better is the quality characteristics for the material. As per the analysis of means from graph the levels of parameters which are to be set for getting optimum value for good surface finish are spindle speed 2000 rpm, feed 0.03 mm/rev and DOC 0.03 mm.

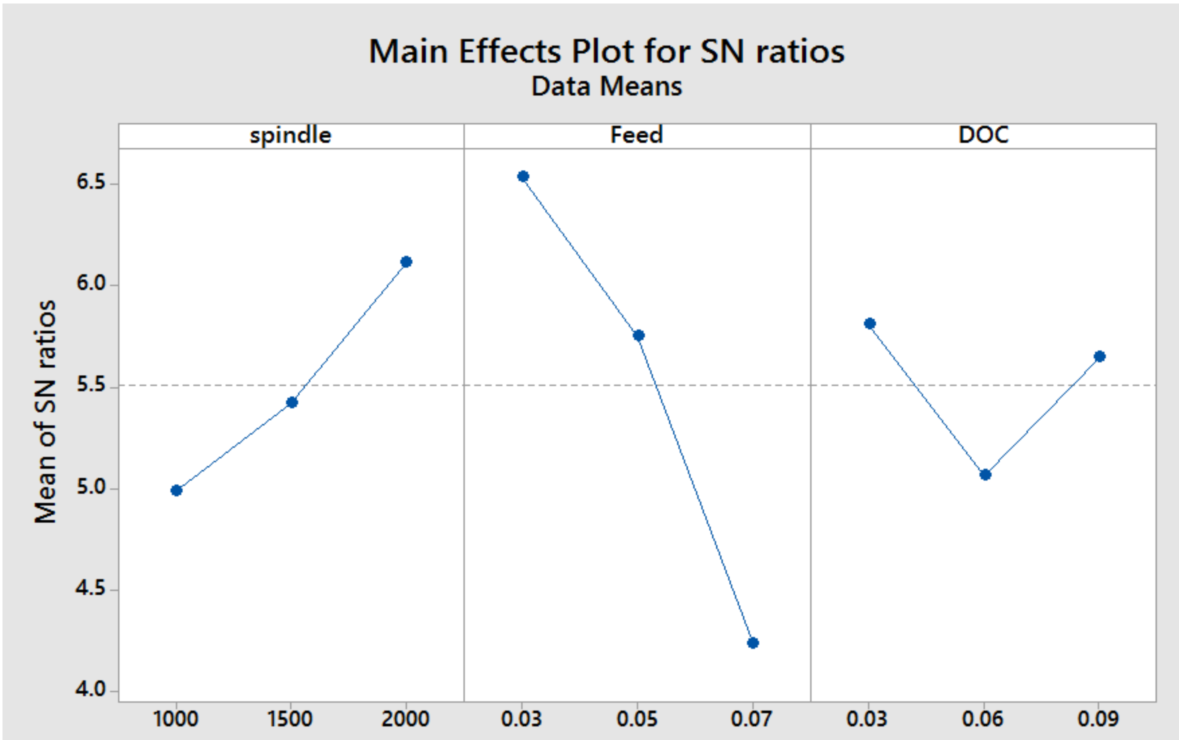

Figure 4.8: Graph for Main Effects Plot for SN ratios

The above Figure 4.8 depicts the SN ratio plot in which the horizontal line is the value of the total mean of the SN ratio. Larger the value of mean better is the quality characteristics for the material. As per the analysis of means from graph the levels of parameters which are to be set for getting optimum value for good surface finish are spindle speed 2000 rpm, feed 0.03 mm/rev and DOC 0.03 mm.

Table 4.9: Table of Response for Mean

Level	Spindle Speed	Feed Rate	Depth of Cut
1	0.5722	0.4711	0.5133
2	0.53889	0.5178	0.5600
3	0.4956	0.6178	0.5333
Delta	0.0767	0.1467	0.0467
Rank	2	1	3

Table 4.9 shows that feed rate is having rank one, which shows that it is one of the significant factor which plays an important role in contribution to optimize the cutting parameters by using S/N ratio plots and mean plots.

4.2.2.3 Graphical optimization

Following are graphs are made in excel for the validation of the results that we get through Taguchi design.

Key points:

Signal to noise ratios are calculated using -10log1/n ($\sum Yi^2$)

We need maximum Signal to Noise ratio & minimum average surface roughness.

(i) Spindle speed and average Surface roughness

Table 4.10 shows the value of average surface roughness and S/N ratio, which is being calculated by taking mean of all the values of Ra and S/N ratio at particular spindle speed.

Table 4.10: Table for Optimal Spindle Speed

Spindle Speed (rpm)	1000	1500	2000
Avg. Ra (µm)	0.57	0.538	0.496
S/N ratio	4.99	5.4236	6.11752

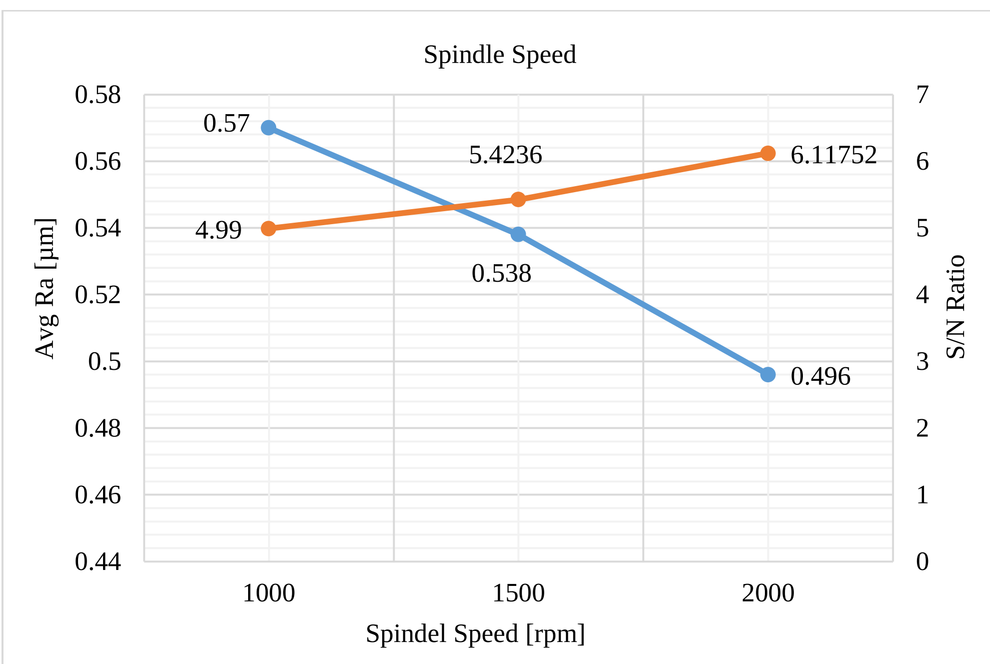

Figure 4.9: Graph for Optimal Spindle Speed

It can be easily concluded from Figure 4.9, that the value of S/N ratio is getting increased and the value of average surface roughness decreases. So, when spindle speed is 2000 the value of S/N ratio is high and the value of surface roughness is low, from this we can conclude that 2000 rpm is the optimal value of spindle speed, for achieving good surface finish.

(ii) Feed & average surface roughness

Table 4.11 shows the value of average surface roughness and S/N ratio, which is being calculated by taking mean of all the values of Ra and S/N ratio at particular Feed Rate.

Table 4.11: Table for optimal Feed Rate

Feed Rate (mm/rev)	0.07	0.05	0.03
Avg. Ra (µm)	0.616	0.517	0.417
S/N ratio	4.239	5.753	6.537

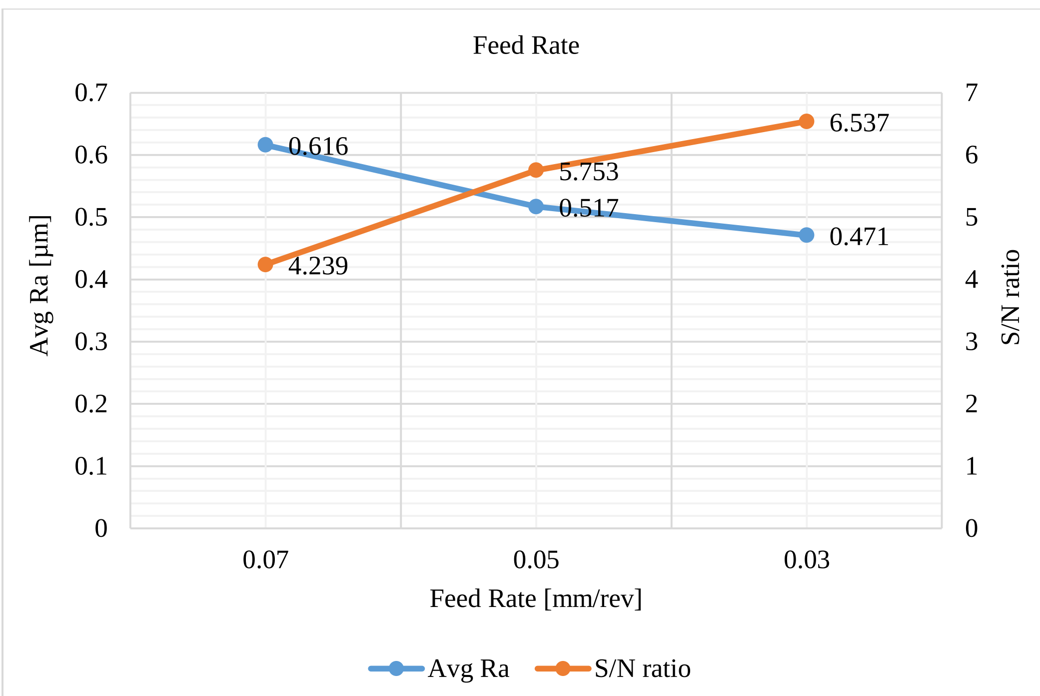

Figure 4.10: Graph for Optimal Feed Rate

It can be easily concluded from Figure 4.10, that the value of S/N ratio is getting increased and the value of average surface roughness decreases. When feed rate is 0.03 the value of S/N ratio is high and the value of surface roughness is low, from this we can conclude that 0.03 mm/rev is the optimal value for feed rate, for achieving good surface finish.

(iii) Depth of cut and average surface roughness

Table 4.12 shows the value of average surface roughness and S/N ratio, which is being calculated by taking mean of all the values of Ra and S/N ratio at particular Depth of Cut.

Table 4.12: Table for Optimal Depth of Cut

Depth of cut (mm)	0.09	0.06	0.03
Avg. Ra (µm)	0.531	0.56	0.513
S/N ratio	5.65	5.068	6.219

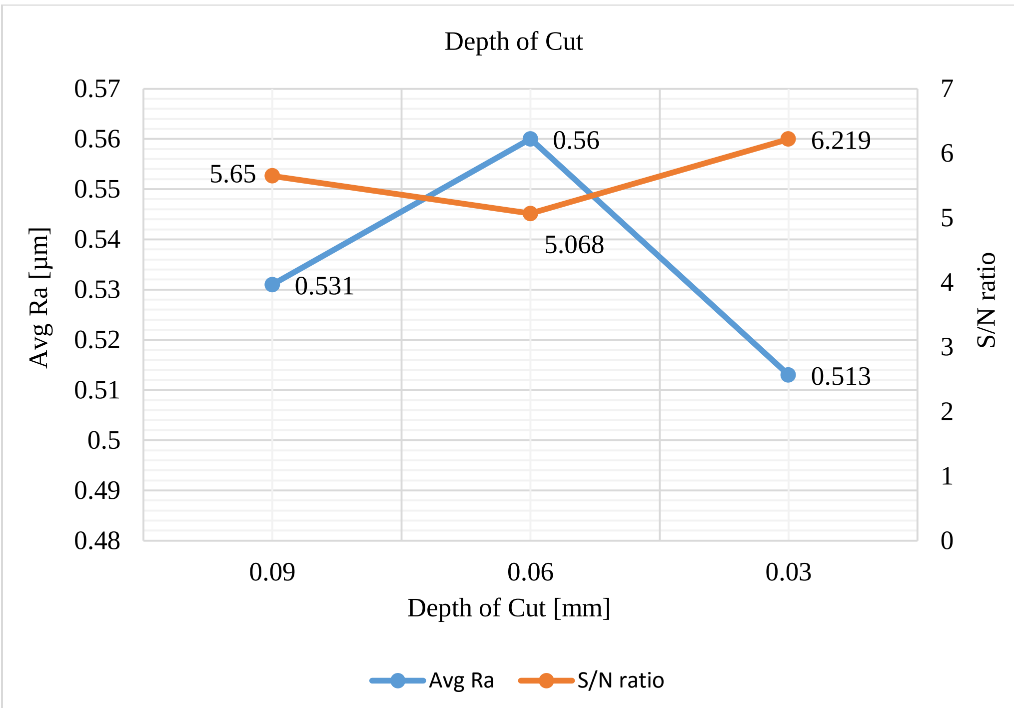

Figure 4.11: Graph for Optimal Depth of Cut

It can be easily concluded from Figure 4.11, that the value of S/N ratio is getting increased and the value of average surface roughness decreases. When Depth of Cut is 0.03 the value of S/N ratio is high and the value of surface roughness is low, from this we can conclude that 0.03 mm is the optimal value for Depth of Cut, for achieving good surface finish.

4.2.3 Design of Experiment for Geometric Parameters

After optimizing the cutting parameters for attaining good surface finish, we have to optimize the geometric parameters and study the effect of the geometric parameters of the cutting tool on surface finish by considering the above optimal cutting parameters.

4.2.3.1 Selection of factors/levels for geometric parameters

After going through exhaustive literature survey as discussed in Chapter 2. Table 4.13 shows which are the parameters and range should be considered during optimizing the geometric parameters.

Table 4.13: Selected Process Factors/Levels for Optimizing Geometric Parameters

Factors/Level	Units	I	II	III
Rake Angle	Degrees	10	15	20
Nose Radius	mm	0.4	0.8	1.2

In order to optimize the geometric parameters of the cutting tool for finishing machining, the parameters which are to be selected are Rake angle and Nose radius because these are the factors which directly affects the surface finish. It should be kept in mind that in which range all these factors are considered to get better result. Liao et al. (2016) studied how to optimize the geometric parameters for attaining good surface finish and in which range these parameters are to be considered. So, two different levels for process parameters along with optimal cutting parameters are considered during turning operation on CNC. These selected geometrical parameters as shown in Table 4.13 are further processed by using L9 orthogonal array, which results in providing different levels for performing the experimental work as discussed in Table 4.14.

Table 4.14: Selected Process Factors with Respective Levels

S.no	Rake Angle (Degrees)	Nose Radius (mm)
1	10	0.4
2	10	0.8
3	10	1.2
4	15	0.4
5	15	0.8
6	15	1.2
7	20	0.4
8	20	0.8
9	20	1.2

After getting the desired level of combinations of rake angle and nose radius , we have to perform our experimental work according to the value that are generated with the help of Taguchi L9 as discussed in Table 4.14. Our experiment is to perform turning operation on CNC lathe. So, in order to perform turning operation on CNC we have to make a program for turning operation on the basis of which the CNC lathe will work. So, in order to get better results for surface finish three different values for surface roughness is calculated as shown in Table 4.15, for each one level by using surface roughness tester. After performing the whole experiment according to the Taguchi L9 array next step is to optimize the parameters for achieving the good surface finish, which is discussed in Section 4.2.3.2.

Table 4.15: Experimentally Calculated Results

S.no	Rake Angle (Degree)	Nose Radius (mm)	Ra 1 (µm)	Ra 2 (µm)	Ra 3 (µm)
1	10	0.4	0.57	0.60	0.59
2	10	0.8	0.47	0.48	0.50
3	10	1.2	0.36	0.37	0.36
4	15	0.4	0.52	0.51	0.54
5	15	0.8	0.44	0.46	0.43
6	15	1.2	0.38	0.35	0.36
7	20	0.4	0.45	0.43	0.42
8	20	0.8	0.32	0.33	0.30
9	20	1.2	0.36	0.37	0.39

4.2.3.2 Taguchi design optimization for geometrical parameters

In order to get best result for surface finish, the results have to be analysed for which signal to noise ratio is being used, which works on the basis of L9 orthogonal array. Where S/N ratio gets affected by two factors controllable and uncontrollable. Controllable factors are also known as signal and can be controlled easily, whereas uncontrollable are known as noise which are to be minimized in order to identify control factors that decreases the variability in the products. In this way signal to noise ratio identifies the optimal factors means these are the factors which has less effect on S/N ratio in order to reduce variability means bringing values closer to the target. The Table 4.16 shows values for mean and S/N ratio for surface roughness, which is achieved by using MINITAB 17 software.

Table 4.16: Table for S/N Ratio and Mean

S.no	Rake Angle (Degree)	Nose Radius (mm)	Ra 1 (µm)	Ra 2 (µm)	Ra 3 (µm)	Mean (µm)	S/N Ratio
1	10	0.4	0.57	0.60	0.59	0.586667	4.63021
2	10	0.8	0.47	0.48	0.50	0.483333	6.31217
3	10	1.2	0.36	0.37	0.36	0.363333	8.79316
4	15	0.4	0.52	0.51	0.54	0.523333	5.62197
5	15	0.8	0.44	0.46	0.43	0.443333	7.06196
6	15	1.2	0.38	0.35	0.36	0.363333	8.78878
7	20	0.4	0.45	0.43	0.42	0.433333	7.25996
8	20	0.8	0.32	0.33	0.30	0.316667	9.98122
9	20	1.2	0.36	0.37	0.39	0.373333	8.55322

Minitab 17 software is used for optimization process. In this table, across every different combinations of rake angle and nose radius surface roughness (Ra) is checked. For every combination three different values of Ra is calculated. Now, by inputting all these values we have calculated what will be the mean of surface roughness and values for signal to noise ratio. The approach that is to be used for calculating the values and graphs for mean is smaller is better. S/N ratio is calculated using $-10\log 1/n\ (\sum Yi^2)$. It is to be noted only that factor is considered as optimal factor for which S/N ratio value is high and this can only be achieved if value of signal is greater than noise means by lowering the effect of the noise we can control the controllable factor also known as signal. On, the basis of these value of mean and S/N ratio graphs are being generated by Minitab 17, which shows that what are the optimal parameters for achieving good surface finish after machining.

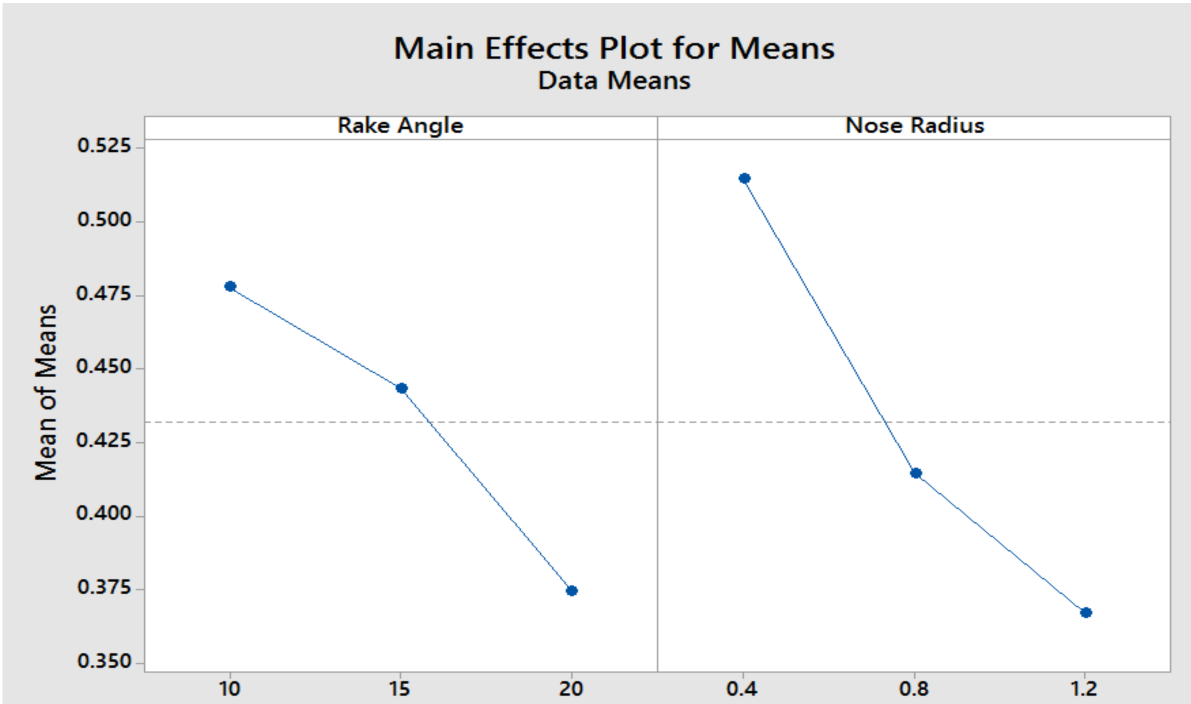

Figure 4.12: Graph for Main Effects Plot for Means

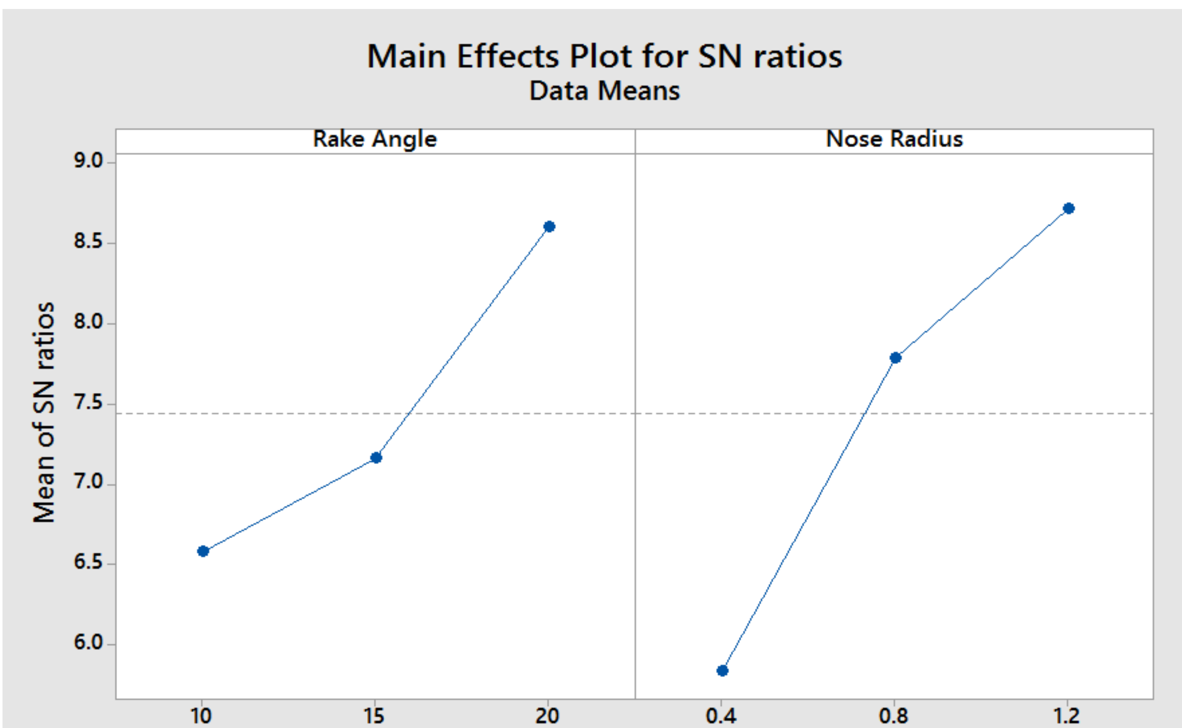

Figure 4.13: Graph for Main Effects Plot for SN ratios

Figure 4.12 depicts mean plot in which the horizontal line is the value of the total mean of the means. Smaller the value of mean better is the quality characteristics for the material. As per the analysis of means from graph the levels of parameters which are to be set for getting optimum value for good surface finish are rake angle is 20°and nose radius is 1.2 mm. Figure 4.13 depicts SN ratio plot in which the horizontal line is the value of the total mean of the SN ratio. Larger the value of mean better is the quality characteristics for the material. As per the analysis of means from graph the levels of parameters which are to be set for getting optimum value for good surface finish are rake angle 20° and nose radius 1.2 mm.

Table 4.17: Table of Response for Mean

Level	Rake Angle	Nose Radius
1	0.5633	0.46089
2	0.5333	0.5311
3	0.4756	0.4322
Delta	0.0878	0.1767
Rank	2	1

Table 4.17 shows that nose radius is having rank one, which depicts that nose radius is of the significant factor which plays an important role in contribution to optimize the geometric parameters by using S/N ratio plots and mean plots.

4.2.3.3 Graphical Optimization for geometric parameters

Following are graphs are also made in excel for the validation of the results that we get through Taguchi design.

Key points:

Signal to noise ratios are calculated using -10log1/n ($\sum Yi^2$)

We need maximum Signal to Noise ratio & minimum average surface roughness

(i) Rake Angle and average Surface roughness

The following Table 4.18 shows the value of average surface roughness and S/N ratio, which is being calculated by taking mean of all the values of Ra and S/N ratio at particular rake angle. It can be easily concluded from Figure 4.14, that the value of S/N ratio is getting increased and the value of average surface roughness decreases. When rake angle is 20° the value of S/N ratio is high and the value of surface roughness is low, from this we can conclude that 20° is the optimal value for Rake angle in finishing machining of D3 steel.

Table 4.18: Table for Optimal Rake Angle

Rake Angle (Degrees)	10	15	20
Avg. Ra (µm)	0.477	0.443	0.374
S/N ratio	6.578	7.157	8.598

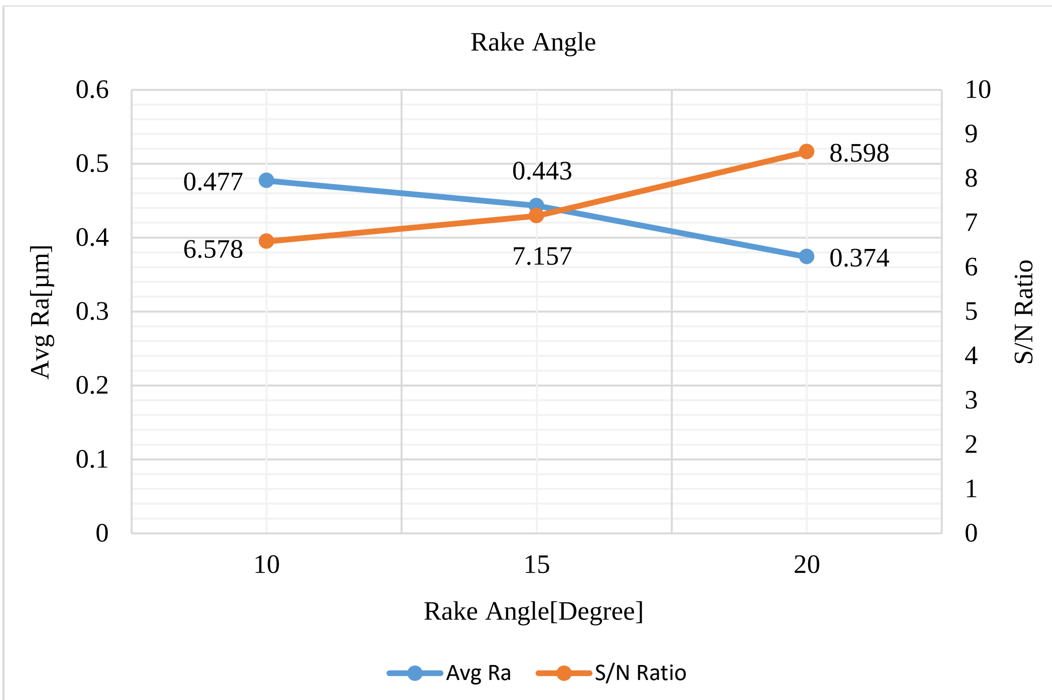

Figure 4.14: Graph for Optimal Rake angle

(ii) Nose Radius and average Surface roughness

Table 4.19 shows the value of average surface roughness and S/N ratio, which is being calculated by taking mean of all the values of Ra and S/N ratio at particular nose radius.

Table 4.19: Table for Optimal Nose Radius

Nose Radius (mm)	0.4	0.8	1.2
Avg. Ra (µm)	0.514	0.414	0.366
S/N ratio	5.837	7.785	8.711

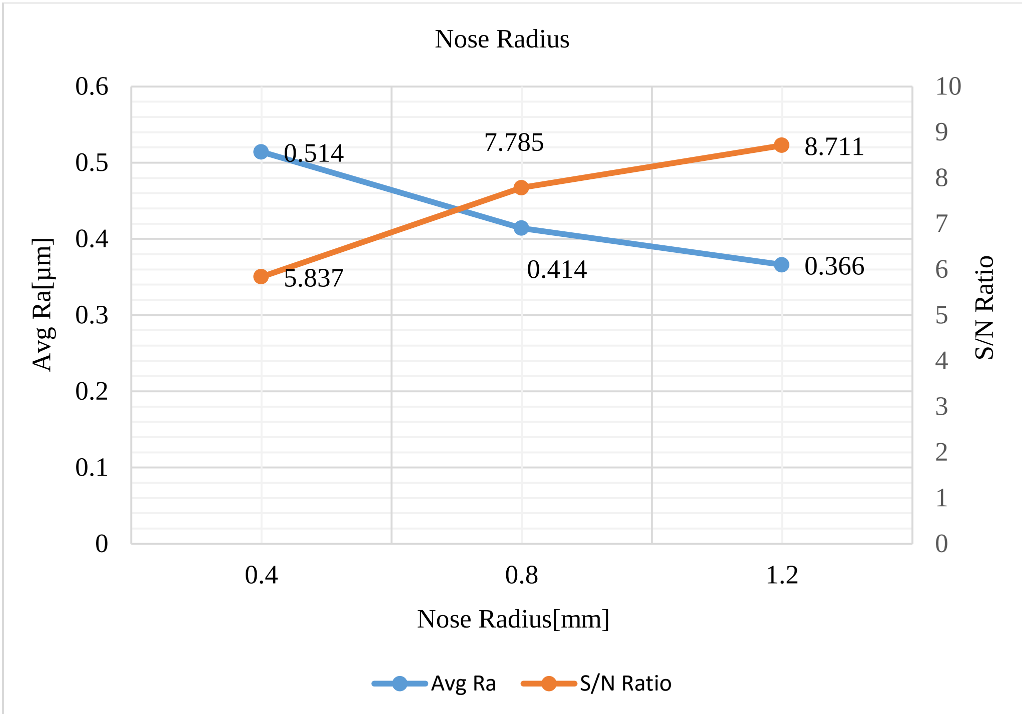

Figure 4.15: Graph for Optimal Nose Radius

It can be easily concluded from Figure 4.15, that the value of S/N ratio is getting increased and the value of average surface roughness decreases. When nose radius is 1.2 mm the value of S/N ratio is high and the value of surface roughness is low, from this we can conclude that 1.2 mm is the optimal value for nose radius in finishing machining of D3 steel.

4.2.4 Validation of Model (Post Analysis)

The optimum results obtained in section 4.3, are validated in this section of experimental study by using post analysis. Post analysis is to be performed, in order to check whether the results obtained by applying any of the technique are valid or not. The analysis consist of two stages i.e. first is to validate the results for cutting parameter and the second step is to validate the results for cutting edge geometry parameters obtained from Taguchi design, which is to be validated by using ANOVA. Figure 4.16 shows system architecture algorithm for the validation process, which is to be followed in order to validate the results obtained from Taguchi Design.

4.2.4.1 Validation of cutting parameters

Step 1: The first stage is to set the factors level, in order to conduct the experiment at that factors level as shown in Table 4.20.

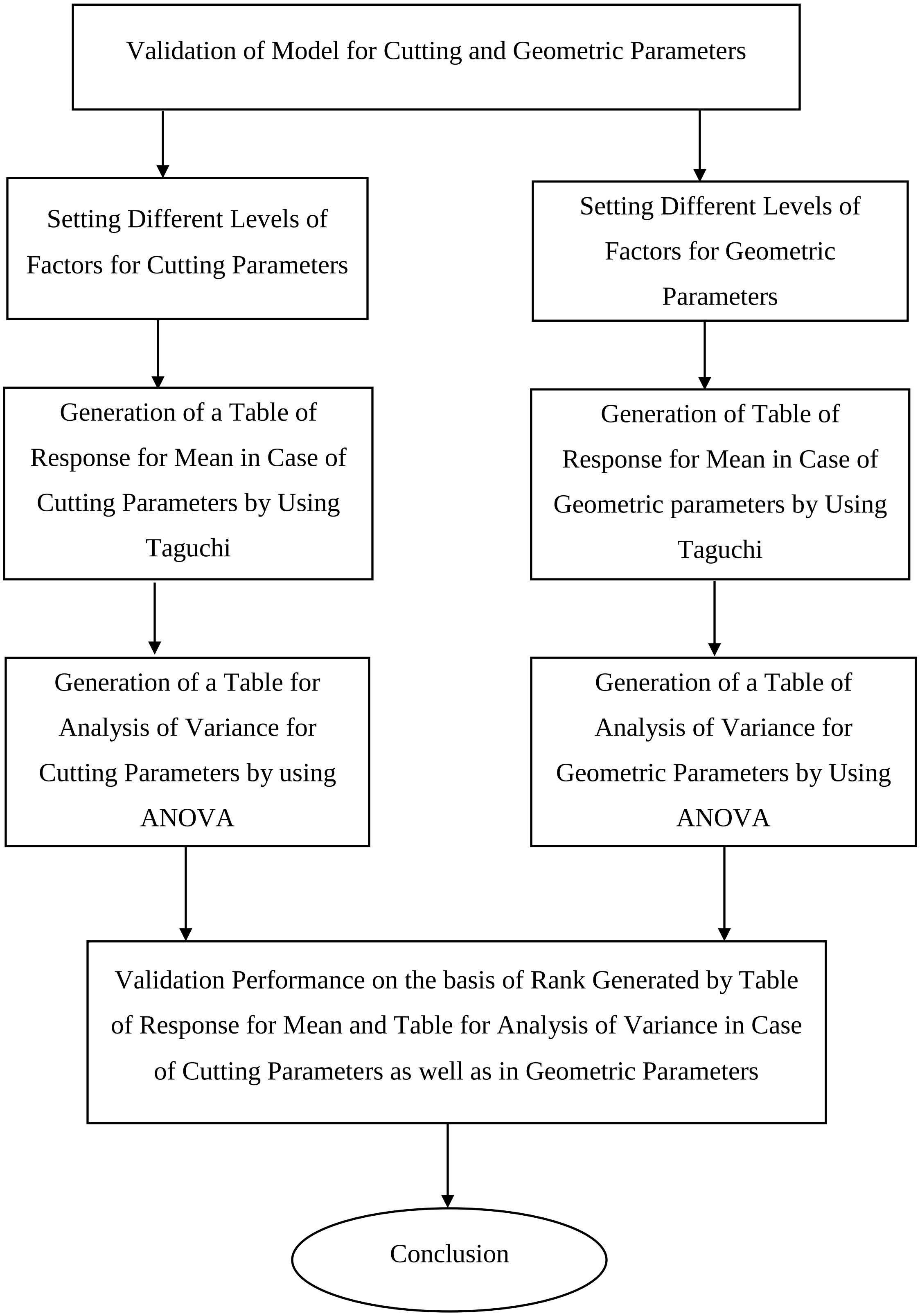

Figure 4.16: Validation of Model for Optimizing the Cutting and Geometric Parameters

Step 2: Using these above factor level input, a response table is generated by Taguchi design as shown in Table 4.21.

According to Table 4.21, obtained from analysis of means, rank one is given to the feed followed by spindle speed and depth of cut respectively.

Table 4.20: Table for Factor Level Setting to Predict Responses

Factor	Name	I	II	III
A	Spindle Speed (rpm)	1000	1500	2000
B	Feed Rate (mm/rev)	0.07	0.05	0.03
C	Depth of Cut (mm)	0.09	0.06	0.03

Table 4.21: Table of Response for Mean of Cutting Parameters

Level	Spindle Speed	Feed Rate	Depth of Cut
1	0.5722	0.4711	0.5133
2	0.53889	0.5178	0.5600
3	0.4956	0.6178	0.5333
Delta	0.0767	0.1467	0.0467
Rank	2	1	3

Table 4.22: Table for Analysis of Variance of Cutting Parameters

Source	DF	Adj SS	Adj MS	F-Value	P-Value	Percentage Contribution	Rank
Speed	2	0.025077	0.012538	26.8	0.036	24.4127	2
DOC	2	0.005410	0.002705	5.78	0.147	5.2666	3
Feed rate	2	0.071299	0.035649	76.19	0.013	69.41	1
Error	2	0.000936	0.000468			0.9	
Total	8	0.102721					
S= 0.021631	R-Sq = 99.69%	R-Sq(adj)= 96.36%					

It means that the contribution of the feed rate is more than spindle speed and feed rate because value of delta is higher in case of feed rate in comparison to other two factors which shows that feed rate is the most contributing factor during optimization of cutting parameters.

Step 3: In this step, post analysis of the work is being done with the help of ANOVA in order to analyse the most contributing factor as shown in Table 4.22. The confidence level for all intervals is kept as 95 indicates a 5% risk of concluding that an effect exists when there is no actual effect i.e., p- value should be less than 0.05. If p-value is less than 0.05 it shows doubt on null hypothesis, which says all sample means equal and effect of that factor on the result is statistically significant. From the above Table 4.21, we can see that the most significant factor is feed rate. Its percentage of contribution is 69.41 followed by Spindle speed contributing 24.41%. The least significant factor is Depth of cut contributing only 5.26%. In ANOVA results, the predictors explain 99.69% of the variation in the response. The adjusted R2 is 96.66%. The lower the value of S, the better the model describes the response and is found to be 0.0216. Thus by comparing on the basis of contribution of factors from the table of response for mean and from the table of analysis of variance. It is found that in both the cases, the most contributing factor is feed rate which is followed by spindle speed and depth of cut. Thus both the methods depicts same type of results on the basis of contribution of factors, which helps in validating our work.

4.2.4.2 Validation of geometric parameters

Step 1: The first stage is to set the factor level, in order to conduct the experiment at that factor levels as shown in Table 4.23.

Table 4.23: Table for Factor Level Setting to Predict Responses

Factor	Name	I	II	III
A	Rake Angle (Degrees)	10	15	20
B	Nose Radius (mm)	0.4	0.8	1.2

Step 2: Using these above factor level input, a response table is generated by Taguchi design as shown in Table 4.24. According to Table 4.24, obtained from response for mean for geometric parameters, rank one is given to the nose radius, which is followed by rake angle. It means that the contribution of the nose radius is more than the rake angle, in optimizing the

geometric parameters of the cutting tool because value of delta in case of nose radius is high in comparison to the rake angle.

Table 4.24: Table of Response for Mean of Geometric Parameters

Level	Rake Angle	Nose Radius
1	0.5633	0.46089
2	0.5333	0.5311
3	0.4756	0.4322
Delta	0.0878	0.1767
Rank	2	1

Step 3: In this step, post analysis of the work is being done with the help of ANNOVA in order to analyse the most contributing factor during optimization process as shown in Table 4.25.

Table 4.25: Table for Analysis of Variance of Geometric Parameters

Source	DF	Adj SS	Adj MS	F-Value	P-Value	Percentage Contribution	Rank
Rake Angle	1	73.500	73.500	147.00	0.007	47.26	2
Nose Radius	2	81.000	40.5000	81.00	0.012	52.09	1
Error	2	1.00	0.5000			0.65	
Total	5	155.500					
S= 0.707107	R-Sq = 99.3%	R-Sq(adj)= 98.39%					

The confidence level for all intervals is kept as 95 indicates a 5% risk of concluding that an effect exists, when there is no actual effect i.e., p- value should be less than 0.05. If p-value is less than 0.05 it shows doubt on null hypothesis, which says all sample means equal and effect of that factor on the result is statistically significant. From the above ANOVA table, we can see that the most significant factor is nose radius. It percentage contribution is 52.09 and rake angle is least significant, contributing 47.26. In ANOVA results, the predictors explain 99.69% of the variation in the response. The adjusted R2 is 99.36%. The lower the value of S, the better the model describes the response, it is found to be 0.7070107. Thus by comparing on the basis of contribution of factors from the table of response and from the table of analysis of variance. It is found that in both the cases the most contributing factor is nose radius which is followed by rake angle. Thus both the methods depict same type of results on the basis of contribution of factors, which helps in validating our work.

4.3 DISCUSSION

The validation of Taguchi model discussed in Section 4.4 validates that the Taguchi model is generated and gives good prediction of responses on the basis of the most contributing factor during optimization process. The validation is divided into two parts, first is validating the response for cutting parameters and other one is validation for geometric parameters. In Table 4.21, Response for Means depicts the rank for contribution of the considered cutting parameters i.e. rank one for feed rate, rank two for the spindle speed and rank 3 for depth of cut, which shows that feed rate is one of the significant and the most contributing factor according to response for means, which is further analysed by using ANOVA. Table 4.22 Analysis of Variance is used validate the results obtained from response for mean. According to analysis of variance, the percentage contribution for spindle speed is 24.417, Depth of Cut is 5.2666 and for feed rate is 69.41. Thus by analysing ANOVA it is found that the most contributing and significant factor is feed followed by spindle speed and depth of cut. Thus, from the above it is concluded that by using response for means and analysis of variance the most significant and the contributing factor is feed rate followed by spindle speed and depth of cut. Table 4.24 shows the response for the geometric parameters, according to the response table nose radius is one of the significant and most contributing factor because the rank avail to the nose radius is one and for rake angle it is two. Where table 4.25 is used to validate the work, which shows that the contribution of nose radius is 52.09 and that of rake angle is 47.26, from this it is found that Analysis of variance ANNOVA also depicts that the most contributing and significant factor is nose radius in comparison to the rake angle. Thus, by comparing on the basis of most contributing factor it is found that feed rate is one of the contributing factor in case of cutting parameters and nose radius is in the case of geometric parameters. In this regard, it is concluded that the proposed model is validated and the proposed research work is authenticated.

CHAPTER 5: CONCLUSION AND FUTURE SCOPE OF WORK

5.1 CONCLUSION

Turning operation is conducted to machine AISI D3 steel with carbide tool and analysed in this proposed research work. Firstly, analysis and behaviour of metal cutting is being studied by using FEM simulation software Abaqus. Abaqus is used to study the effect of von Mises stress by varying geometrical parameters during metal cutting from respective simulation module and it is found that which combination of the geometric parameters are to be considered best for machining purpose. Abaqus is mostly used for simulating the metal cutting processes. After the designing part, turning operation on D3 steel is performed on CNC lathe for achieving good surface finish, D3 steel is a steel which is commonly used for complex blanking and forming tool for long runs and for hard and abrasive material. In order to optimize the cutting geometry, first we have to optimize the cutting parameters for which different process parameters at different levels are to be selected and the combination of the process parameters are performed with the help of Taguchi Design and in this case, L9 orthogonal array is used for attaining different combinations of the spindle speed, feed and depth of cut and the experiment is being performed on the basis of these combination on CNC lathe and after some number of cycles, the surface finish is checked with the help of surface roughness tester. After, calculating the value for surface roughness, we can find what will be the optimal spindle speed, feed and depth of cut for achieving good surface finish with the help of S/N ratio and mean Plots. Now, we are acquainted with what are the cutting parameters should be considered in order to optimize the geometric parameters i.e. rake angle and nose radius of cutting tool. Similarly, different combinations are made for the value of rake and nose radius for achieving optimal parameters for good surface finish. After doing the whole process, next step is post analysis means to validate our work. In this study, post analysis is done by using ANNOVA on the basis of the contributing factor during the whole process. Following are the conclusions drawn from the study:

(i) It is observed from the simulation results that higher the value for rake angle and nose radius, lesser will be the stress produced between the tool and the workpiece.

(ii) It is found that the most contributing factors during the whole optimization process in case of optimization of cutting parameters and geometric parameters are feed rate and nose radius respectively.

(iii) It is observed that the surface roughness decreases with increase in spindle speed and decrease in value for feed rate and depth of cut for finishing machining of AISI D3 steel. Thus, it is found that the optimal values for spindle speed, depth of cut and feed for attaining good surface finish are 2000 rpm, 0.03mm, 0.03mm/rev respectively.

(iv) It is perceived that the optimal values for geometric parameters i.e., rake angle and nose radius are 20° and 1.2µm respectively, for attaining good surface finish during turning operation of AISI D3 steel.

(v) By considering different combinations of geometry of tool, the experiment is being performed and it is observed that, with the increase in value of rake angle and nose radius, the value for surface roughness decreases.

5.2 RECOMMENDATIONS

The following are the recommendations which will be helpful in exploring the present work in order to experiment to make it more reliable:

(i) The present proposed work would recommend to frame cross functioning of the cutting and geometric parameters separately by using Taguchi technique which would make the whole work easier to perform and understand by the new researchers.

(ii) The proposed research work would suggest the selection of the cutting parameters, geometric parameters and objectives in accordance to the proposed objectives. The objective functions in the present work are analysed and validated at each step, which ensures the quality of data and moreover, the results can be reverted back to the industry to make the same manufacturing unit more efficient than earlier system.

(iii) The present study would suggest to perform turning operation on that CNC machine which are in production because these machines can perform work with high accuracy, which will somehow lead experimental work in a better way.

(iv) The present study would recommend to implement the FEM simulation software for analyzing the von Mises stress at different combinations of the rake angle and nose radius along the experimental work, which will make results more reliable when it is to be compared with the results that are computed after experimental work.

(v) The proposed study would synthesize application of Minitab 17 for the evaluation of optimization of cutting and geometric parameters. The objective function of the proposed work is to obtain optimal values for geometric and cutting parameters with the help of S/N ratio graphs generated with the help of Minitab 17, which is one of the well designed and easy to use for any new researcher as the statistical calculations computed by respective software are very accurate and results can be easily formulated using the guidance provided by the software itself.

5.3 FUTURE SCOPE OF WORK

This section addresses the topic related to studies which may be conducted in the future with a potential to change the conventional machining processes in industry. According to results analysis, it is found that in past years, majority of work has been conducted in optimizing the cutting parameters for improving surface finish and less of the work is being devoted in optimizing the geometric and cutting parameters both for finishing machining. This study has been conducted to improve the surface finish of D3 steel by using carbide tool. Following suggestions have been recommended to conduct the future scope of research related to optimizing for finishing machining:

(i) The proposed work has been restricted to evaluate the effect of surface finish under different combinations of cutting and geometric parameters where the same proposed work can be performed for studying the influence on tool life under the effect of wet and dry cutting and influence on surface roughness under the effect of dry and wet cutting. These objectives can be solved individually or taken multiple at time.

(ii) The results obtained by Taguchi can be enhanced by considering more cutting edge parameters so as to make work more efficient. The quality of the solutions can also be seen as an aspect to focus on, by making some amendments in the parameters in order to generate better results.

(iii) Heuristics techniques such as Genetic Algorithm, Fuzzy Logic, Principal Component Analysis or any other recently developed techniques can be combined with Taguchi technique as Hybrid to make work more competent in optimizing the cutting and geometric parameters.

(iv) The proposed work restricts to the use of normal carbide bit tools, which would somehow lead to the wastage of time, money and material where the same turning process can be performed by using the carbide inserts which is less costly and helps in saving time and can be easily fitted on CNC machines in comparison to the normal tool bits.

(v) The proposed simulation problem can also be performed by using different FEM simulation software like ANSYS, AdvantEdge, Elmer FEM solver and multi physics software such as COMSOL by applying more constraints such as adaptive finite element mesh which is being applied to reduce the deformation of the material and isotropic nature of the work material, which would make simulation work more competent with others.

Publications (Journal)

1. Kapoor, A. and Singh, H. (2017), "*Review of Optimizing Machining Parameters for Improving Surface Texture*", Journal of Material Science and Mechanical Engineering (JMSME), Vol. 4, 1, pp. 9-13, ISSN: 2393-9095 (e: 2393-9109).

Publications (Conference Proceedings)

1. Paper titled, "*Review of Optimization of Cutting and Geometric Parameters for Finishing Machining of Steel: Prospects and Challenges*", presented in Proceedings of 5th International Conference on Advancements in Engineering and Technology (ICAET-2017) held on March 24-25 March, 2017 at Bhai Gurudas Institute of Engineering &Technology, Sangrur, PB, India.

2. Paper titled, "*Review of Optimization Techniques for Finishing Machining of Steel: Model Formulation*", presented in Proceedings of 5th International Conference on Advancements in Engineering and Technology (ICAET-2017) held on March 24-25 March, 2017 at Bhai Gurudas Institute of Engineering &Technology, Sangrur, PB, India.

References

1. Abainia, S., Sadredin, N. and Ouelaa, N. (2015), *"Experimental Study of the Combined Influence of the Tool Geometry Parameters on the Cutting Forces and Tool Vibrations"*, International Journal of Advanced Manufacturing Technology, Vol. 79, 5-8, pp. 1127-1138.
2. Abbas, M. (2016), *"Optimization of Cutting Parameters to Improve Surface Roughness of Al 1070 in Turning Operation Using Taguchi Method*". International Journal of Engineering Sciences & Research Technology, Vol. 1, 5, pp. 1324-1329.
3. Agapiou, J. S. (1992*), "The Optimization of Machining Operations Based on a Combined Criterion, Part 1: The Use of Combined Objectives in Single-Pass Operations",* Transactions-American Society of Mechanical Engineers Journal of Engineering for Industry, Vol. 114, 9, pp. 500-500.
4. Albu, S., Cristian, S. and Bolos, V. (2014), *"Determining the Optimal Position of the Frontal-Cylindrical Milling Tool in Finishing in the New Technology for Processing Worms*", Procedia Technology, Vol. 12, pp. 455-461.
5. Asilturk, I. and Akkuş, H. (2011), *"Determining the Effect of Cutting Parameters on Surface Roughness in Hard Turning Using the Taguchi Method"*, Measurement, Vol. 44, 9, pp. 1697-1704.
6. Benlahmidi, S., Aouici, H. and Boutaghane, F. (2016), "*Design Optimization of Cutting Parameters when Turning Hardened AISI H11 Steel (50 HRC) with CBN7020 Tools*", International Journal of Advanced Manufacturing Technology, Vol. 12, 3, pp. 1-18.
7. Bouzakis, K., Michailids, N. and Vidakis N. (2000), "*Optimization of the Cutting Edge Radius of PVD Coated Inserts in Milling Considering Film Fatigue Failure Mechanisms*", Surface and Coatings Technology, Vol. 133, pp. 501-507.
8. Brewer, J. H. and Allgeier, D. L. (1966*), "Optimization of Unit Cost by utilizing Lagrangian Multipliers"*, Measurement, Vol. 14, 6, pp. 985-988.
9. Chang, M. and Zen, J. (2013), *"Multi-Objective Optimization of Oblique Turning Operations Using Finite Element Model and Genetic Algorithm",* International Journal of Advanced Manufacturing Technology, Vol. 71, 1-4, pp. 593-603.

10. Chen, D., Han, Z. and Zhang, L. (2013), "*Study on the Optimization of Cutting Parameters in Turning Thin-Walled Circular Cylindrical Shell Based Upon Cutting Stability*", International Journal of Advanced Manufacturing Technology, Vol. 69, 1-4, pp. 891-899.
11. Chen, X., Ma, L. and Cao, X. (2014), *"Experimental Study and Genetic Algorithm-Based Optimization of Cutting Parameters in Cutting Engineering Ceramics",* International Journal of Advanced Manufacturing Technology, Vol. 74, 5-8, pp. 807-817.
12. Cheng, X., Zha, X. and Jiang, F. (2015), "*Optimizing the Geometric Parameters of Cutting Edge for Rough Machining Fe-Cr-Ni Stainless Steel*", International Journal of Advanced Manufacturing Technology, Vol. 245, 4-9, pp. 1-11.
13. Dahlman, P., Gunnberg, F. and Jacobson, M. (2004), "*The Influence of Rake Angle, Cutting Feed and Cutting Depth on Residual Stresses in Hard Turning*", Journal of Materials Processing Technology, Vol. 147, 2, pp. 181-184.
14. Denkena, A., Kohler, J. and Bergmann, B. (2015), "*Development of Cutting Edge Geometries for Hard Milling Operations*", CIRP Journal of Manufacturing Science and Technology, Vol. 8, 3, pp. 43-52.
15. Ermer, D. S. and Kromodihardjo, S. (1981), *"Optimization of Multi-pass Turning with Constraints"*, J. Eng. Ind. (Trans. ASME), Vol. 103, 4, pp. 462-468.
16. Fang, N. and Fang, G. (2007), "*Theoretical and Experimental Investigations of Finish Machining with a Rounded Edge Tool*", Journal of Materials Processing Technology, Vol. 191, 1, pp. 331-334.
17. Fang, N. and Wu, Q. (2009), "*A Comparative Study of the Cutting Forces in High Speed Machining of Ti–6al–4v and Inconel 718 with a Round Cutting Edge Tool",* Journal of Materials Processing Technology, Vol. 209, 9, pp. 4385-4389.
18. Galanis, J. A., Rizal, M. and Haron, C. H. C. (2014), *"Performance of Green Machining: A Comparative Study of Turning Ductile Cast Iron Fcd700"*, Journal of Cleaner Production, Vol. 85, 5, pp. 289-292.
19. Gilbert, W. W. (1950), *"Economics of Machining",* Machining Theory and Practice, Vol. 70, 2, pp. 465-485.

20. Guoqin, S., Deng, X. and Shet, C. (2012), *"A Finite Element Study of the Effect of Friction in Orthogonal Metal Cutting"*, Finite Elements in Analysis and Design, Vol. 38, 9, pp. 863-883.
21. Hairudin, W., Masrurah, W. and Awang, M. (2011), "*Thermo Mechanical Modeling of Turning Process Using an Arbitrary Lagrangian-Eulerian Method*", National Postgraduate Conference (NPC), IEEE, Vol. 45, 7, pp. 1-6.
22. Hashmi, E. and Khalid H. (2015), "*Optimization of Process Parameters for High Speed Machining of Ti-6al-4v Using Response Surface Methodology*", International Journal of Advanced Manufacturing Technology, Vol. 33, 8, pp. 1-10.
23. Hassan, E. H. (2005), *"Advanced Machining Processes: Nontraditional and Hybrid Machining Processes*", 1/e, McGraw Hill Publications.
24. Hua, J., Umbrello, D. and Shivpuri, R. (2006), *"Investigation of Cutting Conditions and Cutting Edge Preparations for Enhanced Compressive Subsurface Residual Stress in the Hard Turning of Bearing Steel*", Journal of Materials Processing Technology, Vol. 171, 2, pp. 180-187.
25. Janardhan, M. and Krishna, A.G. (2012), *"Multi-Objective Optimization of Cutting Parameters for Surface Roughness and Metal Removal Rate in Surface Grinding Using Response Surface Methodology".* International Journal of Advances in Engineering & Technology, Vol. 3, 1, pp. 270-283.
26. Jayaramachandran, R. and Ganesan, S. (2005), "*Finite Element Analysis of Temperature Rise in Metal Cutting Processes"*, Applied Thermal Engineering, Vol. 25, 14, pp. 2152-2168.
27. Kalyan, C. and Samuel, G. (2015), "*Cutting Mode Analysis in High Speed Finish Turning of ALMSGI Alloy Using Edge Chamfered PCD Tools*", Journal of Materials Processing Technology, Vol. 216, 5-8, pp. 146-159.
28. Kim, C. and Kyoon, K. (2002), "*A Study on the Precision Machinability of Ball End Milling by Cutting Speed Optimization*", Journal of Materials Processing Technology, Vol. 130, 3, pp. 357-362.
29. Klir, G. J. and Yuan, B. (1998), "*Fuzzy System and Fuzzy Logic–Theory and Practice",* Englewood Cliffs, Vol. 57, 8, pp. 12-18.

30. Korkut, I., Kasap, M., Ciftci, I. and Seker, U. (2004), *“Determination of Optimum Cutting Parameters during Machining of AISI 304 Austenitic Stainless Steel”,* Materials & Design, Vol. 25, 4, pp. 303-305.
31. Kuo, L. and Yen, J. (2002), "*A Genetic Algorithm-Based Parameter-Tuning Algorithm for Multi-Dimensional Motion Control of a Computer Numerical Control Machine Tool*", Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, Vol. 216, 3, pp. 429-438.
32. Leo Kumar, S. P., Jerald, J., Kumanan, S. and Prabakaran, R. (2014), *“A Review on Current Research Aspects in Tool-Based Micromachining Processes”*, Materials and Manufacturing Processes, Vol. 29, 11-12, pp. 1291-1337.
33. Li, B. (2014), *“An Experimental Investigation of Dry Cutting Performance for Machining Gray Cast Iron with Carbide Coating Tool*”, International Journal of Advanced Manufacturing Technology, Vol.71, 8, pp. 33-55.
34. Li, L. and Bin, Y. (2014), "*An Experimental Investigation of Dry Cutting Performance for Machining Gray Cast Iron with Carbide Coating Tool*", International Journal of Advanced Manufacturing Technology, Vol. 71, 5-8, pp. 1093-1098.
35. Liao, C. and Tongkai, Y. (2016), "*Optimizing the Geometric Parameters of Cutting Edge for Finishing Machining of Fe-Cr-Ni Stainless Steel*", International Journal of Advanced Manufacturing Technology, Vol. 2, 6, pp. 1-13.
36. Lo, P. and Peng, S. (2000), "*An Analysis of Cutting under Different Rake Angles Using the Finite Element Method"*, Journal of Materials Processing Technology, Vol. 105, 1, pp. 143-151.
37. Majumdar, P., Jayaramachandran, R. and Ganesan, S. (2005), *“Finite Element Analysis of Temperature Rise in Metal Cutting Processes*”, Applied Thermal Engineering, Vol. 25, 14, pp. 2152-2168.
38. Mayer, P., Kirsch, B. and Becker, S. (2016), *"Influence of Cutting Edge Geometry on Deformation Induced Hardening when Cryogenic Turning of Metastable Austenitic Stainless Steel AISI 347*”, Procedia CIRP, Vol. 45, pp. 59-62.
39. McGeough, J. A. (1988), *“Advanced Methods of Machining”*, 1/e, Springer Science & Business Media.

40. Meddour, I., Khattabi, R. and Elbah, M. (2015), "*Investigation and Modeling of Cutting Forces and Surface Roughness When Hard Turning of AISI 52100 Steel with Mixed Ceramic Tool: Cutting Conditions Optimization*", International Journal of Advanced Manufacturing Technology, Vol. 77, 5-8, pp. 1387-1399.
41. Mia, M. and Dhar, N. R. (2016), *"Optimization of Surface Roughness and Cutting Temperature in High-Pressure Coolant-Assisted Hard Turning Using Taguchi",* International Journal of Advanced Manufacturing Technology, Vol. 45, 1-5, pp. 1-15.
42. Mozammel, M. and Dhar, N. (2016), "*Optimization of Surface Roughness and Cutting Temperature in High-Pressure Coolant-Assisted Hard Turning Using Taguchi Method*", International Journal of Advanced Manufacturing Technology, Vol. 45, 4, pp. 1-15.
43. Nalbant, M. and Muammer, A. (2009), *"The Experimental Investigation of the Effects of Uncoated, PVD-and CVD-Coated Cemented Carbide Inserts and Cutting Parameters on Surface Roughness in CNC Turning and its Prediction Using Artificial Neural Networks",* Robotics and Computer-Integrated Manufacturing, Vol. 25, 1, pp. 211-223.
44. Nataraj, M. and Balasubramanian, K. (2016), *"Parametric Optimization of CNC Turning Process for Hybrid Metal Matrix Composite*", International Journal of Advanced Manufacturing Technology, Vol. 90, 6, pp. 1-10.
45. Negrete, C., Najera, J. and Valenzuela, J. (2016), "*Optimization of Cutting Parameters to Minimize Energy Consumption During Turning of AISI 1018 Steel at Constant Material Removal Rate Using Robust Design*", International Journal of Advanced Manufacturing Technology, Vol. 83, 5-8, pp. 1341-1347.
46. Oktem, H. (2009), *"An Integrated Study of Surface Roughness for Modeling and Optimization of Cutting Parameters during End Milling Operation",* International Journal of Advanced Manufacturing Technology, Vol. 43, 9-10, pp. 852-861.
47. Paiva, A. (2012), *"A Multivariate Robust Parameter Design Approach for Optimization of AISI 52100 Hardened Steel Turning with Wiper Mixed Ceramic Tool",* International Journal of Refractory Metals and Hard Materials, Vol. 30, 1, pp. 152-163.

48. Pignatiello, J. J. (1988), *“An Overview of the Strategy and Tactics of Taguchi”,* IEEE Transactions, Vol. 20, 3, pp. 247-254.
49. Prasad, A. V. S. R. K., Rao, P. N. and Rao, U. R. K. (1997*), “Optimal Selection of Process Parameters for Turning Operations in a CAPP System”*, International Journal of Production Research, Vol. 35, 6, pp. 1495-1522.
50. Pytlak, C. and Bogusław, A. (2010), *"Multicriteria Optimization of Hard Turning Operation of the Hardened 18HGT Steel",* International Journal of Advanced Manufacturing Technology, Vol. 49, 1-4, pp. 305-312.
51. Qureshi, A. (2015), *“Optimization of Cutting Parameters for Surface Roughness in CNC Turning of P20 Steel”*, International Journal of Scientific & Engineering Research, Vol. 6, 12, pp. 2229-5518.
52. Rashid, M. and Bin, W. (2016), *"Parametric Design Optimization of Hard Turning of AISI 4340 Steel (69 HRC)",* International Journal of Advanced Manufacturing Technology, Vol. 82, 1-4, pp. 451-462.
53. Rocha, C. and Souza, L. (2016), *"Robust Multiple Criteria Decision Making Applied to Optimization of AISI H13 Hardened Steel Turning with PCBN Wiper Tool",* International Journal of Advanced Manufacturing Technology, Vol. 45, pp. 1-18.
54. Santos, M. and Bin, W. (2011), *"Multi-Objective Optimization of Cutting Conditions when Turning Aluminum Alloys (1350-O And 7075-T6 Grades) Using Genetic Algorithm",* International Journal of Advanced Manufacturing Technology, Vol. 76, 5-8, pp. 1123-1138.
55. Shinozuka, J., Obikawa, T. and Shirakashi, T. (1996), *"Chip Breaking Analysis from the Viewpoint of the Optimum Cutting Tool Geometry Design",* Journal of Materials Processing Technology, Vol. 62, 4, pp. 345-351.
56. Sikdar, S. K. and Chen, M. (2002), *“Relationship between Tool Flank Wear Area and Component Forces in Single Point Turning”,* Journal of Materials Processing Technology, Vol. 128, 1, pp. 210-215.
57. Sullivan, L. P. (1987), “*The Power of Taguchi Methods to Impact Change in US Companies”*, Quality Progress, Vol. 344, 4, pp. 76-79.

58. Taylor, F. W. (1907), "*On the Art of Cutting Metals"*, New York, The American Society of Mechanical Engineers, Vol. 74, 1-6, pp.1-19.

59. Thakur, J., Dinesh G., Ramamoorthy, B. and Vijayaraghavan, L. (2010), *"Investigation and Optimization of Lubrication Parameters in High Speed Turning of Super alloy Inconel 718"*, International Journal of Advanced Manufacturing Technology, Vol. 50, 5-8, pp. 471-478.

60. Tsai, Y., Chien, Y. and Hsieh, J. (2005), *"An Analysis of Cutting-Edge Curves and Machining Performance in the Inconel 718 Machining Process"*, International Journal of Advanced Manufacturing Technology, Vol. 25, 3-4, pp. 248-261.

61. Umbrello, D. and Shivpuri, R. (2006), *"Investigation of Cutting Conditions and Cutting Edge Preparations for Enhanced Compressive Subsurface Residual Stress in the Hard Turning of Bearing Steel"*, Journal of Materials Processing Technology, Vol. 171, 2, pp. 180-187.

62. Umer, M. and Usama, A. (2014), *"Multi-Objective Optimization of Oblique Turning Operations Using Finite Element Model and Genetic Algorithm"*, International Journal of Advanced Manufacturing Technology, Vol. 71, 1-4, pp. 593-603.

63. Varghese, L., Aravind, S. and Shunmugesh, K. (2017) *"Multi-Objective Optimization of Machining Parameters during Dry Turning of 11SMn30 Free Cutting Steel Using Grey Relational Analysis"* Materials Today: Proceedings, Vol. 4, 2, pp. 4196-4203.

64. Walvekar, A. G. and Lambert, B. K. (1970), *"An Application of Geometric Programming to Machining Variable Selection"*, The International Journal of Production Research, Vol. 8, 3, pp. 241-245.

65. Wan, L., Wang, D. and Gao, Y. (2016), *"Investigations on the Effects of Different Tool Edge Geometries in the Finite Element Simulation of Machining"*, Journal of Mechanical Engineering, Vol. 61, 3, pp. 157-166.

66. Wang, Q., Lin, H. and Zhang, Z. (2011), *"Prediction of Chip Flow Angle to Study the Relation between Chip Flow and Ratio of the Cutting Edge Lengths Using Sharp Corner Tools"*, International Journal of Advanced Manufacturing Technology, Vol. 56, 9-12, pp. 841-855.

67. Wang, X. and Jawahir, I. S. (2004), *"Web-Based Optimization of Milling Operations for the Selection of Cutting Conditions Using Genetic Algorithms*", Proceedings of

the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, Vol. 218, 6, pp. 647-655.

68. Witty, M., Bergs, T., Schafer, A. and Cabral, G. (2012*), "Cutting Tool Geometry for Plunge Milling–Process Optimization for a Stainless Steel"*, Procedia CIRP, Vol. 89, 1, pp. 506-511.
69. Yahya, E., Ding, G. and Qin. S. (2015), *"Optimization of Machining Parameters Based on Surface Roughness Prediction for AA6061 Using Response Surface Method".* American Journal of Science and Technology. Vol. 2, 5, pp. 220-231.
70. Yang, W. P. and Tarng, Y. S. (1998*), "Design Optimization of Cutting Parameters for Turning Operations Based on the Taguchi Method",* Journal of Materials Processing Technology, Vol. 84, 1, pp. 122-129.
71. Yen, C., Billy, B. and Chang, Y. (2004), *"Estimation of Tool Wear in Orthogonal Cutting Using the Finite Element Analysis",* Journal of Materials Processing Technology, Vol. 146, 1, pp. 82-91.
72. Yen, C., Yang, P. and Lin, H. (2004), *"Influence of Cutting Edge Radius of Coated Tool on Chip Formation in Orthogonal Cutting of Alloy Steel"*, Proceedings of the 7th CIRP International Workshop on Modeling of Machining Operations, Vol. 2004, pp. 22-40.
73. Yu, S. and Lee, B. (2003), "*The Optimal Cutting-Parameter Selection of Production Cost in HSM for SKD61 Tool Steels*", International Journal of Machine Tools and Manufacture, Vol.43, 7, pp. 679-686.
74. Zerti, H., Qingming, W. and Oussama, K. (2007), *"Design Optimization for Minimum Technological Parameters when Dry Turning of AISI D3 Steel Using Taguchi Method"*, International Journal of Advanced Manufacturing Technology, Vol. 78, pp. 1-20.
75. Zong, W. J., Li, D., Cheng, K., Sun, T. and Liang, Y. C. (2007), *"Finite Element Optimization of Diamond Tool Geometry and Cutting-Process Parameters Based on Surface Residual Stresses"*, International Journal of Advanced Manufacturing Technology, Vol. 32, 7, pp. 666-674.

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