EXPERIMENTAL INVESTIGATION AND OPTIMIZATION OF CUTTING PARAMETERS IN HARD TURNING OPERATION

A PROJECT REPORT

submitted by

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TKM20MECI08

to

the APJ Abdul Kalam Technological University

in partial fulfillment of the requirements for the award of the Degree

of

Master of Technology

In

Computer Integrated Manufacturing

Department of Mechanical Engineering

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Kollam

SEPTEMBER, 2022

DECLARATION

I, Muhammed Bukhari B N, hereby declare that the project report "Experimental Investigation and Optimization of Cutting Parameters in Hard Turning Operation", submitted for partial fulfillment of the requirements for the award of degree of Master of Technology ofthe APJ Abdul Kalam Technological University, Kerala is a bonafide work done by me under supervision of Kannan S, Assistant Professor, Department of Mechanical Engineering, TKM College of Engineering, Kollam. This submission represents my ideas in my own words and where ideas or words of others have been included, I have adequately and accurately cited and referenced the original sources. I also declare that I have adhered to ethics of academic honesty and integrity and have not misrepresented or fabricated any data or idea or fact or source in my submission. I understand that any violation of the above will be a cause for disciplinary action by the institute and/or the University and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been obtained. This report has not been previously formed the basis for the award of any degree, diploma or similar title of any other University.

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Date: 12/09/2022 Muhammed Bukhari B N

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CERTIFICATE

This is to certify that the report entitled **"EXPERIMENTAL INVESTIGATION AND OPTIMIZATION OF CUTTING PARAMETERS IN HARD TURNING"** submitted by **MUHAMMED BUKHARI B N, TKM20MECI08** to the APJ Abdul Kalam Technological University in partial fulfillment of the requirements for the award of the Degree of Master of Technology in Computer Integrated Manufacturing, Department of Mechanical Engineering, is a bonafide record of the project work carried out by him/her under my/our guidance and supervision. This report in any form has not been submitted to any other University or Institute for any purpose.

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ACKNOWLEDGEMENT

First of all, I am indebted to the **GOD ALMIGHTY** for giving me an opportunity to excel in my efforts to complete this project on time.

I am extremely grateful to **Dr. T A SHAHUL HAMEED**, Principal, TKM college of Engineering and **Dr. DILEEP P.N**, Head of the Department, Department of Mechanical Engineering, for providing all required resources for successful completion of my project.

I am greatly obliged to my internal supervisor **Prof. KANNAN S**, Assistant professor, Department of CIM, **SINU K JACOB,** Phd Scholar, Department of Mechanical Engineering for their encouragement, guidance and support.

My heartfelt gratitude to **Prof. KANNAN S**, Assistant professor, Department of CIM & **Prof. FAIZAL N. S**, Assistant professor, Department of CIM for their valuable suggestions and guidance in the preparation of the project presentation and report.

I express my thanks to all Faculties and Technical staffs, Department of Mechanical Engineering, and all staff members and friends for all help and coordination extended in bringing out this project successfully in time.

I will be failing in duty if I do not acknowledge with grateful thanks to the authors of the references and other literatures referred to in this project.

Last but not the least, I am very much thankful to my parents who guided me in every steps which I took.

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ABSTRACT

The need for materials with extraordinary characteristics is one of the major challenges faced by the engineering sector. This project takes an alternative strategy since it addresses the economic impact on pure hard elements like titanium, vanadium, tungsten, and their alloys as well as the difficulties of availability from the open market. The parent pure metal is purchased to the machine's level of difficulty and a number of characteristics were examined during a hard turning operation. Since few research have been done on the behaviour of the cutting tool during CBN hard turning, pure EN31 round bar is taken into consideration for this purpose and is purchased at a hardness level of 60–64 HRC. This is done in order to understand the variance in some parameters. CBN tools were utilized for this. As a result, this study examines how cutting factors affect hard turning. Through the analysis of variance, the combined impact of the process (cutting speed, feed rate, and depth of cut) on performance metrics (surface roughness and chip morphology) is examined (ANOVA). The output factors taken into account are the type of chips produced (chip morphology) and the surface roughness. Chip morphology study only takes continuing and discontinuous chips into account because CBN is the cutting tool being employed.The experiment revealed that feed rate is the dependent parameter for Ra, Rq, and Rz surface roughness measurements. Using Design Xpert software, the Box Behnken technique was used to construct the experiment, and regression analysis was used to conform the results.

Keywords- Anova, Cbn Tool, Hardened En-31 Steel, Regression Analysis, Surface Roughness, Box Behnken design, Optimization

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ABBREVIATIONS

HRC	-Rockwell Hardness C scale
cBN	-Cubic Boron Nitride
EN	-Emergency Number
DOC	-Depth of Cut
MRR	-Material Removal Rate
CNC	-Computer Numerical Control
OHNS	-Oil Hardened Non Shrinking
R_a	-Arithmetic Mean of Roughness
R_q	-Root Mean Square Value of Roughness
R_z	-Roughness Depth Value

NOTATIONS

F	-FEED
N	-SPEED

CHAPTER 1

INTRODUCTION

The method of hard turning involves using a single point cutting tool to mill materials that have reached a hardened condition (45–70 HRC). The development of new cutting tool materials like cubic boron nitride (cBN) and diamond, this is now achievable. Rough turning, heat treatment, and subsequently grinding are the steps involved in the classical method of machining harder materials. Hard turning reduces the number of operations needed to make the component, shortening the production cycle and increasing productivity.

Surface Roughness affects the fatigue strength, wear rate, coefficient of friction, and corrosion resistance of the machined components, it is crucial. In hard turning, it has been discovered that a variety of elements, including feed rate, cutting speed, tool nose radius, tool geometry, cutting duration, work piece hardness, machine tool stability, work piece setup, etc., affect surface finish. With the use of the Box Behnken design (Response Surface Methodology), this thesis examined how the cutting speed, feed rate, and depth of cut affected the surface roughness while hardened EN-31 steel was being worked with cBN cutting tools. Results highlight the extent to which feed rate, cutting speed, and depth of cut all have an impact on surface roughness. Based on the required range of values, the trials were conducted utilising various feed rates (0.05, 0.10, 0.15 mm/rev), cutting speeds (100, 150, 200 m/min), and depths of cut (0.1, 0.2, 0.3 mm). The optimization of the surface finish during the process has been revealed by experiments of hard turning with cBN cutting tools. Cutting speed, feed, depth of cut (DOC), material removal rate (MRR), and tool workpiece interface temperature are the parameters taken into account. For this, a variety of engineering techniques, procedures, and software was used.

CHAPTER 2

LITERATURE REVIEW

Hard turning is the process of employing single point cutting tools to machine materials that are in their hardened state (45–70 HRC). Due to their great strength and wear resistance, hardened steels were traditionally machined using the grinding process; however, grinding processes are time-consuming and have a limited number of possible geometries. Recently, grinding has been partially substituted for this purpose by turning the hardened steel using a single point cutting tool[1]. Hard workpiece materials necessitate cutting tools that are much harder. Cubic boron nitride (cBN), as opposed to diamond, is incredibly suitable for the machining of materials that are challenging to work with. It is really the second hardest substance known to man[2]. Studies were done to find out how cBN cutting tool edge preperation affected process variables and tool performance during high speed orthogonal cutting[3]. Hard-turnined work is commonly found in the 58 to 68 HRC range [4]. Surface roughness, tool wear, cutting force specific cutting force, and work material hardness all affect a material's ability to be machined[5].

In order to determine the best cutting settings, experimental studies using PCBN cutting tool inserts on difficult-to-machine materials were conducted[6]. In order to determine the tool life and behaviour of different cutting tools under various cutting circumstances, studies on the machining of hardened carbon steel were conducted[7]. It has been discovered that the kind of work material has a significant impact on the metal cutting process. Optimized machining settings produce a superior surface finish when working with hard materials[8]. Hard turning using multilayer coated carbide tools provides a number of benefits over grinding, including lower processing costs, higher output, shorter cycle times, suitable surface roughness, and less environmental impact as no cutting fluids are used[9]. When machining hardened steel, the Box Behnken technique is used to determine the best process parameters for end milling. In order to analyse the performance characteristics of machining settings while taking tool life and surface finish into account, orthogonal array and analysis of variance techniques were used[10]. The goal of tool producers is to provide high-quality tools that can handle greater cutting forces, temperature resistance, increased wear resistance, and longer tool lives, as well as superior surface finishes and the maintenance of required dimensional accuracy[11]. A wider range of workpiece materials are intended to be accommodated by newly designed cutting tool grades, which are intended to allow diverse usage in roughing and finishing applications. The cutting force is directly impacted by the material of the cutting tool during machining, as per data obtained with a constant depth of cut and feed rate[12]. Major influences on tool performance and workpiece shape or characteristics have been identified as cutting temperature and heat produced at the tool-chip contact during high speed machining operations[13]. Studies have been conducted to determine how surface roughness and cutting force are affected by speed, feed, and depth of cut while turning mild steel using high-speed cutting tools[14]. Understanding turning mechanics has long been challenged by the impact of cutting tool shape. When turning, tool geometry significantly affects chip formation, heat generation, tool wear, surface integrity, and surface finish[16].

2.1 OBJECTIVE

The optimization of the surface finish during the process has been revealed by experiments of hard turning with cBN cutting tools. Cutting speed, feed, depth of cut (DOC), material removal rate (MRR), and tool workpiece interface temperature are the parameters taken into account. For this, a variety of engineering techniques, procedures, and software was used. To demonstrate the validity of the thesis, experiment confirmation is carried out. Due to the difficulty in finding a base material that meets the necessary requirements on the market, heat treatment is used to increase the material's hardness level from the parent specimen. For the experiment, five different hardened specimens were selected, and before the start of each machining process, the hardness levels were confirmed. With reference to the physical values produced during the hard turning procedure, the thesis' integrity is assured.

2.2 SCOPE OF STUDY

The purpose of this thesis is to examine how cutting parameters affect hard turning operations. Hard turning is the process of turning materials with a hardness ranging 45 to 70 HRC. A CNC lathe with the appropriate machine capabilities is used to carry out the machining operation in accordance with the experiment's requirements. The basic material for this is EN 31(OHNS), which has a hardness of 35 HRC and is then hardened to a level of 65 HRC to suit the experimental requirement. Parent basic materials are not being considered due to its ready availability in the market. Since diamond, which is associated with carbon steel is also a possibility, cBN cutting tool bits are taken into consideration for severe turning operations. Response Surface Method and ANOVA method is used for optimization with the aid of Design Xpert software. Surface roughness is measured using Mitutoyo SJ 410 Machine. Regression analysis is used to conform the experiment in comparison to the physical values collected and the response relation.

In order to understand the type of chip that is being formed, a chip morphology analysis was carried out using a variety of cutting circumstances. During this step, a different strategy is being used because the sort of chip that had been produced was wholly different from the traditional turning process utilising standard cutting tools. This has provided more information that is helpful in proving the thesis.

2.3 DEFINITIONS AND SIGNIFICANCE OF EXPERIMENT

1.3.1 Speed: The rate of rotation of the spindle in which the tool is held is referred to as speed. It is measured in minutes of rotations (RPMs).

1.3.2 Feed: The rate at which the tool is inserted into the part or the part is inserted into the tool is known as the feed. Feed is quantified per time period in feet, inches, or millimetres.

1.3.3 Depth of Cut (DOC): The measurement (normally in inches or millimeters) of how wide and deep the tool cuts into the work piece.

1.3.4 Material Removal Rate (MRR): The amount of the material removed per unit of time is known as the material removal rate. In a turning operation, we remove a ring-shaped layer of material from the work piece for each rotation, with a cross sectional area equal to the product of the tool's feed (F) and the average ring circumference ($\pi\ D_{avg.}$). If the work piece rotates at N RPM and the rate of material removal is,

$$MRR = (\pi D_{avg.})\ (d)\ (F)\ (N)$$

The Metal Removal Rate is calculated using the factors of speed, feed, and DOC all combined (MRR). Numerous elements of machining performance, including tool life, surface finish, dimensional accuracy of the machined part, power needed by the machine tool, etc., are influenced by speeds, feeds, and DOC.A tool's useful life is a measurement of how long it will continue to work and produce usable parts. The tool can have an infinite lifespan if it isn't used at all. Naturally, there would be no productivity and nothing would be accomplished.

The surface finish or smoothness of the finished work item may be measured with a variety of tools and documented in a variety of units of measurement, as we found in our Surface Finish Skill Builder. Dimensional accuracy refers to a bigger segment or the complete product, whereas surface finish is often tested on a tiny portion of a part.

Additionally, there are thermal concerns. Some machines are extremely sensitive to changes in their surroundings. Many machine tools have been shown to not consistently produce components of the same quality throughout the day unless the shop floor temperature is appropriately managed. Additionally, the alloy being machined could be sensitive to temperature variations. One important factor affecting the precision of a component is the Metal Removal Rate (MRR). The chance of part accuracy drops as the MRR rises.

Multiple regression and Analysis of Variance (ANOVA) techniques were used to identify a significant linear association between the parameters and the response (surface roughness).

For the three parameters that were selected—cutting speed, feed rate, and depth of cut—experiments were constructed utilising Box Behnken's design of experiments (DOE). For the experiments on a CNC turning centre, 17 combinations were employed, and they were modified through three distinct levels.

Surface integrity, which includes topological parameters (surface roughness and other surface topological features), mechanical properties (residual stresses, hardness, etc.), and metallurgical states of the work material during processing, is directly related to the quality and performance of a machined component (phase transformation, microstructure changes and related property variations).

The amount of surface roughness on the finished product will determine how well mechanical parts operate and how much it costs to make them. However, in some circumstances it is necessary to uphold these requirements.

- The surface finish of any given part is measured in terms of average heights and depths of peak and valleys on the surface of the work piece.
- A popularly used molded to estimate the surface roughness value is:

  Stream 1

  $R_a = F^2/8r$

  R_a – Ideal Arithmetic Average (AA) of Surface roughness (µm).

  F - Feed (mm/rev).

  r – Cutter nose radius.

  Stream 2

  $R_a = C * V * F$.

  V – Speed in rpm.

  C – Constant.

  F – Feed (mm/rev).

However, the surface roughness is only partially explained by the two lines of reasoning mentioned above. As a result, there is always a need to dig further into the examination of surface roughness-influencing elements, especially with regard to the interaction effects of cutting speed, feed, and depth of cut, as well as their various combinations.

There has been a lot of study on the thermal problem in metal cutting, according to reviews of recent work on heat generation in high-speed metal cutting, but the accuracy of the measurements and the method used to monitor temperature are in doubt. However, it is possible to ignore the premise that readings have a linear change in their accuracy and acceptability.

However, the experiment's primary objective is to investigate how cutting factors affect surface roughness. By adjusting the cutting parameter, which consists of the cutting speed, feed, and depth of cut, the roughness values Ra, Rq, and Rz, were taken into consideration for analysis. The effect on the temperature at the tool-workpiece contact and the rate of material removal under various changing situations were gathered throughout the investigation. Using Design Xpert software, the parameters are optimised and experimentally confirmed. The chip morphology approach was used to study chip shapes under various operating combinations. This can serve as a reference for handling machined components going forward.

CHAPTER 3

HARD TURNING OPERATION

Workpiece machinability decreases as hardness rises, and surface integrity, surface polish, tool wear, and fracture can all become serious issues. Machining steel with a hardness of 45 HRC or above is referred to as hard machining. Other mechanical procedures, notably grinding, and unconventional techniques are available for inexpensively removing material from hard or hardened metals and alloys. However, by employing the proper tool material and machine tools with sufficient stiffness, classical cutting procedures may still be used on hard metals and alloys. One such instance is employing polycrystalline cubic boron nitride (PcBN) or straightforward cubic boron nitride (cBN) tools to complete machining heat-treated steel shafts, gears, pinions, and other automotive components (in the range of 45 to 65 HRC). This technique, also known as hard turning, creates machined components with high surface quality (as low as 0.25 m) and surface integrity. Hard turning can successfully compete with the grinding process from a technical and financial standpoint. For instance, hard turning uses five times less energy than grinding, is three times quicker, and needs fewer operations. One such instance is employing polycrystalline cubic boron nitride (PcBN) or straightforward cubic boron nitride (cBN) tools to complete machining heat-treated steel shafts, gears, pinions, and other automotive components (in the range of 45 to 65 HRC). This technique, also known as hard turning, creates machined components with high surface quality (as low as 0.25 m) and surface integrity. Hard turning can successfully compete with the grinding process from a technical and financial standpoint. For instance, hard turning uses five times less energy than grinding, is three times quicker, and needs fewer operations.

Additionally, there is a lower likelihood of heat and other damage to the workpiece's surface, cutting fluids might not be required, and machine tools are less costly. Additionally, completing the item while it's still within the lathe removes the requirement for extra material handling equipment or part resetting.

The material is plasticized or annealed at the cutting spot by the heat created during severe machining. The heat is carried away from the cutting spot by the chips because of the fast speed. In difficult machining, the tool just slides across the work surface. Hard turning is the type of finishing.

3.1 SPECIMEN MATERIAL

Materials with a hardness of 45 HRC or above are referred to as hard parts. The base material used is EN 31-OHNS steel with a 35 HRC hardness. a heat treatment procedure was carried out to reach the experimental hardness level of 65. (HRC). A total of 5 specimens bearing the numbers 1, 2, 3, 4, and 5 were created, each measuring 75mm in length and 38mm in diameter. The length is calculated using a 40mm machining length. Throughout the experiment, the specimen's hardness is constantly monitored. For the purpose of retaining the specimen during heat treatment, grooves were constructed.

Fig.3.1 (a) Rockwell Hardness Tester (b) Performing Hardness Test

Skin removal is done in order to ensure the specimen's surface integrity prior to the start of the real experimental machining process. The specimens will be rejected at this point, and specimen number 7 has been rejected because of a visible surface break.

Fig. No. 3.2(a) and 3.2(b) Testing Specimen

3.2 CNC MACHINE FOR HARD TURNING

The (HMT- STALLION 100S) CNC lathe, which permits high precision machining and job production, was used for the experiment. Technical details include the centre height, maximum power of the machine, restrictions on cutting speed, feed, and depth of cut, as well as the maximum workpiece hardness that can be handled based on the cutting tool specification.

Fig. No. 3.3(a) and 3.3(b) CNC Turning Machine

3.3 WHY HARD PART TURNING

In the past, components made of hardened steel were often finished by grinding. Turning hard parts now has a considerable positive impact on production and the environment. The primary benefits are as follows:

- High qualities
- Reduced production time per component
- Process flexibilities
- Lower machine investment cost
- Reduced energy requirements
- Coolant not required
- Easier scrap handling
- Possibility to recycle chips.

In order to validate the constancy of the hardness level, the specimen's hardness levels were constantly monitored.

Table No. 3.1 Hardness of the specimen

Experiment No	Sequence No	Specimen No.	Hardness HRC
1	1	1	64
2	2	2	63
3	3	3	60
4	4	4	60
5	5	5	59
6	6	1	63
7	7	2	62
8	8	3	58
9	9	4	59
10	10	5	57

11	11	1	61
12	12	2	63
13	13	3	65
14	14	4	63
15	15	5	63
16	16	1	62
17	17	2	60

Throughout the test, the required amount of hardness was maintain

CHAPTER 4

CUTTING TOOL SELECTION

4.1 THE CUTTING TOOL

The cBN (Cubic Boron Nitride) cutting tool has developed into a popular machining option for materials that are challenging to work with. Hardened steel, cast irons, heat-resistant super alloys (HRSA), and powder metals are some of the application areas. These workpiece materials all have the overall reputation for being challenging to machine. While still maintaining its cutting edge, a cBN insert can resist the high cutting temperatures and forces. This is why cBN creates components with outstanding surface finishes and offers extended, consistent tool life.

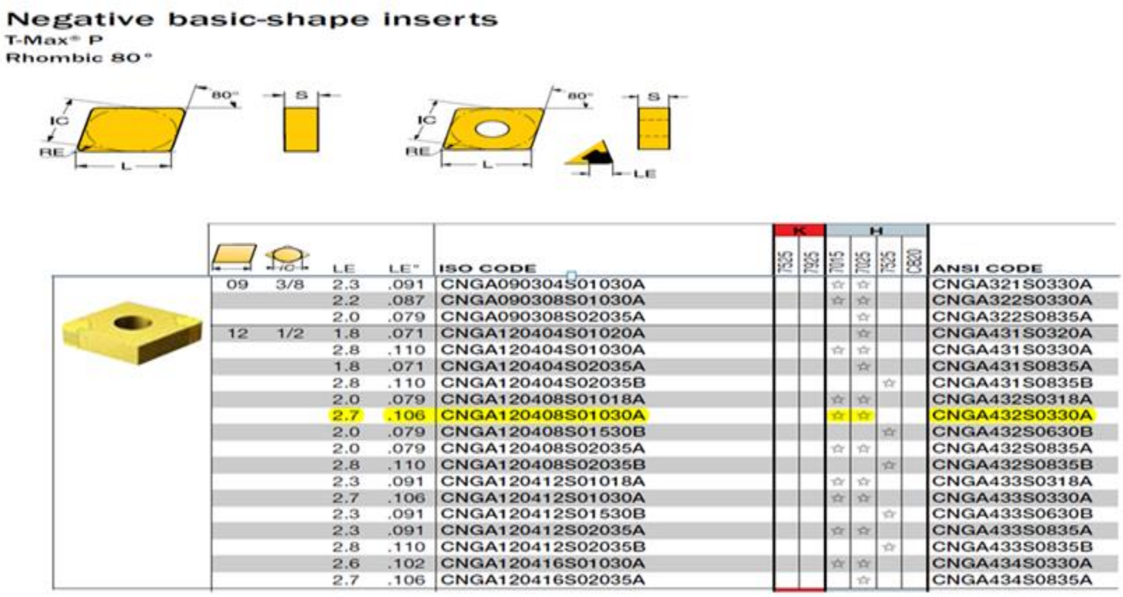
Fig. No. 4.1(a) and 4.1(b) cBN Cutting Tool.

The second-hardest cutting tool material in the world after diamond is cBN. This makes it the perfect material for cutting tools for tough, abrasive workpieces, in addition to many other extreme qualities. cBN is more resistant to chemicals and heat than diamond, which dissolves in iron and has a maximum operating temperature of about

7000C. The chemical inertness of cBN to ferrous materials, on the other hand, allows it to maintain its hardness at temperatures higher than 10,000°C.

4.2 CHOOSE THE RIGHT GRADE

The term hard part turning describes the machining of materials with a hardness of 45 HRC or above. For this, a Sandvik uncoated CB 7025 tool insert is utilised. A special patented substance called CB 7025 has a bimodal grain distribution (1 and 3 m) contains 60% cBN in a ceramic binder. It is a particularly adaptable grade for turning hard parts due to its high fracture resistance. In interrupted cutting, it has great tool life and it is also advised for mixed production and when there is some machine setup instability.



L	IC	LE	LE"	ISO CODE	K 7525	K 7925	H 7015	H 7025	H 7525	H CB20	ANSI CODE
09	3/8	2.3	.091	CNGA090304S01030A			☆	☆			CNGA321S0330A
		2.2	.087	CNGA090308S01030A			☆	☆			CNGA322S0330A
		2.0	.079	CNGA090308S02035A				☆			CNGA322S0835A
12	1/2	1.8	.071	CNGA120404S01020A				☆			CNGA431S0320A
		2.8	.110	CNGA120404S01030A			☆	☆			CNGA431S0330A
		1.8	.071	CNGA120404S02035A				☆			CNGA431S0835A
		2.8	.110	CNGA120404S02035B					☆		CNGA431S0835B
		2.0	.079	CNGA120408S01018A			☆	☆			CNGA432S0318A
		2.7	.106	CNGA120408S01030A			☆	☆			CNGA432S0330A
		2.0	.079	CNGA120408S01530B					☆		CNGA432S0630B
		2.0	.079	CNGA120408S02035A			☆	☆			CNGA432S0835A
		2.8	.110	CNGA120408S02035B					☆		CNGA432S0835B
		2.3	.091	CNGA120412S01018A			☆	☆			CNGA433S0318A
		2.7	.106	CNGA120412S01030A			☆	☆			CNGA433S0330A
		2.3	.091	CNGA120412S01530B					☆		CNGA433S0630B
		2.3	.091	CNGA120412S02035A			☆	☆			CNGA433S0835A
		2.8	.110	CNGA120412S02035B					☆		CNGA433S0835B
		2.6	.102	CNGA120416S01030A			☆	☆			CNGA434S0330A
		2.7	.106	CNGA120416S02035A				☆			CNGA434S0835A

Fig. No. 4.2 cBN Cutting Tool Code Key.

4.3 CUTTING DATA RECOMMENDATIONS

The insert's CNGA 120408 S 01030 A 7025 tool signature is valid for the proposed hard turning operation.

Here is a list of recommended cutting information from the SANDVIK catalogue.

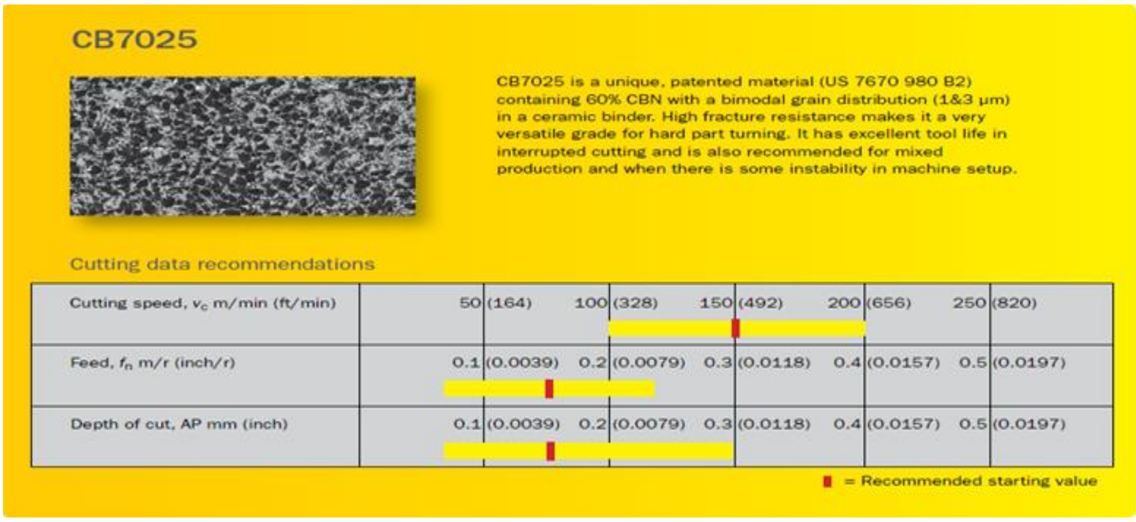


Fig. No. 4.3 cBN Cutting Tool data recommendations.

Cutting parameters for the hard turning operation were chosen based on the aforementioned guideline. The Box Behnken design of experiment is used with the generated orthogonal array to form the experimentation sequence. In light of this, a random sequence is applied for the five specimens that were chosen. To lessen the possibility of error during optimization, this is being done. The experiment's chosen parameters are shown in Table No. 4.1 below;

Table No. 4.1 Selected operating parameters

Operating Parameters	**Experimental Range**
Cutting speed (Vc)	100 - 200m/min
Feed (F)	0.05 - 0.25 m/rev
Depth of cut	0.1 - 0.3 mm

One of the main benefits of turning hard parts with cBN inserts is dry cutting. Over 10,000°C cutting temperatures are no challenge for cBN inserts. Another benefit of these instruments is the elimination of coolant. These are the major benefits of using these sorts of tools:

- Reduces production cost
- Leads to easier chip handling
- Is more environmental friendly

In hard part turning, insert geometry and edge preparation are crucial because they have a big impact on tool life and productivity. While wipers and Xcel provide an unparalleled mix of great productivity and outstanding surface finish, the conventional nose radius delivers the lowest cutting forces and has the lowest stability requirements.

The radius of the insert is a crucial performance factor. A small nose radius 02, 04 mm (0.008–0.016 inch) offers effective chip breaking. In hard component turning operations, a large nose radius of 08, 12 mm (0.03-0.05 inch) results in superior surface finish and thinner chips, which lowers the degree of crater wear. Entry and exit forces are decreased as a result of the broad nose radius and shallow cut. A large nose radius typically offers more edge strength and thus longer tool life. Use the largest nose radius permitted by the constraints of your process.

The chosen tool insert, designated as CNGA 120408 S 01030 A 7025—uncoated insert—is. Figures 4.4(a) and 4.4(b) describe the code key, which in turn gives information on the tool signature under consideration. The surface roughness obtained during forceful turning has been prioritised in efforts to choose the insert.

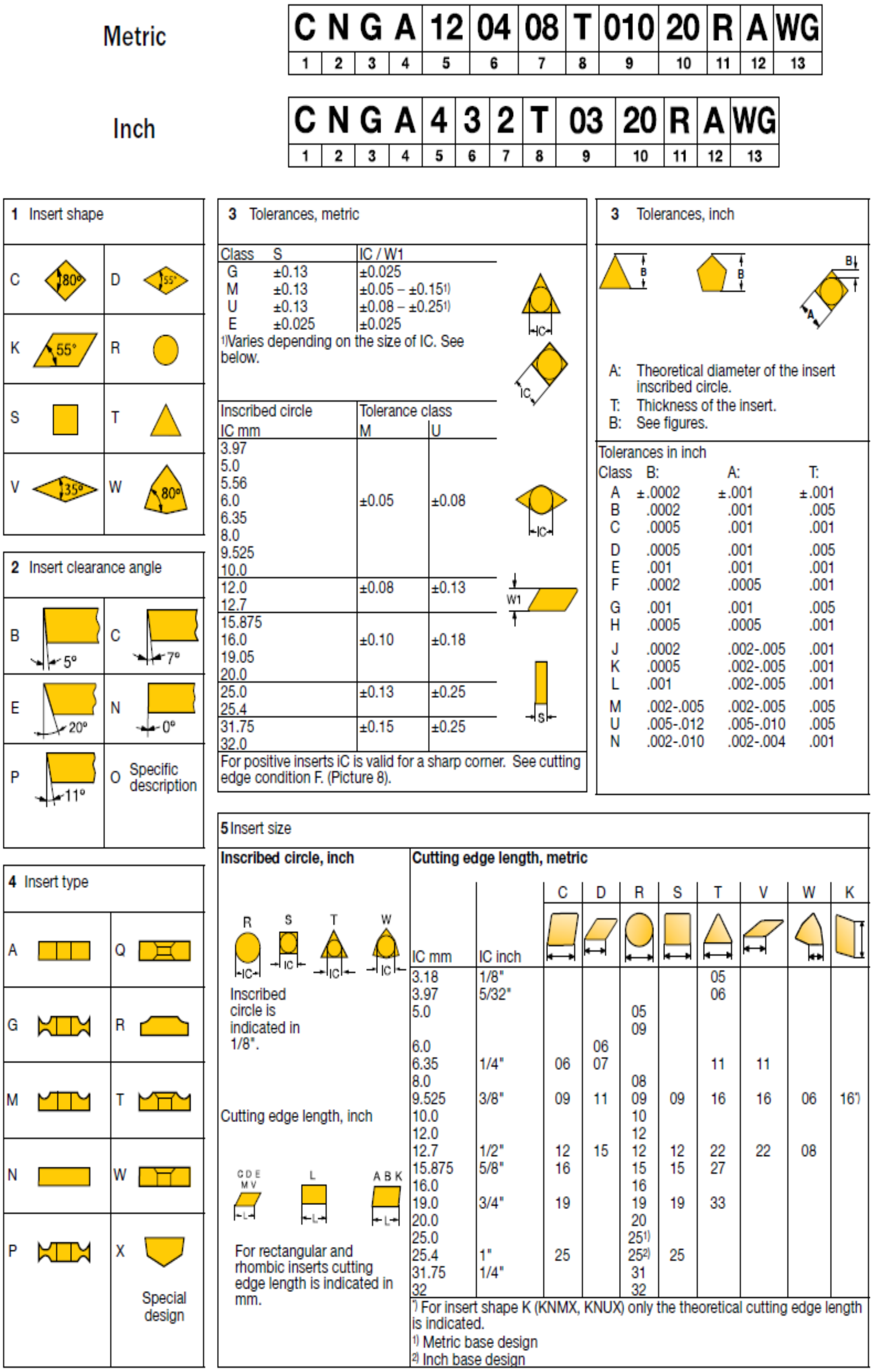
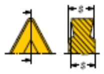


Fig. No. 4.4(a) Insert Code Key.

6 Insert thickness, S mm, inch



Metric			Inch		
01	S =	1.59	1.	S =	.0625
T1	S =	1.98	(1.2)	S =	.075
02	S =	2.38	(1.5)	S =	3/32
03	S =	3.18	2	S =	1/8
T3	S =	3.97	(2.5)	S =	5/32
04	S =	4.76	3	S =	3/16
05	S =	5.56	4	S =	1/4
06	S =	6.35	5	S =	5/16
07	S =	7.94	6	S =	3/8
09	S =	9.52	6.3	S =	.394
10	S =	10.00	7.6	S =	.475
12	S =	12.00			

7 Nose radius, RE mm, inch

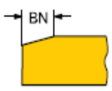
Metric:	Inch:	Actual dimension:
00 = 0	00	Round
01 = 0.1	03	.004
02 = 0.2	0	.008
04 = 0.4	1 = 1/64	.0156
05 = 0.5		
08 = 0.8	2 = 1/32	.0312
10 = 1.0		
12 = 1.2	3 = 3/64	.047
15 = 1.5		
16 = 1.6	4 = 1/16	.0625
24 = 2.4	6 = 3/32	.094
32 = 3.2	8 = 1/8	.125

Note: See example for approximation of metric nose radius.
16=1.6mm=.063=.0625 inch

8 Cutting edge condition

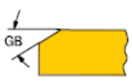
Code	Description
F	Sharp cutting edge
E (A)	ER treated cutting edge A (inch) E (metric)
T	Negative land
K	Double negative lands
S	Negative land and ER treated cutting edge

9 Chamfer width



ISO mm	ANSI inch
010 BN = 0.10	03 BN = (.003)
015 BN = 0.15	06 BN = (.006)
020 BN = 0.20	08 BN = (.0078)
025 BN = 0.25	08 BN = (.0098)
070 BN = 0.70	30 BN = (.030)
150 BN = 1.50	60 BN = (.060)
200 BN = 2.00	80 BN = (.080)

10 Chamfer angle, degrees



15 GB = 15°	30 GB = 30°
20 GB = 20°	35 GB = 35°
25 GB = 25°	

11 Hand of insert

Inserts designed solely for machining in left or right direction are indicated as below.

R	Right hand design
L	Left hand design

12 Insert Type (CBN)

To allow a variety of machining demands to be met, several types of inserts comprising CBN and PCD is manufactured. To easy identify the different types Sandvik Coromant uses a letter to denote the variants.

A CBN, Multi Corner Inserts
- Fully indexable
- CBN top to bottom of the carbide carrier corners

B CBN, Multi Corner Inserts
- Fully indexable
- CBN brazed to the top and bottom of the carbide carrier corners.

E CBN, Single tip inserts
- Non-indexable
- CBN brazed to the top of one of the carbide carrier corners

F CBN, Multi tip inserts
- Indexable
- CBN brazed to each corner of the carbide carrier

D CBN, Full top inserts
- Indexable
- CBN sintered to the complete top surface of the carbide carrier

M CBN, Solid inserts
- Fully indexable
- Complete insert mode from CBN

13 Wiper Geometry

Our unique Wiper and Xcel technologies can be used to boost productivity and generate superior surface finish.

WG Wiper geometry for general purpose machining
Allows high feed rates in HPT
Suitable for finish machining of GCI

WH Wiper geometry optimized for HPT
Low cutting forces for superior surface finish
Designed for peak performance at HPT finishing feed rates

Xcel XA Allows the use of higher feed rates than other wiper geometries
Maintains surface finish

Fig. No. 4.4(b) Insert Code Key

4.4 SELECTED INSERT KEY CODE DESCRIPTION

C	Insert Shape	Rhombic 80^0
N	Insert Clearance Angle	0^0
G	Tolerances	+/- 0.13mm
A	Insert Type	Negative Basic-Shape Insert
12	Insert Size	Cutting Edge Length in mm
04	Insert Thickness	4.76 mm
08	Nose Radius	0.8 mm
S	Cutting Edge Condition	Negative Land & ER Treated Cutting Edge
010	Chamfer Width	0.10 mm
30	Chamfer Angle	30 Deg.
A	Insert Type	-cBN Multi Corner Inserts -Fully Indexable -Top to Bottom of the Carbide Carrier Corners
7025	Coating Type	Uncoated

CHAPTER 5

EQUIPMENTS, SPECIFICATIONS AND PROCESS

5.1 CNC TURNING CENTRE

Computer-based software tools are used in computer-aided manufacturing to help engineers and machinists produce or prototype product components. Utilizing computer assisted design software, physical models can be produced using CAM, a programming tool. A software package's planned components are translated into physical objects through CAM. Computer numerical control (CNC) technology was developed from the software-based machine tool control approach known as Computer numerical technology. CNC can be used to manage any process that can be represented as a series of motions and switching operations. Alphanumeric instructions are input to control these movements and switching operations. Some of the key characteristics of CNC are unlimited muscular power, unattended operation, independent axis controlled by software, streamlined generic tooling even for the most complex jobs, and accurate construction.

Fig. No. 5.1 HMT Stallion 100 S Turning machine.

5.1.1 Equipment Specification

- Type of bed - Inclined at 45 Deg.
- Swing over bed - 400 mm.
- Max. turning dia. Over cross slide - 200 mm.
- Max. turning dia. Of chucking job - 200 mm.
- Max. turning length - 410 mm.
- Max. chuck size - 200 mm.
- Spindle speed range - 30-3500 RPM.
- Type of spindle drive - AC Variable speed drive.
- Longitudinal feed range - 1-5000mm/min.
- Longitudinal feed rapid traverse - 12M/min.
- Longitudinal stroke - 455 mm.
- Longitudinal type of drive - AC Servo.
- Cross feed range - 1-5000mm/min.
- Cross feed rapid traverse - 12 M/min.
- Cross slide stroke - 155mm.
- Cross feed type of drive - AC Servo.
- Tail stock spindle dia. - 70mm.
- Spindle stroke - 120mm (hyd.).
- Spindle taper - MT 3.
- Turret type - Standard wedge lock type.
- No. of tools - 8.
- Turret indexing position - 8 Bi directional random.
- Turret activation - Hydraulic.

- Turning tool shank size - 20X20 mm.
- Max. boring bar size - 32 mm.
- CNC System - FANUC OIMATE-TB.
- Accuracy (x-axis) / (z-axis) - (0.008mm / 100mm.)/ (0.015mm / 300mm.)
- Repeatability (x-axis/z-axis) - +/- 0.002 mm.

5.1.2 Hard Turning Operation Part Programming

The basic material, EN-31 (OHNS), has an initial hardness of 35 HRC and has been further hardened to 65 HRC for the purpose of hard turning. A total of 5 specimens with the numbers 1, 2, 3, 4, and 5 were made, each measuring 75 mm in length and 38 mm in diameter. For the experiment, the length is taken into account with a 40 mm machining length. Only turning operations are handled by the part programming. Each time, the diameter is decreased based on the orthogonal array's set cut depth. Skin must be removed prior to heat treatment in order to prevent the buildup of any debris or scale. This will make it easier to see any surface flaws and make it possible to achieve uniformity. This will make it easier to see any surface flaws and enable the specimen to have a uniform hardness. The specimen is shown in Fig. No. 10 with the skin removed.

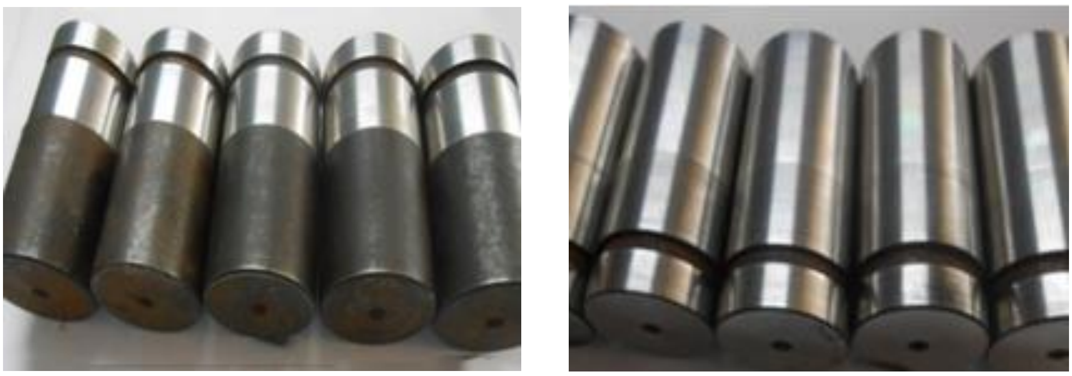


Fig. No. 5.2(a) and 5.2(b) Specimen undergone skin removal.

5.1.2 Part programming for turning operation (Typical)

N5 G54;

N10 G40;

N15 G92 S2500;

N20 M83;

N25 G00 X300 Z100;

N30 T0303;

N35 G96 M04 S200;

N40 G00 X50 Z3 M08;

N45 G01 X34.8 F0.5;

N50 Z-41.5 F0.1;

N55 X38;

N60 G00 X300 Z100 T00;

N65 M30;

5.1.3 Preparatory function description

(G Functions)

G00 - Positioning rapid feed.

G01 - Linear interpolation.

G40 - Cutter radius composition cancel.

G54 - Selection of work coordinate system.

G92 - Maximum spindle speed.

G96 - Constant surface speed control.

(M Functions)

M04 - Spindle Counter clockwise.

M30 - End of program and rewind.

M83 - Step mode tool change cycle.

(Special Functions)

S200 - Spindle speed 200

T00 - Tool function

T0303 - Tool number.

5.2 HEAT TREATEMENT PROCESS

In order to meet the requirements of the experiment, heat treatment of the work piece is used to raise the hardness of the base material of the specimen from 35 HRC to 65 HRC. Skin from the original specimen is removed before to heat treatment to guarantee homogenised hardness. For holding purposes during the heat treatment procedure, a groove is present on the specimen's chucking end. The heat treatment operation involved the following steps.

5.2.1 Preheating Operation

Before beginning the heat treatment, the specimen is heated in an oven to release the contained moisture contents. In a preheating oven, the preheating is done for one hour at 450^0C.

Fig. No. 5.3(a) and 5.3(b) Preheating Oven.

5.2.2 Heat Treatment Operation

The preheated sample should be loaded into a salt bath that is kept at a temperature of 850^{0}C and submerged completely for 20 minutes. The holding period is determined by the size and shape of the handled specimen, and the treatment temperature is above the eutectoid temperature of 727^{0}C. Coils made of electricity are used to heat the bath. In a salt bath, 1000^{0}C natural salt that has reached a molten state is used for heat treatment. 90% dehydrated sodium chloride, barium chloride, and traces of sodium cyanide are the major ingredients of salt bath solutions. Transfer the specimen for the quenching process after 20 minutes of soaking.

Fig. No. 5.4(a) and 5.4 (b) Salt baths for heat treatment.

5.2.3 Quenching

The alloy composition and the rate of cooling or quenching on the hardness are both influenced by the previous treatment of hardenability. The rate of heat energy extraction, which is a function of the quenching medium in contact with the specimen surface, as well as specimen size and geometry, all affect how quickly a specimen cools. The oil more efficient among the three fundamental types of quenching medium such as water, air, or oil. Thermoquench 50 is the quenching oil used in this case. The specimen is moved for washing after it reaches room temperature.

Fig. No. 5.5 Quenching Basin

5.2.4 Washing

Washing is done to get rid of dirt and leftover quenching oil from the specimen's surface. For this, high-pressure water jets are employed.

Fig. No. 5.6 Washing Area

5.2.5 Stress Releiving

Subcritical annealing which removes any remaining stress from intensive machining or other heat-treating procedures. Typically, it is performed below the lower critical line of temperature. In this instance, the specimen is held for an hour in a bake oven set at 200^0C to release any residual stress that was created during the heat treatment.

Fig. No. 5.7 Oven for Stress reliving.

5.2.6 Hardness Testing

The Rockwell hardness testing machine was used to measure obtained hardness levels after the specimen was taken out of the oven and allowed to cool to room temperature. The average Rockwell hardness value on the C scale for the treated specimen is found to be between 64 and 65 HRC. Additionally, the specimen's hardness was confirmed in order to maintain its value within the hard turn machining limitations before each machining operation. Every time, it was discovered that the amount of hardness was within accepted limits. It is made sure that the hardness measurement point does not coincide with roughness inspection.

5.3 TEMPERATURE MEASUREMENT

An infrared digital non-contact thermometer is used to measure the temperature at the tool-workpiece interface during the turning operation. This is accomplished with a professional non-contact infrared thermometer of HTC MTX-2. This device is capable of quickly, easily, and accurately reading temperatures. It is possible to detect the surface temperature of challenging-to-reach items using non-contact technologies without harming those objects.

Fig. No. 5.8(a) and 5.8(b) HTC Infrared Thermometer.

5.3.1 Specifications

Range	-	-50^0C to 550^0C.
Accuracy	-	+/- 2%
Resolution	-	0.1^0C
Operating Temperature	-	0^0C to 50^0C
Laser	-	Diode Laser

Fig. No. 5.9 Performing Temperature measurements.

5.3.2 Operations

Hold the metre by the handle grip and direct it toward the surface to be measured to complete the procedure. When the metre is turned on, pull and hold the trigger until the scan symbol appears and the testing starts. On the LCD Screen, the surface temperature under test will be shown. Release the trigger, and the reading will hold for a few seconds while the hold indicator is visible. After 20 seconds, the metre will automatically turn off. The principle which an optical sensor works is that it can emit, reflect, and transmit energy. This energy is then captured on a detector, converted into a temperature reading by electronics, and shown on an LED screen. To achieve an accurate reading, the metre needs to be placed closer to the the target item.

5.4 SURFACE ROUGHNESS MEASUREMENT

Mitutoyo's SURFTEST SJ-410 portable surface roughness tester is the tool used to measure surfaces. Surface roughness measurements were taken at three different points on the work piece for a probe movement of 25mm, and the average value was utilised for the study. The waviness and finely stepped features will be precisely measured by the stylus as it moves across the surface to be measured. A basic column stand is used to install and adjust the detector so that it is at the proper height for the object being measured. A touch screen display with colour graphics may be used to see the output. It is also possible to use the provision for a graphical printout or the measurement and portal link to the computer.

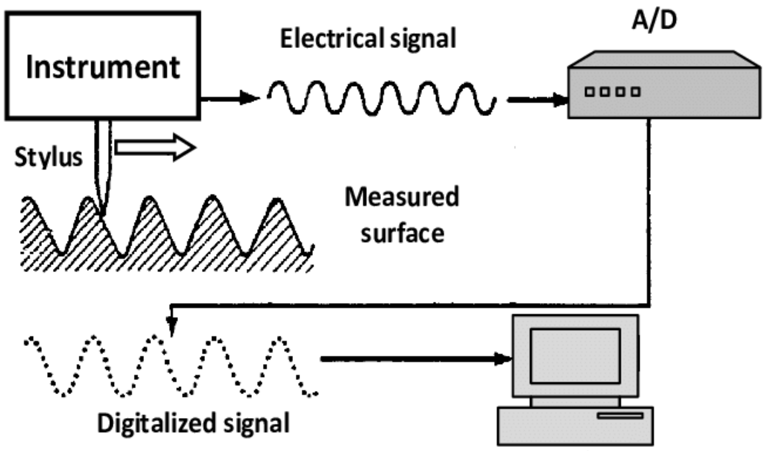


Fig. No. 5.10 Surface roughness detectors and stylus movement.

In this experiment, the analysis was done on the Ra (Arithmetic Mean of Roughness), Rq (Mean Square of Roughness), and Rz (Maximum Height). A "V" block is used to correctly hold the measurement sample on the base of the stand. The column adjustment knob provides the initial pressure between the specimen and the stylus probe, while the detector's height adjustment knob allows for fine tuning.

Fig. No. 5.11 Mitutoyo SURFTEST SJ-410

The output screen display panel allows for the selection of the pressure indicator. Now turn on the touch screen's start indicator so that the stylus can scroll through the values and travel back and forth along the specimen. If required, a printout of the results can also be made. The readings were recorded, and the identical process was used for all 17 tests. Before taking a measurement, it is crucial to make sure the surface is free of dust and dirt. Three sets of values were taken for each specimen, and the average value was used for analysis.

Fig. No. 5.12 Performing surface roughness measurement.

5.4.1 Specifications

Measuring Range	-	25mm (X axis).
Detector unit	-	8µm to 2400µm
Drive unit speed	-	0.5 to 5mm/min
Fine height adjustment	-	10 mm
Tilt adjustment	-	+/- 1.5 Deg.
Resolution	-	0.01- 0.0001mm

CHAPTER 6

THEORETICAL ANALYSIS

6.1 INTRODUCTION

The data that were gathered during the experiment serve as the foundation for the theoretical analysis. The analysis's goal is to look into how cutting parameters affect hard turning. The values were based on cutting speed, feed rate, and cut depth; affecting factors included surface roughness, material removal rate, and temperature fluctuation at the tool-to-workpiece interface. The real numbers were gathered, and with the use of regression analysis, variance response analysis, and generating defining factors.

6.2 CUTTING CONDITION AND PROCEDURE

Three levels of cutting parameters were chosen based on the cutting tool's permitted range of cutting speed, feed, and depth of cut.

Table No. 6.1 Selected cutting parameters

Factors	Level 1	Level 2	Level 3
Cutting speed (mm/min)	100	150	200
Feed (mm/rev)	0.05	0.10	0.15
DOC (mm)	0.1	0.2	0.3

6.2.1 Mathematical Model

Box-Behnken designs in statistics are experimental designs for the response surface methodology that were created in 1960 by George E. P. Box and Donald Behnken. Due to the absence of an embedded factorial or fractional factorial design, the Box-Behnken design is an independent quadratic design. The treatment combinations in this design are located in the middle, on the edges, and in the exact centre of the process space. These designs require three layers of each factor and are rotatable (or nearly rotatable). Compared to the central composite designs, the designs have a limited capacity for orthogonal blocking.

- Each independent variable, or factor, is assigned to one of three equally spaced values, which are often coded as 1, 0, or +1. (The objective requires at least three levels.)
- A quadratic model, or one with squared terms, products of two components, linear terms, and an intercept, should be fit by the design.
- There should be an acceptable ratio between the number of experimental points and the number of coefficients in the quadratic model (in fact, their designs kept in the range of 1.5 to 2.6).
- The estimation variance should mostly rely on the distance from the centre (which is precisely the case for designs with 4 and 7 components) and should not significantly fluctuate inside the smallest (hyper)cube containing the experimental sites.

Table No. 6.2 Design of Experiments generated on Design Xpert Software

Run	Factor 1 A:speed m/min	Factor 2 B:FEED mm/rev	Factor 3 C:DEPTH OF CUT mm
1	200	0.1	0.3
2	150	0.1	0.2
3	100	0.1	0.3
4	150	0.05	0.3
5	200	0.15	0.2
6	150	0.05	0.1
7	200	0.05	0.2
8	100	0.15	0.2
9	100	0.1	0.1
10	100	0.05	0.2
11	150	0.15	0.1
12	200	0.1	0.1
13	150	0.15	0.3

6.2.2 Regression Analysis

Francis Galton used the phrase "regression analysis" in the late nineteenth century in reference to his research on the correlation between father's height and son's height. After gathering the data, the least squares method was utilised to get the response relation needed for the study. The anticipated height of the son was pulled back toward the mean;

Galton selected the term regression line since regression denotes a coming or going back. Regression effect is the name given to the phenomena of being drawn back towards the mean, which has been seen in many other circumstances.

Predictions are frequently the major goal of statistical research, especially based on mathematical formulae. Usually, such predictions require a formula to be found which relates dependent variable to one or more independent variables. Regression analysis is a method used for estimating unknown values of one variable corresponding to known values of another variable. Based on the variables data's and relationship a plot is generated which is called scatter diagram. If the scatter diagram indicates some relationship between the two variables, then the dots of the scatter diagram will be concentrated round a curve. The regression curve is the name of this curve.. When the curve is a straight line, it is called a line of regression.

The decision making process for a hypothesis test is based on the p-value, which indicates the probability of falsely rejecting the null hypothesis when it is actual.

- If the p-value is less than or equal to a predetermined significant level (also known as alpha or α), then you reject the null hypothesis and claim support for the alternative hypothesis.
- If the p-value is greater than α, then you fail to reject the null hypothesis and cannot claim support for the alternative hypothesis.

Here we are considering two ways of generalizing the regression model. The first method is to employ a nonlinear function in place of the regression function, and the second is to use a regression function that uses several independent variables. A statistical method called simple regression analysis is used to calculate the associations between one independent variable and one dependent variable. Simple regression analysis includes linear, quadratic, exponential, logarithmic, sigmoid, etc., on the basis of the functional model. Multiple regression analysis can be utilised when there are two or more independent variables and one dependent variable. This test is used also when there is an interaction between two independent variables.

After fitting a regression function of the chosen form to the given data, it is important to have the methods available for making inferences about the parameters of the chosen model. It is important to assess the validity of the chosen model before initiating the analysis. Therefore based on the primarily graphical analysis of the residuals, checking on the aptness of the fitted model is carried out.

In this experiment respond relations were generated using regression analysis with the aid of Design Xpert software. The slope of the regression line is called the coefficient of regression. It represents the change in the value of the dependent variable corresponding to a unit change in the value of the independent variable. Example; b_{xy}, denotes the change in the value of x corresponding to a unit change in the value of y.

6.2.3 Regression Analysis: Ra versus (SPEED, FEED, DEPTH OF CUT)

This is based on the data's obtained from Table No. 6.3 and the analysis is in accordance with Design Xpert software. The experiment is performed with a confidence interval of 95%, which relives a level of significance α as 0.05. The variables are the cutting speed, feed and depth of cut and the output is the roughness value R_a. Relation so obtained with the coefficients of the variables is called respond relation.

Regression Equation R_a = +0.026308-0.000190SPEED+4.64250FEED-0.113750DEPTHOFCUT

Table No. 6.3 Values Obtained on R_a

EXP. NO	SPEED m/min	FEED mm/rev	DEPTH OF CUT mm	SURFACE ROUGHNESS	
				R_a(μm)	AVG R_a(μm)
1	200	0.10	0.10	.378	.377
				.370	
				.385	
2	200	0.05	0.20	.276	.259
				.240	
				.262	
3	100	0.15	0.20	.688	.680
				.682	
				.670	
4	150	0.05	0.10	.234	.229
				.221	
				.234	
5	150	0.10	0.20	.360	.354
				.352	
				.350	
6	100	0.05	0.20	.230	.211
				.194	
				.210	
7	200	0.15	0.20	.645	.666
				.664	
				.691	
8	150	0.15	0.10	.753	.752
				.749	
				.756	
9	200	0.10	0.30	.395	.388
				.386	
				.383	

10	100	0.10	0.30	.431	.417
				.404	
				.416	
11	150	0.05	0.30	.233	.231
				.225	
				.236	
12	100	0.10	0.10	.463	.458
				.461	
				.450	
13	150	0.15	0.30	.678	.689
				.692	
				.699	

6.2.4 Regression Analysis: Rq versus (SPEED, FEED, DEPTH OF CUT)

In this analysis the variation of R_q with respect to the changes in speed, feed and depth of cut is being carried out and the findings are illustrated in table no. 6.4.This is based on the data's obtained from Table No. 6.4 and the analysis is in accordance with DESIGN XPERT software. The experiment is performed with a confidence interval of 95%, which relieves a level of significance as 0.05.

Regression Equation, R_q = +0.052577-0.000180SPEED+5.16750FEED-0.121250DEPTHOFCUT

Table No. 6.4 Values Obtained on R_q

EXP. NO	SPEED m/min	FEED mm/rev	DEPTH OF CUT mm	SURFACE ROUGHNESS	
				R_q(μm)	AVG R_q(μm)
1	200	0.10	0.10	.450	.456
				.453	
				.467	
2	200	0.05	0.20	.325	.316
				.323	
				.301	
3	100	0.15	0.20	.802	.797
				.790	
				.801	
4	150	0.05	0.10	.284	.289
				.289	
				.295	
5	150	0.10	0.20	.439	.436
				.443	
				.428	
6	100	0.05	0.20	.248	.251
				.244	
				.263	
7	200	0.15	0.20	.763	.756
				.750	
				.756	
8	150	0.15	0.10	.830	.856
				.825	
				.914	
9	200	0.10	0.30	.473	.466
				.462	
				.465	

10	100	0.10	0.30	.478	.481
				.480	
				.486	
11	150	0.05	0.30	.299	.290
				.287	
				.285	
12	100	0.10	0.10	.542	.537
				.533	
				.537	
13	150	0.15	0.30	.795	.804
				.797	
				.820	

6.2.5 Regression Analysis: Rz versus (SPEED, FEED, DEPTH OF CUT)

In this analysis the variation of Rz with respect to the changes in speed, feed and depth of cut is being carried out and the findings are illustrated in table no. 6.5. This is based on the data's obtained from Table No. 6.5 and the analysis is in accordance with Design Xpert software. The experiment is performed with a confidence interval of 95%, which relives a level of significance α as 0.05.

Regression Equation, Rz =+1.18827+0.002670SPEED+12.21250FEED-2.30625DEPTHOFCUT

Table No. 6.5 Values Obtained on R_z

EXP. NO	SPEED m/min	FEED mm/rev	DEPTH OF CUT mm	SURFACE ROUGHNESS	
				R_z(µm)	AVG R_z(µm)
1	200	0.10	0.10	2.208	2.206
				2.226	
				2.185	
2	200	0.05	0.20	1.470	1.447
				1.425	
				1.446	
3	100	0.15	0.20	3.107	3.122
				3.120	
				3.140	
4	150	0.05	0.10	1.386	1.385
				1.370	
				1.400	
5	150	0.10	0.20	1.913	1.932
				2.006	
				1.877	
6	100	0.05	0.20	1.371	1.375
				1.370	
				1.384	
7	200	0.15	0.20	3.225	3.205
				3.191	
				3.200	
8	150	0.15	0.10	3.410	3.614
				3.808	
				3.624	
9	200	0.10	0.30	2.181	2.214
				2.223	

				2.238	
10	100	0.10	0.30	2.367	2.300
				2.290	
				2.244	
11	150	0.05	0.30	1.429	1.451
				1.440	
				1.485	
12	100	0.10	0.10	2.185	2.207
				2.206	
				2.231	
13	150	0.15	0.30	3.265	3.339
				3.369	
				3.385	

6.2.6 Regression Analysis: MRR versus (SPEED, FEED, DEPTH OF CUT)

In this analysis the variation of MRR with respect to the changes in speed, feed and depth of cut is being carried out and the findings are illustrated in table no. 6.6. This is based on the data's obtained from Table No. 6.6 and analysis in accordance with Design Xpert software. The experiment is performed with a confidence interval of 95%, which relives a level of significance α as 0.05.

This is based on the data's obtained from Table No. 6.6 and the analysis is in accordance with Design Xpert software. The experiment is performed with a confidence interval of 95%, which relives a level of significance α as 0.05.

Regression Equation for MRR=+3.61317-0.018025SPEED-2.70000FEED+36.78750DEPTHOFCUT

Table No. 6.6 Values Obtained on MRR

EXP. NO	SPEED m/min	FEED mm/rev	DEPTH OF CUT mm	MRR gram
1	150	0.10	0.20	7.39
2	100	0.15	0.20	8.33
3	200	0.15	0.20	7.88
4	100	0.10	0.30	12.61
5	100	0.10	0.10	4.60

6	150	0.15	0.10	4.52
7	150	0.05	0.10	5.59
8	200	0.10	0.10	3.78
9	100	0.05	0.20	8.86
10	150	0.15	0.30	11.30
11	200	0.10	0.30	10.44
12	150	0.05	0.30	13.57
13	200	0.05	0.20	5.09

6.2.7 Regression Analysis: TEMP. Versus SPEED, FEED, DEPTH OF CUT

In this analysis the variation of TEMP with respect to the changes in speed, feed and depth of cut is being carried out and the findings are illustrated in table no. 6.7. This is based on the data's obtained from Table No. 6.7 and analysis in accordance with Design Xpert software. The experiment is performed with a confidence interval of 95%, which relives a level of significance α as 0.05.

This is based on the data's obtained from Table No. 6.7 and analysis in accordance with Design Xpert software. The experiment is performed with a confidence interval of 95%, which relives a level of significance α as 0.05.

Regression Equation for TEMP=-0.872115+.027150SPEED-165.5000FEED+658.675DEPTHOFCUT+2.5300SPEED.FEED-2.39600SPEED.DEPTHOFCUT-2075.00FEED.DEPTHOFCUT

Table No. 6.7 Values Obtained on Temperature

EXP. NO	SPEED m/min	FEED mm/rev	DEPTH OF CUT mm	TEMPERATURE °C
1	100	0.10	0.30	95.22
2	150	0.05	0.10	57.30
3	150	0.15	0.30	58.50
4	200	0.10	0.30	51.50

5	200	0.15	0.20	77.60
6	150	0.10	0.20	80.30
7	200	0.05	0.20	89.50
8	100	0.10	0.10	51.40
9	150	0.05	0.30	94.90
10	100	0.05	0.20	86.20
11	100	0.15	0.20	49
12	150	0.15	0.10	62.40
13	200	0.10	0.10	55.60

Following are the summary of relationship between various cutting parameters to the output based on the experiment conducted as the response relation using Design Xpert software,

- Regression Equation R_a = +0.026308-0.000190SPEED+4.64250FEED-0.113750DEPTHOFCUT
- Regression Equation, R_q = +0.052577-0.000180SPEED+5.16750FEED-0.121250DEPTHOFCUT
- Regression Equation, Rz =+1.18827+0.002670SPEED+12.21250FEED-2.30625DEPTHOFCUT

- Regression Equation for MRR=+3.61317-0.018025SPEED-2.70000FEED+36.78750DEPTHOFCUT
- Regression Equation for TEMP=-0.872115+.027150SPEED-165.5000FEED+658.675DEPTHOFCUT+2.5300SPEED.FEED-2.39600SPEED.DEPTHOFCUT-2075.00FEED.DEPTHOFCUT

6.3 ANOVA- ANALYSIS OF VARIANCE

Analysis of variance is one of the most powerful techniques in statistical analysis and was developed by R A. Fisher. It is also called the F-Test. Analysis of variance is a technique that will enable to test for the significance of the differences among more than two sample means. Using analysis of variance, we will be able to make inferences about whether our samples are drawn from populations having the same mean. The ANOVA problem is referred to variously as a single factor or one-way, two-way ANOVA etc, involves the analysis either of data sampled from more than two numerical populations or of data from experiments in which more than two treatments have been used. The characteristic that differentiates the treatments or populations from one another is called the factor under study and the different treatments or populations are referred to as the level of the factors. The null hypothesis that we are going to test is based on the assumption that there is no significant difference among the means of different population. The alternate hypothesis will state that at least two means are different from each other.

In order to accept the null hypothesis, all means must be equal. Even if one means is not equal to the other, then we cannot accept the null hypothesis. The simultaneous comparison of several population means is called Analysis of Variance or ANOVA. It is nothing but an arithmetical procedure used to express the total variation of data as the sum of its non-negative components. Moreover it is useful to determine whether there is a significant difference between class means in view of variability within the separate classes. It is achieved by separating the total variation in the whole number of observation into two sections namely (i) the variance between the classes (ii) the variance arising from individual differences within the classes.

The methodology of ANOVA is based on following assumptions;

- Each sample of size is drawn randomly and each sample is independent of the other samples.
- The populations are normally distributed.
- The populations from which the samples are drawn have equal variances.

In F-Test, R A. Fisher determined that the difference between the $\sigma^2_{(between)}$ and $\sigma^2_{(within)}$ values could be expressed as the ratio to be designated as the F-value, so that

$$F = (\sigma^2_{(between)} / \sigma^2_{(within)})$$

If the population means are exactly the same, the value of F- value will be equal to 1. However because of sampling errors and other variations, some disparity between the two values will be there, even when the null hypothesis is true. The extent of disparity between the two variances and consequently, the value of F, will influence our decision on whether to accept or reject the null hypothesis.

The F distribution being a family of curves, each curve reflects the degree of freedom relative to both $\sigma^2_{(between)}$ and $\sigma^2_{(within).}$ This means that the degree of freedom is associated both with the numerator as well as the denominator of the F-ratio.

- The numerator, since the variance between sample σ^2, comes from many samples and if there are k number of samples, then the degree of freedom, associated with the numerator would be (k-1).

- The denominator, mean variance of the variances of k samples and since each variance in each sample is associated with the size of the sample(n), then the degree of freedom associated with each sample would be (n-1).

Hence, the total degree of freedom would be the sum of degree of freedom of k samples or

$d_f = k(n-1)$, when each sample is of size n.

The steps involved in the analysis of variance are,

- Determine one estimate of the population variance from the variance among the sample means.
- Determine a second estimate of the population variance from the variance within the sample.
- Compare these two estimates. If they are approximately equal in value, accept the null hypothesis.

Data's shall be collected based on the levels of treatments and the number of replication at each level of factors. The factors can be either fixed or random depending on the selection of certainty or randomness. The partitioning of the total variability is presented as follows;

1. Calculate the degree of freedom.
2. Find the Sum of Squares (SS) by applying the Correction Factor (CF).
3. Hence calculate Sum of Squares of Treatment (SST), Total Sum of Squares (TSS) and Error Sum of Squares (SSE) such that, TSS=SST+SSE.
4. Now Mean Sum of Square (MSS) = SST/CF, for treatment and error.
5. Calculate F Ratio and compare it with the table value to arrive at the significant parameter affecting the output.

6.3.1 Anova for R_a versus SPEED, FEED, DEPTH OF CUT

The following are the main features of the F-distribution:

• Unlike the normal distribution, the curve's form varies as the degree of freedom changes. Since the distribution is continuous, the value of F cannot be negative.

• The F distribution's curve is positively skewed.

• F's value increases favourably from 0 to infinity.

Table No. 6.8 Anova for R_a

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	0.4328	3	0.1443	55.19	< 0.0001	significant
A-speed	0.0007	1	0.0007	0.2762	0.6119	
B-FEED	0.4311	1	0.4311	164.89	< 0.0001	
C-DEPTH OF CUT	0.0010	1	0.0010	0.3960	0.5448	
Residual	0.0235	9	0.0026			
Cor Total	0.4563	12				

Three levels of experiments were taken into consideration for the three factors under consideration in order to determine the actual values of Ra. In order to identify the important element that influences the output, measurements were made at three separate places, and the average value of those measurements was taken into consideration for the study. The analysis is being done with Design Xpert software. It is clear from the results that the feed rate impacts the arithmetic mean of surface roughness in a considerable way (Ra). Analytical comparisons are made between the values that can be acquired realistically and the response connection that can be found using regression analysis. Physical and analytical data are compared in order to demonstrate the validity of the thesis experimentation.

Table No. 6.9 Values Obtained on R_a

EXP. NO	SPEED m/min	FEED mm/rev	DEPTH OF CUT mm	SURFACE ROUGHNESS	
				R_a(µm)	AVG R_a(µm)
1	200	0.10	0.10	.378	.377
				.370	
				.385	
2	200	0.05	0.20	.276	.259
				.240	
				.262	
3	100	0.15	0.20	.688	.680
				.682	
				.670	
4	150	0.05	0.10	.234	.229
				.221	
				.234	
5	150	0.10	0.20	.360	.354
				.352	
				.350	
6	100	0.05	0.20	.230	.211
				.194	
				.210	
7	200	0.15	0.20	.645	.666
				.664	
				.691	
8	150	0.15	0.10	.753	.752
				.749	
				.756	
9	200	0.10	0.30	.395	.388
				.386	

				.383	
10	100	0.10	0.30	.431	.417
				.404	
				.416	
11	150	0.05	0.30	.233	.231
				.225	
				.236	
12	100	0.10	0.10	.463	.458
				.461	
				.450	
13	150	0.15	0.30	.678	.689
				.692	
				.699	

6.3.2 Anova for R_q versus SPEED, FEED, DEPTH OF CUT

Table No. 6.10 Anova for R_q

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	3.55	3	1.18	3.31	0.0710	not significant
A-speed	0.1426	1	0.1426	0.3991	0.5432	
B-FEED	2.98	1	2.98	8.35	0.0179	
C-DEPTH OF CUT	0.4255	1	0.4255	1.19	0.3034	
Residual	3.21	9	0.3572			
Cor Total	6.77	12				

Three levels of experiments were taken into consideration for the three factors under consideration in order to determine the actual values of Rq. In order to identify the important element that influences the output, measurements were made at three separate places, and the average value of those measurements was taken into consideration for the study. The analysis is being done with Design Xpert software. It is clear from the results that the feed rate impacts the arithmetic mean of surface roughness in a considerable way (Rq). Analytical comparisons are made between the values that can be acquired realistically and the response connection that can be found using regression analysis. Physical and analytical data are compared in order to demonstrate the validity of the thesis experimentation.

Table No. 6.11 Values Obtained on R_q

EXP. NO	SPEED m/min	FEED mm/rev	DEPTH OF CUT mm	SURFACE ROUGHNESS	
				R_q(μm)	AVG R_q(μm)
1	200	0.10	0.10	.450	.456
				.453	
				.467	
2	200	0.05	0.20	.325	.316
				.323	
				.301	
3	100	0.15	0.20	.802	.797
				.790	
				.801	
4	150	0.05	0.10	.284	.289
				.289	
				.295	
5	150	0.10	0.20	.439	.436
				.443	
				.428	
6	100	0.05	0.20	.248	.251
				.244	
				.263	
7	200	0.15	0.20	.763	.756
				.750	

				.756	
8	150	0.15	0.10	.830	.856
				.825	
				.914	
9	200	0.10	0.30	.473	.466
				.462	
				.465	
10	100	0.10	0.30	.478	.481
				.480	
				.486	
11	150	0.05	0.30	.299	.290
				.287	
				.285	
12	100	0.10	0.10	.542	.537
				.533	
				.537	
13	150	0.15	0.30	.795	.804
				.797	
				.820	

6.3.3 Anova for R_z versus SPEED, FEED, DEPTH OF CUT

Table No. 6.12 Anova for R_z

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	3.55	3	1.18	3.31	0.0710	not significant
A-speed	0.1426	1	0.1426	0.3991	0.5432	
B-FEED	2.98	1	2.98	8.35	0.0179	
C-DEPTH OF CUT	0.4255	1	0.4255	1.19	0.3034	
Residual	3.21	9	0.3572			
Cor Total	6.77	12				

Three levels of experiments were taken into consideration for the three factors under consideration in order to determine the actual values of Ra. influences the output, measurements were made at three separate places, and the average value of those measurements was taken into consideration for the study.

Table No. 6.13 Values Obtained on R_z

EXP. NO	SPEED m/min	FEED mm/rev	DEPTH OF CUT mm	SURFACE ROUGHNESS	
				R_z(μm)	AVG R_z(μm)
1	200	0.10	0.10	2.208	2.206
				2.226	
				2.185	
2	200	0.05	0.20	1.470	1.447
				1.425	
				1.446	
3	100	0.15	0.20	3.107	3.122
				3.120	
				3.140	
4	150	0.05	0.10	1.386	1.385
				1.370	
				1.400	
5	150	0.10	0.20	1.913	1.932
				2.006	
				1.877	
6	100	0.05	0.20	1.371	1.375
				1.370	
				1.384	
7	200	0.15	0.20	3.225	3.205
				3.191	
				3.200	

8	150	0.15	0.10	3.410	3.614
				3.808	
				3.624	
9	200	0.10	0.30	2.181	2.214
				2.223	
				2.238	
10	100	0.10	0.30	2.367	2.300
				2.290	
				2.244	
11	150	0.05	0.30	1.429	1.451
				1.440	
				1.485	
12	100	0.10	0.10	2.185	2.207
				2.206	
				2.231	
13	150	0.15	0.30	3.265	3.339
				3.369	
				3.385	

The analysis is being done with Design Xpert software. It is clear from the results that the feed rate impacts the arithmetic mean of surface roughness in a considerable way (Ra). Analytical comparisons are made between the values that can be acquired realistically and the response connection that can be found using regression analysis. Physical and analytical data are compared in order to demonstrate the validity of the thesis experimentation.

6.3.4 Anova for MRR versus SPEED, FEED, DEPTH OF CUT

Table No. 6.14 Anova for MRR

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	114.91	3	38.30	30.78	< 0.0001	significant
A-speed	6.50	1	6.50	5.22	0.0482	
B-FEED	0.1458	1	0.1458	0.1171	0.7400	
C-DEPTH OF CUT	108.27	1	108.27	86.99	< 0.0001	
Residual	11.20	9	1.24			
Cor Total	126.11	12				

Table No. 6.15 Values Obtained on MRR

EXP. NO	SPEED m/min	FEED mm/rev	DEPTH OF CUT mm	MRR gram
1	150	0.10	0.20	7.39
2	100	0.15	0.20	8.33
3	200	0.15	0.20	7.88
4	100	0.10	0.30	12.61
5	100	0.10	0.10	4.60
6	150	0.15	0.10	4.52
7	150	0.05	0.10	5.59
8	200	0.10	0.10	3.78

9	100	0.05	0.20	8.86
10	150	0.15	0.30	11.30
11	200	0.10	0.30	10.44
12	150	0.05	0.30	13.57
13	200	0.05	0.20	5.09

To determine the physical values of MRR for the three factors taken into consideration. Throughout the experiment, measurements were obtained, and the average of three measurements was used in the analysis to identify the key element that affected the outcome. The analysis is being done with Design Xpert software. The results clearly show that the depth of cut factor has a substantial impact on MRR. Analytical comparisons are made between the values that can be acquired realistically and the response connection that can be found using regression analysis. Physical and analytical data are compared in order to demonstrate the validity of the thesis experimentation. Later in the thesis, this is illustrated, and the consistency of the values is clearly demonstrated. MRR values in the machining process are based on the variation in the work piece's weight before and after the machining procedure. In addition, the chips are gathered and weighed in an electronic weighing equipment to guarantee the correctness of the results. For the analysis, it is being cross-checked and verified. This method was used to tabulate the results during the experiment.

6.3.5 Anova for TEMPERATURE versus SPEED, FEED, DEPTH OF CUT

Table No. 6.16 Anova for Temperature

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	2653.76	6	442.29	2.42	0.1532	not significant
A-speed	7.26	1	7.26	0.0397	0.8486	
B-FEED	808.02	1	808.02	4.42	0.0802	
C-DEPTH OF CUT	673.81	1	673.81	3.69	0.1033	
AB	160.02	1	160.02	0.8755	0.3856	
AC	574.08	1	574.08	3.14	0.1267	
BC	430.56	1	430.56	2.36	0.1757	
Residual	1096.69	6	182.78			
Cor Total	3750.44	12				

Table No. 6.17 Values Obtained on Temperature

EXP. NO	SPEED m/min	FEED mm/rev	DEPTH OF CUT mm	TEMPERATURE °C
1	100	0.10	0.30	95.22
2	150	0.05	0.10	57.30
3	150	0.15	0.30	58.50
4	200	0.10	0.30	51.50
5	200	0.15	0.20	77.60

6	150	0.10	0.20	80.30
7	200	0.05	0.20	89.50
8	100	0.10	0.10	51.40
9	150	0.05	0.30	94.90
10	100	0.05	0.20	86.20
11	100	0.15	0.20	49
12	150	0.15	0.10	62.40
13	200	0.10	0.10	55.60

Three levels of experiments were taken into consideration to determine the physical values of temperature for each of the three factors. Measurements were made at the point where the cutting tool interfered with the work piece, and the highest value obtained from those measurements was used in the analysis to identify the important factor influencing the output. The analysis is being done with Design Xpert software. The results clearly show that the feed rate impacts the highest temperature generated during machining in a considerable way. Analytically, the values that are achieved in practise are contrasted with the regression analysis's response relation. Physical and analytical data are compared in order to demonstrate the validity of the thesis experimentation. Later in the thesis, this is illustrated, and the consistency of values is clearly demonstrated. Major influences on tool performance and work piece shape or characteristics have been identified as cutting temperature and heat produced at the tool-chip contact during high speed machining processes. However, the heat generated in the cutting zone rises as more material is removed in a shorter amount of time. Almost all of the energy used to cut metal is converted into heat near the tool's cutting edge. The concentration of heat in the region of contact can have an impact on the work piece's dimensional precision, alter how well the tool performs, or result in significant tool damage and breakage. Dry cutting is used in the machining process using cBN tool, and interface temperature may be regulated by adjusting the feed rate. The fluctuation in air temperature is not taken into account when conducting experiments.

The procedure can be thought to have equivalent effects if F does not reach the acceptable level of significance. Otherwise, there will be unequal treatment effects.

The major factors impacting the output parameters were confirmed by the aforementioned studies and are summarised as indicated below;

Table No. 6.18 Significant Factors in ANOVA Analysis

OUTPUT PARAMETER	SIGNIFICANT INPUT
R_a	FEED
R_q	FEED
R_z	FEED
MRR	DEPTH OF CUT
TEMPERATURE	FEED

6.4 Plot for R_a R_q and R_z at .05 mm/rev FEED

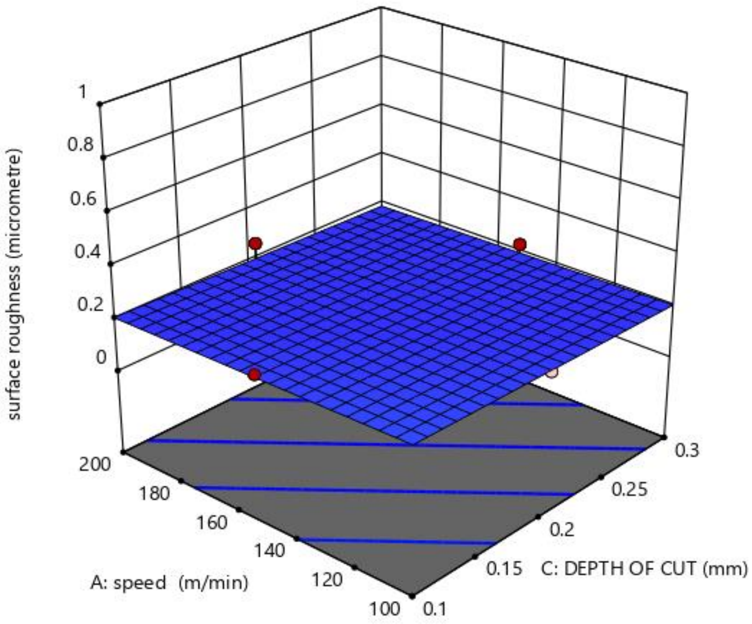


Fig No. 6.1 Plot of R_a

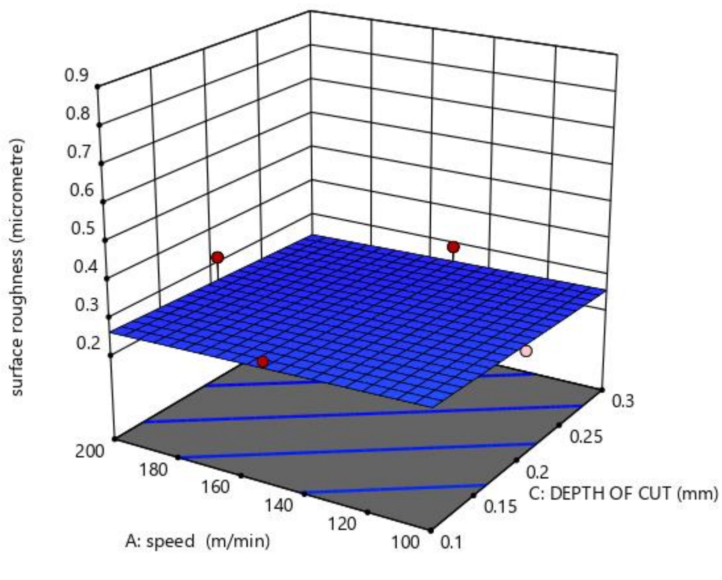


Fig No. 6.2 Plot of R_q

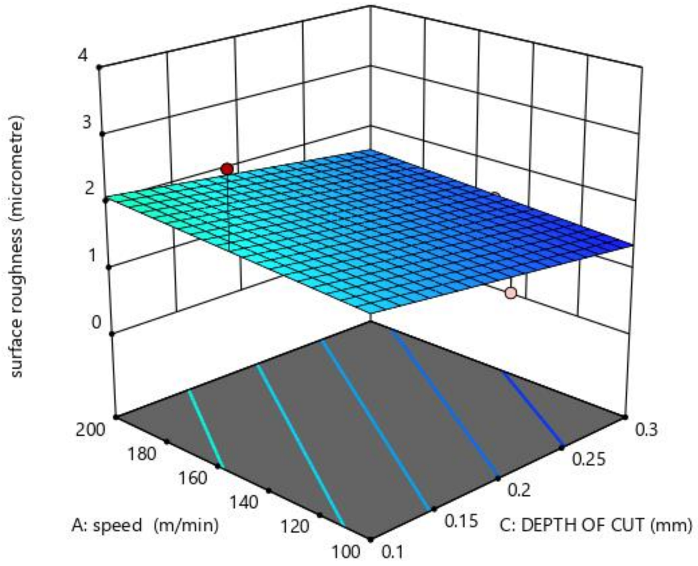


Fig No. 6.3 Plot of R_z

CHAPTER 7

CONFIRMATION ANALYSIS OF THE EXPERIMENT

Confirmation analysis of the experiment determines the closeness of the experimental values to the analytical values obtained through respond relation. The factors which are considered during the machining of hard turning materials are the roughness values Viz; R_a, R_q and R_z, material removal rate (MRR) and tool-work interface temperature. All these factors considered are having the practical values measured through instruments and its competency is evaluated with the values obtained from the respond relation which is generated through regression analysis. The respond relation generated through regression analysis is evolved by utilizing the Design Xpert software.

For any given set of variables during an experiment there exists a direct relation with the output of the experiment which in turn is called the respond relation. This type of relation will provide a mathematical, i.e., an analytical approach to the outcome of the experiment. In this the primary variables are the cutting speed, feed and depth of cut on the 13 sequence of experiments generated by Box Behnken Design. Thus the respond relation gives the outcome of the experiment based on the primary variables. The analytical output of all the experiment were evaluated and is being cross checked with the physical readings for its competency and accuracy of the result. This is achieved by taking the ratio of each experimental to calculated values and vice versa, further taking the average. This will provide confidence of any inaccuracies during measurements during experimentation so that the average value leans towards unity.

Table 8.1 as in general gives following details as per planed experiment;

- Total 13 experiments conducted
- Feed, Speed and Depth of cut are the primary variables.
- The output of the experiment is R_a
- Both experimental and calculated values were charted.
- Confirmation ratio average lean toward unity.

Table No. 7.1: Confirmation chart of R_a

EX NO	C SPEED	FEED	DOC	R_a EXPT.	R_a CALC	R_a EXPT/CALC	R_a CALC/EXPT
1	200	0.10	0.10	.377	.441	.854	1.17
2	200	0.05	0.20	.259	.197	1.32	.760
3	100	0.15	0.20	.680	.680	1	1
4	150	0.05	0.10	.229	.218	1.04	.950
5	150	0.10	0.20	.354	.439	.806	1.24
6	100	0.05	0.20	.211	.216	.976	1.02
7	200	0.15	0.20	.666	.661	1	.990
8	150	0.15	0.10	.752	.682	1.10	.906
9	200	0.10	0.30	.388	.418	.928	1.07
10	100	0.10	0.30	.417	.437	.954	1.04
11	150	0.05	0.30	.231	.195	1.18	.844
12	100	0.10	0.10	.458	.460	.990	1.00
13	150	0.15	0.30	.689	.660	1.04	.957
					AVG	.99	1.09

Even though there are some variations in certain individual values, the average value is close to unity. This provides competency of the conducted experiment with R_a as the output. Similar confirmation experimentation has conducted for the entire output variable with primary variable as cutting speed, feed and depth of cut.

Table No. 7.2: Confirmation chart of R_q

EX NO	C SPEED	FEED	DOC	R_q EXPT.	R_q CALC	R_q EXPT/CALC	R_q CALC/EXPT
1	200	0.10	0.10	.456	.521	.875	1.14
2	200	0.05	0.20	.316	.250	1.26	.791

3	10	0.15	0.20	.797	.785	1.01	.984
4	150	0.05	0.10	.289	.271	1.06	.937
5	150	0.10	0.20	.436	.3518	.841	1.18
6	100	0.05	0.20	.251	.268	.936	1.06
7	200	0.15	0.20	.756	.767	.985	1.01
8	150	0.15	0.10	.856	.788	1.08	.920
9	200	0.10	0.30	.466	.496	.939	1.06
10	100	0.10	0.30	.481	.514	.935	1.06
11	150	0.05	0.30	.290	.247	1.17	.851
12	100	0.10	0.10	.537	.539	.990	1
13	150	0.15	0.30	.804	.764	1.05	.950
					AVG	1	.99

Even though there are some variations in certain individual values, the average value is close to unity. This provides competency of the conducted experiment with R_q as the output. Similar confirmation experimentation has conducted for the entire output variable with primary variable as cutting speed, feed and depth of cut.

Table No. 7.3: Confirmation chart of R_Z

EX NO	C SPEED	FEED	DOC	R_Z EXPT.	R_Z CALC	R_Z EXPT/CALC	R_Z CALC/EXPT
1	200	0.10	0.10	2.206	2.707	.814	1.22
2	200	0.05	0.20	1.447	1.866	.775	1.28
3	10	0.15	0.20	2.122	2.820	.752	1.32
4	150	0.05	0.10	1.385	1.963	.705	1.41
5	150	0.10	0.20	1.932	2.343	.824	1.21
6	100	0.05	0.20	1.375	1.599	.859	1.16
7	200	0.15	0.20	3.205	3.087	1.03	.963
8	150	0.15	0.10	3.614	3.184	1.13	.881
9	200	0.10	0.30	2.214	2.246	.985	1.01
10	100	0.10	0.30	2.300	1.979	1.16	.860
11	150	0.05	0.30	1.451	1.501	.966	1.03
12	100	0.10	0.10	2.207	2.440	.904	1.10
13	150	0.15	0.30	3.339	2.723	1.22	.815
					AVG	.98	1.09

Even though there are some variations in certain individual values, the average value is close to unity. This provides competency of the conducted experiment with R_Z as the output. Similar confirmation experimentation has conducted for the entire output variable with primary variable as cutting speed, feed and depth of cut.

Table No. 7.4: Confirmation chart of MRR

EX NO	C SPEED	FEED	DOC	MRR EXPT.	MRR CALC	MRR EXPT/CALC	MRR CALC/EXPT
1	150	0.10	0.20	7.39	7.99	.924	1.08
2	100	0.15	0.20	8.33	8.76	.950	1.05
3	200	0.15	0.20	7.88	6.96	1.13	.883
4	100	0.10	0.30	12.61	12.57	1	.996
5	100	0.10	0.10	4.60	5.21	.882	1.13
6	150	0.15	0.10	4.52	4.18	1.08	.924
7	150	0.05	0.10	5.59	4.45	1.25	.796
8	200	0.10	0.10	3.78	3.41	1.10	.902
9	100	0.05	0.20	8.86	9.03	.981	1.01
10	150	0.15	0.30	11.30	11.54	.979	1.02
11	200	0.10	0.30	10.44	10.77	.969	1.03
12	150	0.05	0.30	13.57	11.81	1.14	.870
13	200	0.05	0.20	5.09	7.23	.704	1.42
					AVG	1.00	1.00

Even though there are some variations in certain individual values, the average value is close to unity. This provides competency of the conducted experiment with MRR as the output. Similar confirmation experimentation has conducted for the entire output variable with primary variable as cutting speed, feed and depth of cut.

Table No. 7.5: Confirmation chart of Temperature

EX NO	C SPEED	FEED	DOC	TEMP EXPT.	TEMP CALC	TEMP EXPT/CALC	TEMP CALC/EXPT
1	100	0.10	0.30	95.22	92.06	1.03	.966
2	150	0.05	0.10	57.30	60.45	.947	1.05
3	150	0.15	0.30	58.50	75.25	.777	1.28
4	200	0.10	0.30	51.50	58.70	.877	1.13
5	200	0.15	0.20	77.60	65.27	1.18	.841
6	150	0.10	0.20	80.30	69.95	1.14	.871
7	200	0.05	0.20	89.50	72.72	1.23	.812

8	100	0.10	0.10	51.40	49.75	1.03	.967
9	150	0.05	0.30	94.90	99.55	.953	1.04
10	100	0.05	0.20	86.20	87.28	.987	1.01
11	100	0.15	0.20	49	54.53	.898	1.11
12	150	0.15	0.10	62.40	61.10	1.02	.979
13	200	0.10	0.10	55.60	71.80	.774	1.29
					AVG	0.99	1.02

Even though there are some variations in certain individual values, the average value is close to unity. This provides competency of the conducted experiment with TEMP as the output.

A reverse confirmation is done by taking random points from the predicted graph and experiment is done inorder to check whether experimental value and chosen value is same.

Table No.7.6 Confirmation chart of R_a

EXP NO	C.SPEED	FEED	D.O.C	R_a PREDICTED VALUE(P)	EXPERIMENTAL VALUE(E)	P/E
1	100	.05	.30	0.192	0.195	.98
2	200	.15	.30	.834	.829	1.00

Table No.7.7 Confirmation chart of R_q

EXP NO	C.SPEED	FEED	D.O.C	R_q PREDICTED VALUE(P)	R_q EXPERIMENTAL VALUE(E)	P/E
1	100	.05	.30	.239	.239	1
2	200	.15	.30	.960	.962	.99

Table No.7.8 Confirmation chart of R_Z

EXP NO	C.SPEED	FEED	D.O.C	R_Z PREDICTED VALUE(P)	R_Z EXPERIMENTAL VALUE(E)	P/E
1	100	.05	.30	1.212	1.216	.99
2	200	.15	.30	3.501	3.503	.99

Table No.7.9 Confirmation chart of Material Removal Rate

EXP NO	C.SPEED	FEED	D.O.C	MRR PREDICTED VALUE(P)	MRR EXPERIMENTAL VALUE(E)	P/E
1	100	.05	.30	16.13	16.12	1.00
2	200	.15	.30	13.37	13.40	.99

Table No.7.10 Confirmation chart of Temperature

EXP NO	C.SPEED	FEED	D.O.C	TEMP PREDICTED VALUE(P)	TEMP EXPERIMENTAL VALUE(E)	P/E
1	100	.05	.30	91.50	90.10	1.01
2	200	.15	.30	64.90	66.01	.98

From the chart, it is clearly evident that the ratio of predicted and experimental value is leaning towards 1 or close to one. So the validity of the Regression Equation is confirmed.

CHAPTER 8

CHIP MORPHOLOGY

The complexities of chip production in machining operations is caused by the interaction of many mechanical, thermal, and chemical physical phenomena that take place at extremely high strain rates. In order to forecast cutting force and regulate surface integrity, it is important for industry to have a fundamental understanding of these processes. Variation in cutting speed, feed and depth of cut can help in achieving the desired chip form in order to improve the surface integrity and productivity. However, due to the requirements of the machining operations and their influence on tool life, surface polish, and surface integrity, modifying the cutting conditions to break the chip is typically not practical. For study purpose, chip form can be classified into desired and undesired chips. Desired chip form in turning is C-type broken chips and helical broken chips with length ranges from 0.5 inch to 2 inch. While long helical unbroken chips with the length larger than 2 inch and snarled chips are undesired chip forms. Here the four types of chip forms were considered for the analysis. This will make it simpler to choose the settings in accordance with the demand. As a result, the results may be used as a reference for choosing the cutting condition and the necessary surface integrity for the intended application.

Usually in the normal turning operation the chips are mainly classified into continuous chips, segmented chips and chips with built up edges. Out of which the continuous chips drastically affect the surface finish of the work piece. The main reason of this is due to the rubbing of the chip with the finished surfaces. But this type of classification is not found suitable for hard turning operation using cBN cutting tool. Since this is a finish turning operation the proper study of chip form plays an important role. As the normal classification is found not suitable a new mode of approach towards this need to be followed and has to decide on the desireness of the form. For this purpose collected chips during the operation and the form of chips were investigated and the categorization is carried out on table no 9.1. Chips were collected separately for all the 27-experiments and detail investigation has been made based on this and the chips are thus classified into the following categories as listed below;

A - C-Type Broken Chips.

B - Helical broken chips with length ranges from 0.5 inch to 2 inch.

C - Long Helical unbroken chips with length larger than 2 inch.

D - Snarled unbroken chips.

Table No. 9.1 Chip From during hard turning.

EXP.NO.	CUTTING SPEED m/min	FEED mm/rev	DEPTH OF CUT mm	CHIP FORM
1	100	0.10	0.30	D
2	150	0.05	0.10	B
3	150	0.15	0.30	A
4	200	0.10	0.30	D
5	200	0.15	0.20	D
6	150	0.10	0.20	D
7	200	0.05	0.20	D
8	100	0.10	0.10	B
9	150	0.05	0.30	A
10	100	0.05	0.20	C
11	100	0.15	0.20	C
12	150	0.15	0.10	D
13	200	0.10	0.10	D

Fig No. 8.1 Form A-C Type Broken Chips.

Fig No. 8.2 Form B-Helical broken chips of length ranges from 0.5 - 2 inch.

Fig No. 8.3 Form C-Long Helical unbroken chips of length more than 2 inch.

Fig No. 8.4 Form D-Snarled unbroken chips.

Predicted segmentation, recommentation and conclusion for the future research are presented so that chip morphology knowledge will help better understand and model the hard machining process. The chips produced in machining most metals and alloys can be classified diffrently according to their physical appearance and with the variying cutting conditions. Here the classification is carried out in accordance with the mode of chip developed by using cBN cutting tool and the adopted cutting parameters. It has been observed that the overall chip shape evolves as tool wear in machining hardened steels. Besides better understanding toward chip formation mechanisms, the chip morphology can be a good and a convenient indicator of tool wear in hard machining. Also, the knowledge on the chip morphology evolution can improve manufacturing productivity where tool wear and work piece dimentional accuracy need to be closely monitored.

To develop a new cutting process and to reduce time and resource costs, it is necessary to determine optimal ranges for cutting parameters, such as cutting speed, feed and depth of cut. Selection of cutting parameters directly influences the interaction at the tool-chip interface and consequently the chip morphology. This is especially true with the complex tool geometries currently in use on the market. Due to increasing interest in high speed machining and hard turning, investigation of chip formation with high cutting speeds and hard materials have appeared.

CHAPTER 9

EXPERIMENTAL RESULTS

As the part of the thesis work the following investigations were made in understanding the influence of cutting parameters on hard turning as listed below;

- Selection of cutting parameters.
- Development of orthogonal array using Box Behnken.
- Randomization of experiment.
- Specimen preperation for hard turning.
- Selection of turning centre and cutting tool.
- Conducting experiment for achieving,
    - Roughness Values (R_a, R_q and R_z)
    - Tool – Work Piece interface temperature
    - Material Removal Rate (MRR)
- Regression analysis using Design Xpert Software
- ANOVA technique for optimazation using Design Xpert Software
- Confirmation experiment.
- Chip Morphology analysis.

After finalizing the design of experiments the results of the analysis are discussed here with in each sections.

9.1 Regression Analysis

The aim of the regression analysis is to develop respond relation between the dependent variable and the output of the experimental analysis. Based on the input datas following are the generated respond relation with the aid of Design Xpert software,

- Regression Equation R_a = +0.026308-0.000190SPEED+4.64250FEED-0.113750DEPTHOFCUT
- Regression Equation, R_q = +0.052577-0.000180SPEED+5.16750FEED-0.121250DEPTHOFCUT
- Regression Equation, Rz =+1.18827+0.002670SPEED+12.21250FEED-2.30625DEPTHOFCUT
- Regression Equation for MRR=+3.61317-0.018025SPEED-2.70000FEED+36.78750DEPTHOFCUT
- Regression Equation for TEMP=-0.872115+.027150SPEED-165.5000FEED+658.675DEPTHOFCUT+2.5300SPEED.FEED-2.39600SPEED.DEPTHOFCUT-2075.00FEED.DEPTHOFCUT

This respond relation is used to conduct the confirmation experiment such that it will give the consistancy between the physical and analytical value. The confirmation experiment had been conducted and the results were compaired to be proved in the analysis.

9.2 Analysis of Varience (ANOVA)

Analysis of varience were conduted in order to optimize the parameters such that through this analysis the significant parameter that affects the output can be obtained. This analysis were conducted using Design Xpert software and the results of which will provide the significant factor that affect the outcome of the experiment as listed on table 10.1;

Table No. 10.1 Significant Input parameters affecting output.

OUTPUT PARAMETER	SIGNIFICANT INPUT
R_a	FEED
R_q	FEED
R_z	FEED
MRR	DEPTH OF CUT
TEMPERATURE	FEED

With this technique, emphesis can be given on the significant input parameters in order to optimize the hard turning operation. Keeping this as a guideline the productivity can be planned in order to obtain the optimum results. Based on the products requirement priority can be given to those significant input parameters in the production line.

9.3 Confirmation Experiment

Confirmation analysis of the experiment determines the closeness of the experimental values to the analytical values obtained through respond relation. The factors which are considered during the machining of hard turning material are the roughness values Viz; Ra**,** R_q and R_z, material removal rate (MRR) and tool-work interface temperature. All these factors considered are having the physical values measured through instruments and its competency is evaluated with the values obtained from the respond relation which is generated through regression analysis. Even though there are minor variations in the individual value the average values shows a leanness towards unity and which proves the confirmation of experiment.

9.4 Chip Morphology

In chip morphology variation in the chip form were analysed at various combinations of cutting parameters. This is conducted by collecting the chips produced in each experiment and classifying into different predetermined chip forms.

CHAPTER 10

CONCLUSION

The purpose of the thesis is to perform a detailed investigation on the influence of cutting parameter on hard turning operation. In conjection with this a design of experiment were developed with the aid of Box Behnken technique, regression analysis and analysis of varience technique. In order for perform this the aid of software such as Design Xpert were utilized for optimization an surface profile generation respectively. The confirmation of experiment were conducted in order to assess the competency of the experiment with the help of respond relation developed using regression analysis. While performing chip morphology analysis a guideline were generated in providing the various chip forms generated at different combination of cutting parameter in hard turning operation.

The main challenges in this thesis is to arrive at a specimen of hard turning level, selection of appropriate turning center to perform the machining operation, machining with cBN tool insert whose hardness is second next to diamond, confirmation of the hardness level after each turning operation, selection of measuring tools and the further analyses involved. Through this has attained aquaintace with latest softwares and analysing techniqes like Design Xpert. Finally the competency of the design of experiment were proved in coincidence with the respond relation generated through regression analysis.

CHAPTER 11

FUTURE WORK

The primary and most important challenges facing the modern metal cutting and machining industries are the attainment of high quality in terms of work piece dimensional accuracy, surface finish, high production rate, minimal tool wear, economy of machining in terms of cost savings, and improvement in product performance with minimal environmental impact. Due to their great strength and wear resistance, hardened steels are often manufactured using the grinding process; nevertheless, grinding processes are time-consuming and have a limited number of possible geometries. In recent years, turning with a single point cutting tool to machine hardened steel has partially replaced grinding for such applications. This leads to reduced the number of setup changes, product cost and ideal time without compromising on surface quality to maintain the competitiveness. To achieve the desired surface topology similar to grinding, an improved technical process, appropriate tool selection, identification of the best machining parameters, or tool geometry are required.

The statistical design of experiments is often used to determine surface quality. Designing an experiment is the act of organising an experiment such that the right data can be collected and analyzed using statistical techniques, leading to reliable and impartial results.

During this experimentation aquiented with the effect of various machining parameters affecting hard turning operation. This kind of machining operation using cBN tool inserts is useful for the advanced engineering industries those are working in the field of precision machining. The right machining parameters must be chosen in order to machine surfaces with the desired quality. This may be done by increasing metal cutting industry quality and output. The information gathered for this thesis' facts and figures can be utilised as a reference for analysing severe operating circumstances.

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