MACHINABILITY STUDY ON

SiC - Al CO-CONTINUOUS COMPOSITE

A PROJECT REPORT

Submitted by

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APPENDIX 2

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BONAFIDE CERTIFICATE

Certified that this project report "**MACHINABILITY STUDY ON SiC - Al CO-CONTINUOUS COMPOSITE"** is the bonafide work of "**ADHARSH R, GAUTAM PRASANTH G, MOHANAKKUMAR P, NAGARAJAN CS.**" who carried out theproject work under my supervision.

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INTERNAL EXAMINER **EXTERNAL EXAMINER**

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ABSTRACT

MMCs are used in aerospace, space ships, automotive, nuclear, biotechnology, electronic and other industries. The machinability of MMC is different from traditional materials because of presence of abrasive particles. It is important to know the ideal speed, feed and depth of cut at which the machining should be done, so that the cutting force, tool wear and the surface roughness developed is minimum. Cutting speed, feed rate, and depth of cut are the parameters used for conducting the experiment. Depending on the cutting speed, feed and depth of cut, the cutting force, surface roughness and tool wear that is developed varies in a particular pattern. For example if the Depth of Cut increases, the Tool wear increases. If the feed increases, the surface roughness increases also the tool wear increases and so on. Based on these relations, experiments are conducted on the composite with various speed, feed and depth of cut to determine the ideal conditions at which the composite can be machined. The machining process that is being studying in this experiment is turning. The machining is done on a PSG Trainer lathe. The results of tool wear, cutting force, and surface roughness developed is then analyzed using Reponse Surface Methodology with the help of Design Expert software. Graphs are then plotted to understand how the results vary when the machining parameters are changed. An equation is obtained for cutting force, tool wear and surface roughness using the software.

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CHAPTER 1

INTRODUCTION

There are high chances for conventional materials like Steel, Brass, Aluminium to fail without any indication. This might also lead to crack initiation and propagation within a short span of time. To sort out this issue the conventional materials are replaced with Aluminium alloys. The distinct characteristic of Aluminium alloys is that it can be designed accordingly to give the required properties. Aluminium alloys or composites are nothing but a combination of two or more materials. They are combined in such a way that the resulting material possesses additional design properties when compared to the individual materials.

In automobile industries, fuel consumption and greenhouse gas emission have become a major concern these days. The companies have started to use Aluminium to a great extent in light vehicles to reduce the weight and improve the fuel efficiency of the automobiles. Aluminium alloy based metal matrix composite (MMCs) with ceramic particulate reinforcement can definitely be relied on for such applications [1, 2]. These materials are advantageous over conventionally used gray cast iron because these materials have low density and high thermal conductivity. So they can be used to reduce the weight in brake systems up to 50-60% [3]. Moreover, these advanced materials have the potential to perform better under severe service conditions like higher speed, higher load etc. which are increasingly being encountered in modern automobiles.

MMC'S can be considered as the best replacement for the usually used cast iron because of the following reasons.

1) High strength to weight ratio.
2) High thermal conductivity.
3) High corrosion resistance.

The composites can be made by using one of the following reinforcement materials.

1) Particulate matter.
2) Foam.

According to the type of reinforcement material used, the production process will differ. For particulate matter, stir casting technique is used. Here the composite is produced by adding the particulate matter to the powdered form of the molten metal. Once this is done, the mixture is stirred well to produce the composite. For foam, infiltration technique is used. Based on the type of process carried out, the properties of the final product will vary.

Once the composite is ready, the machinability tests are carried out. This will help us reach a conclusion whether the composite can be machined effectively and converted into a useful product or not. In this report, we have included every information regarding the manufacturing of a composite using Aluminium and silicon carbide. We have also attached the results of the machinability tests that we carried out using the composite along with the step by step procedures.

CHAPTER 2

LITERATURE SURVEY

Many materials were used in old times which exhibited the property which were inherent. Machines and components were designed only by using those available materials. Composites materials were introduced in the market, which were made of two or more materials in combination, which had properties of all the combined materials. Composites were given more importance in the modern era due to exhibition of different properties and ability to be applied in various sectors like aerospace, automobile, medicine, industries, household components, etc..,+

Composite can have a combination of a metal and fiber, metal and ceramics which gives various properties. Accordingly to that, there came many types of composites. One of which is the co-continuous composites. These composites have bi-directional strength, high wear resistance and light in weight.

1. The turning of an Al/SiC metal-matrix composite

Author

L.A.Looney , J.M.Monaghan, P.O'Reilly , Trinity College, Dublin.

Key Findings

- Cutting tool used for turning of metal matrix composite.
- Tool wear and Surface finish results after turning.
- Cutting force determination using lathe tool dynamometer.

2. **A study on machinability of Al/SiC- MMC**

Author

A Manna , B Bhattacharya , Jadhavpur University

Key Findings

- Machinabilty test process of Al/SiC MMC.
- Experimental Procedure of the machinabilty tests.
- Test results of turning operation

3. **Machining of Al/SiC particulate metal-matrix composites**

Author

M. El- Gabab , M.Sklad , McMaster University , Canada

Key Findings

- Cutting parameters involved in turning operation.
- Tool performance

4. **Analysis on Al/SiC Co-Continuous composites**.

Author

A.S.Prasanth and R.Ramesh , PSG College of Technology.

Key Findings

- Manufacturing methods of Al/SiC co-continuous composites
- Analysis on the test results.

5. **Methods for selection of materials.**

Author

Maleque M A

Key Findings

- Material performance requirements
- Alternative Solutions for material selection.

6. **Investigation of mechanical and machinability properties of SiC particle reinforced Al-MMC.**

Author

Ozben, T., Kilickap, E., & Çakır, O.

Key Findings

- Results of investigation of mechanical properties
- Machinability properties of silicon carbide particle (SiC-p) reinforced Aluminium metal matrix composite.

7. **Machinability issues in turning of Al-SiC metal matrix composites.**

Author:

Muthukrishnan.N., Murugan.M.,&Prahlada Rao.K.(2007)

Key Findings

- Experimental investigation on the machinability of fabricated aluminium metal matrix composites.

CHAPTER 3

PROBLEM STATEMENT

Aluminum-(Silicon Carbide) is a metal-ceramic composite material consisting of silicon carbide particles dispersed in a matrix of aluminum alloy. It combines the benefits of high thermal conductivity of metal and low Coefficient of thermal expansion of ceramic. SiC/Al composites possess low density (2.94 g/cm3), high elastic modulus (220 GPa), prominent thermal management function as a result of low coefficient of thermal expansion (8×10^{-6} K^{-1}) and high thermal conductivity (235 W/(m·K)) as well as unique preventability of resonance vibration The most important property of Aluminium-silicon carbide with reference to the aero space industry is its strength to weight ratio, which is three times more than mild steel.

From some early conventional turning tests on Al/SiC-MMCs it is found that the tool wear is excessive and surface finish is very poor while carbide tip tools are used for machining. Our objective is to find the ideal parameters such as speed, feed, and depth of cut at which the composite can be machined so that the cutting force, tool wear and surface roughness is minimum. Due to some constraints the machinability studies were performed only on turning operation.

CHAPTER 4

MATERIAL SELECTION

4.1 COMPOSITE MATERIAL

A composite is a combination of two or more different materials that results in a superior (often stronger) product. Humans have been creating composites for thousands of years to build everything from simple shelters to elaborate electronic devices. While the first composites were made from natural materials like mud and straw, today's composites are created in a lab from synthetic substances. Regardless of their origin, composites are the ones that have made life as we know it possible.

Today, the use of composites has evolved to commonly incorporate a structural fiber and a plastic, this is known as Fiber Reinforced Plastics or FRP for short. Like straw, the fiber provides the structure and strength of the composite, while a plastic polymer holds the fiber together. Common types of fibers used in FRP compositesinclude,

- Fiberglass
- Carbon fiber
- Aramid fiber
- Boron fiber
- Basalt fiber
- Natural fiber (wood, flax)

In the case of fiberglass, hundreds of thousands of tiny glass fibers are compiled together and held rigidly in place by a plastic polymer resin. Common plastic resins used in composites include:

1. Polyester
2. Polyurethane
3. Polypropylene

Common Uses and Benefits

The most common example of a composite is concrete. In this use, structural steel rebar provides the strength and stiffness to the concrete, while the cured cement holds the rebar stationary. Rebar alone would flex too much and cement alone would crack easily. However, when combined to form a composite, an extremely rigid material is created.

The composite material most commonly associated with the term "composite" is Fiber Reinforced Plastics. This type of composite is used extensively throughout our daily lives. Common everyday uses of fiber reinforced plastic composites include:

1. Aircraft
2. Boats and marine
3. Sporting equipment (golf shafts, tennis rackets, surfboards, hockey sticks, etc.)
4. Automotive components
5. Wind turbine blades
6. Body armor
7. Building materials
8. Water pipes

4.2 CLASSIFICATION OF COMPOSITES

There are two levels of classification when it comes to composite materials. The first level of classification is usually made with respect to the matrix constituents. Following are the different classes of composite.

1. Organic Matrix Composites (OMC).
2. Metal Matrix Composites (MMC)
3. Ceramic Matrix Composites (CMC).

The second level of classification is made with respect to the reinforcement form.

1. Fiber reinforced composites.
2. Laminar composites.
3. Particulate composites.

4.3 ALUMINIUM METAL MATRIX COMPOSITE (Al-MMC)

When it comes to MMC'S, Aluminium and its alloys are the most sought after materials. MMC'S are made by combining ceramic materials with Aluminium. Here, we've made use of silicon carbide (grade 2014).

4.4 REASON FOR CHOOSING THIS COMBINATION:

Aluminium Silicon Carbide can be considered as a perfect choice due to the following reasons.

1) High thermal conductivity.
2) Less weight.
3) High strength.
4) Cost effective.

4.5 ABOUT ALUMINIUM ALLOY 2014

4.5.1 CHEMICAL COMPOSITION

The alloy composition of 2014

- Aluminum: Remainder
- Chromium: 0.1% max
- Copper: 3.9% - 5%
- Iron: 0.7% max
- Magnesium: 0.2% - 0.8%
- Manganese: 0.4 - 1.2%
- Remainder: Each 0.05% max
- Remainder: Total 0.15% max
- Silicon: 0.5% - 1.2%
- Titanium: 0.15% max
- Titanium + Zinc: 0.2% max
- Zinc: 0.25% max

4.5.2 PROPERTIES

Typical material properties for 2014 aluminum alloy are

- Density: 2.80 g/cm3, or 175 lb/ft3.
- Young's modulus: 73 GPa, or 11 Msi.
- Electrical conductivity: 34 to 50% IACS.
- Ultimate tensile strength: 190 to 480 MPa, or 28 to 70 ksi.
- Thermal Conductivity: 130 to 190 W/m-K.
- Thermal Expansion: 23 μm/m-K.

PROPERTIES	VALUES
Tensile Strength	130 Max MPa
Elongation A50 (mm)	16 Min %
Brinell Hardness	25 HB
Elongation A	18 Min %
Density	2700 kg/m^3
Melting Point	600°C
Thermal Conductivity	200 W/m.K
Thermal Expansion	23.5 x 10^{-6} /K

TABLE 4.1

Fig 4.1

4.5.3 SPECTROSCOPY ANALYSIS

Spectroscopy Analysis is done to know the composition of elements in the given specimen. Spectroscopy test was done on Aluminium 2014 to know the composition of elements.

An Aluminium rod with the following dimension was given for the analysis,

- Diameter – 20 mm
- Length – 30 mm

Name of the Test, Clause No., Test Method Parameter	Units of Measure	Observed Values or Results
Silicon (Si)	%	0.86
Iron (Fe)	%	0.24
Manganese (Mn)	%	0.82
Copper (Cu)	%	4.70
Tin (Sn)	%	0.0005
Magnesium (Mg)	%	0.71
Zinc (Zn)	%	0.089
Chromium (Cr)	%	0.01
Lead (Pb)	%	0.006
Nickel (Ni)	%	0.004
Titanium (Ti)	%	0.051
Aluminium (Al)	%	92.43

TABLE 4.2

Note: The above test's remaining elements or impurities are Traces

4.6 SELECTION OF SILICON CARBIDE

Silicon carbide is generally porous in nature. The structure is generally an open celled foam. It has solid struts interconnected with each other. A ceramic foam is generally used because of the following reasons.

1) Thermal insulation.

2) Acoustic insulation

3) Adsorption of environmental pollutants.

Carbide compounds are extensively used for drills and various other tools due to the following reasons.

1) Hardness.

2) Wear resistance.

3) Corrosion resistance.

4) Heat resistance.

5) Toughness.

6) Low thermal expansion.

7) Good electrical conductivity.

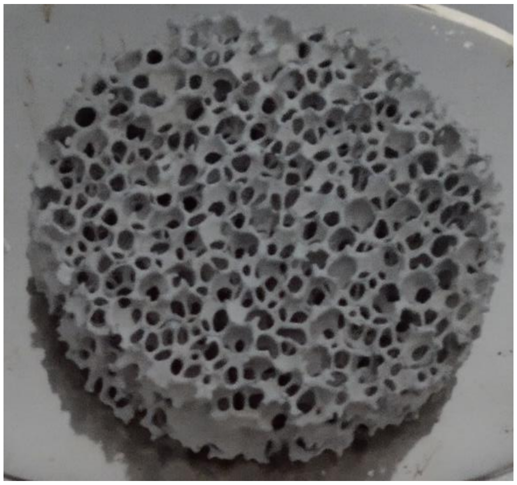


Fig 4.2

FOAM SPECIFICATIONS

Silicon carbide foams are generally specified by mentioning the following characteristics.

- Pore size
- Relative density

4.6.1 PORE SIZE

The foam generally consists of facets which are fourteen in number. Pores are nothing but the openings in these facets and are polygonal. Even though the pores have more than one size and shape, for simplification they are brought down to one average size and shape (circular). Generally the quantity of the pores in silicon carbide ceramic ranges from five to hundred per inch. The number of these pores that would subtend one inch then designates the foam "pore size".

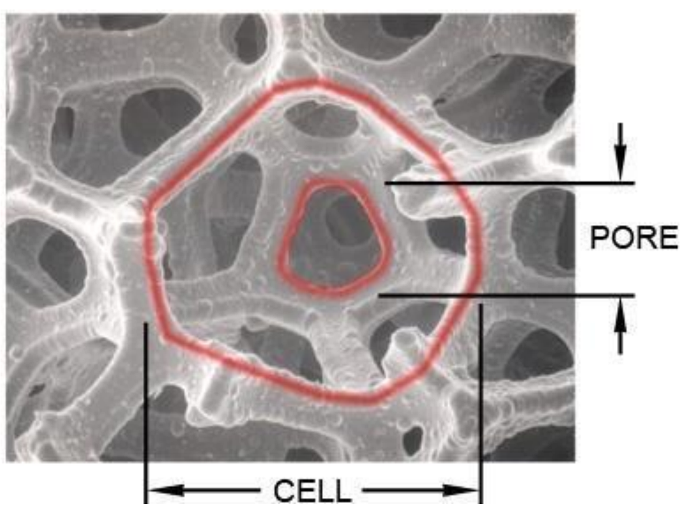


Fig 4.3

Effects of Pore Size (PPI) –The fineness in the division of raw materials is determined by the pore size of the foam. Even though the bubble and strut structural shape remains the same, there would be a difference between a five PPI and 50 PPI foam. Similarly, the size of the foam pore affects the following parameters, namely

- Cross section size.
- Nominal ligament length.
- Pore diameter.

4.6.2 RELATIVE DENSITY:

Relative density refers to the ratio between foam density and the density of the solid parent material of the struts. Generally the relative density ranges between two and fifteen percent. Taking into consideration the physical characteristics of tiny structures, the foam density ranges from three to ten percent. For parameters without dimension, relative density is used because it is precise and non-deceptive.

Effects of Relative Density –Relative density affects the following parameters, namely

- Ligament cross shape.
- Actual size.

The mechanical properties of the foam such as stiffness electrical conductivity and thermal conductivity are directly governed by moment of inertia and cross section of struts. In the same way, relative density governs the structural behavior of the following parameters, namely

- Monolithic components.
- Composite panels.
- Energy absorbers.

4.7 PROPERTIES OF SiC

PROPERTIES	VALUES
Density	3.1 g/cm^3
Elastic Modulus	410 GPa
Hardness	2800 Kg/mm^2
Thermal Conductivity	120 W/m.K
Coefficient of Thermal Expansion	4.0 10^{-6}/^{o}C
Specific Heat	750 J/Kg.K
Poisson's Ratio	0.14

TABLE 4.3

CHAPTER 5

FABRICATION OF AL (6063) - SIC COMPOSITE

The two main processes that are used for fabricating Aluminium metal matrix composite are as follows.

- **STIR CASTING**
- **INFILTRATION PROCESS**

5.1 STIR CASTING

Mechanical stir casting is a liquid state method for the fabrication of composite materials, in which a dispersed phase is mixed with a molten matrix metal by means of mechanical stirring. Stir Casting is the simplest and the most cost effective method of liquid state fabrication. The stir casting set-up is shown in Three combinations of reinforcement are fabricated with Aluminium metal matrix.

The metal matrix is reinforced with SiC particle having average particle size (APS) -25µm. Silicon carbide is preheated at 473 K for 1 h prior to introduction into the melt. In liquid metal stir casting, the AA6082 was placed in specially designed Muffle furnace with top pouring mechanism as shown in Figure

The amount of silicon carbide is varied from 0%wt to 7% wt. in each matrix. A thermocouple has inserted and it gives the feedback of the temperature inside the furnace.The temperature inside the furnace is controlled around 7500^{o}C in order to minimize the chemical reaction between the substances.

The temperature is controlled by connecting the relay from the furnace and thermocouple. The function of relay is to cut-off the power supply when temperature goes beyond the 7000 C. The mechanical stirring is used to disperse the silicon carbide particles in matrix alloy. The preheated particles of reinforcement is added to the melt and stirred at 650 rpm for 10 minutes. The stirring is continued before the composite reaches the mushy zone. The cooling is done in the furnace.

5.2 INFILTRATION PROCESS

Liquid metal infiltration is the apt process for the production of MMC'S with varying shapes and with intense reinforcement. In this process, the molten metal is poured into the Silicon carbide foam which is placed in the setup.

The temperature is maintained such a way that the process will not let the foam to melt. Once the molten metal is poured into the Silicon carbide foam, it perfectly settles in the pores, thus resulting in the composite. There are two types of liquid infiltration techniques. They are as follows

- Pressurized infiltration process
- Gravity infiltration process. (Pressure less infiltration)

The different types of infiltration process are given below.

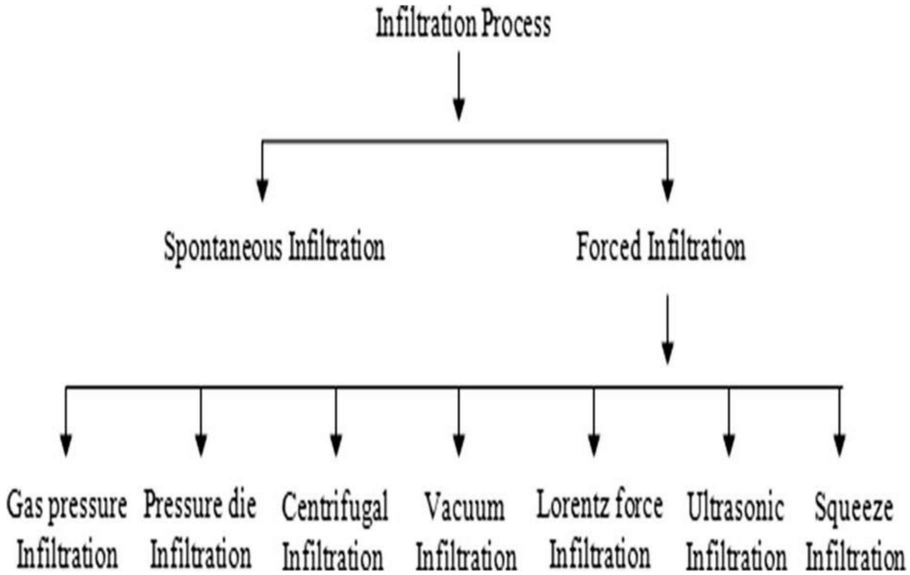


Fig 5.1

5.2.1 PRESSURISED INFILTRATION PROCESS

Pressurized infiltration is the process is the technique in which, the composite is made with the help of external force. Mechanical energy is employed to avoid the effect of improper wetting between the Aluminium and SiC.

5.2.2 GRAVITY INFILTARTION PROCESS

In this process, infiltration is done without the help of external mechanical force. This is achieved by manipulating the temperature and gas atmosphere in an efficient manner. This will result in proper wetting conditions

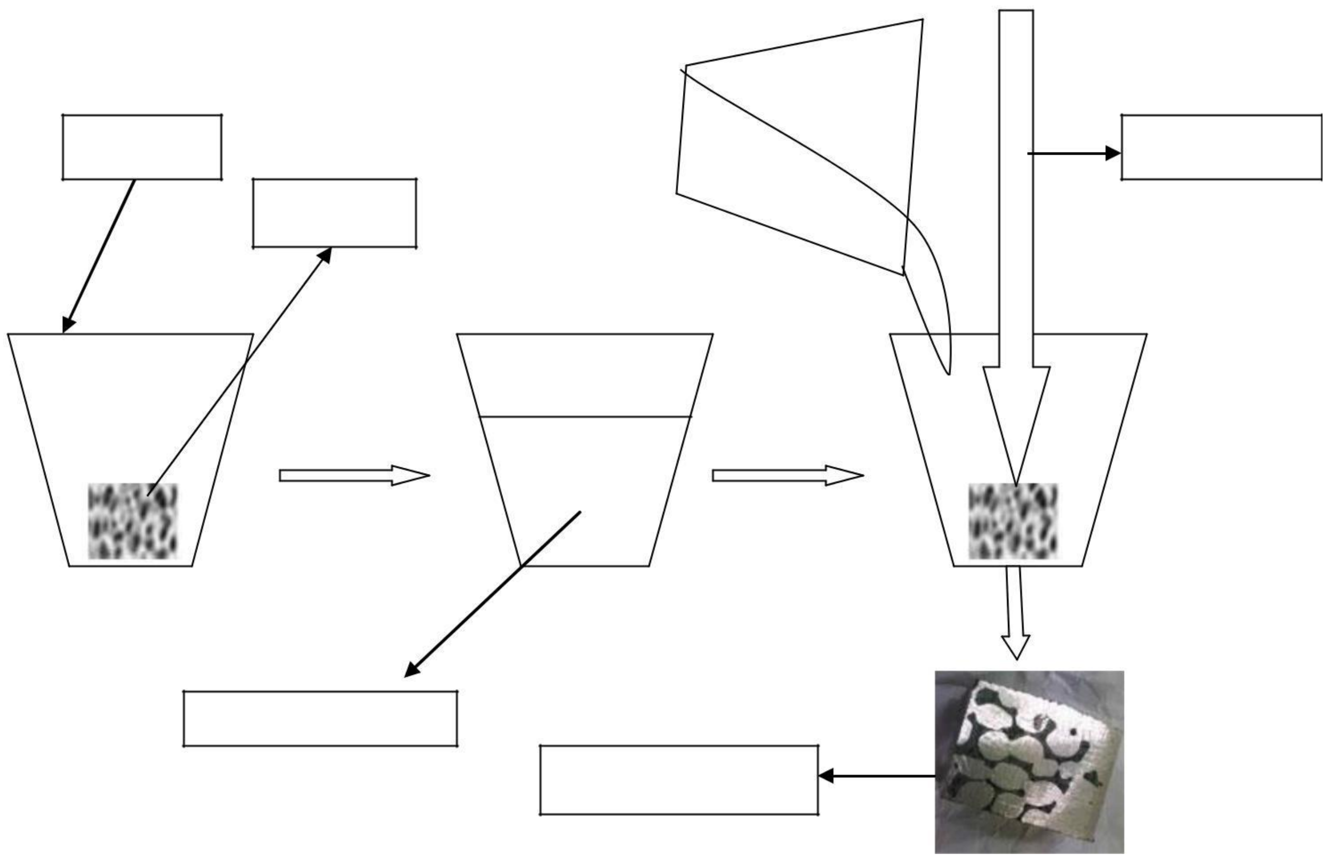


Fig 5.2

Numerous studies in gravity infiltration process have been carried out using Al-Si, Al-Zn, Al-Mg alloys into porous Sic perform and however there are some challenges that should be tackled to develop gravity infiltration a very promising and industry adaptable methods. Conventional drawback of the infiltration synthesis method is the poor wettability between the matrix and the reinforcement resulting from the formation of oxide layer on the melt surface.

Poor wettability negatively influences the infiltration process by slowing down the infiltration process leading to undesirable reactions at the interface resulting in the formation of intermetallic such as Al4C3 and Al3SiC4 in aluminum-SiC-based systems

5.3 COMPONENTS REQUIRED FOR FABRICATION:

Following components are essential for the manufacturing of Aluminium and metal matrix composite.

- Muffle Furnace
- Crucible
- Carbon rod

5.3.1 MUFFLE FURNACE:

It refers to a box that is loaded from the front and is capable of maintaining **high temperatures** (**95 ^{o}C-1600 ^{o}C**) within. Both ovens and kilns (**thermally insulated chamber**) qualify as **Muffle Furnaces** by this definition. In historical usage it is a **furnace** in which the subject material is isolated from the fuel and all of the products of combustion including gases and flying ash.

These **Muffle Furnaces** use open coil heating elements on both sides of the heating chamber to allow fast heating with minimal temperature gradient. This energy efficiency is enhanced through the use of high thermal-efficient ceramic insulation surrounding the chamber. The free-floating, ceramic fiber door includes a chamber plug that prevents heat loss around the door by totally sealing when the spring-loaded door is closed. These ovens have a door safety switch which cuts power to the elements if the door is opened during use.

Operating principle

The **furnace chamber** is heated by **Electric Resistance Elements** and is insulated with **Ceramic Fiber Insulation**. The controller is located under the **Furnace Chamber** and is well insulated from the heat generated in the **Furnace Chamber**. A door safety switch removes power to the heating elements whenever the **Furnace** door is opened. The temperature is controlled by one of three types of controllers.

A **Muffle Furnace** most frequently uses the heating method known as **Conduction**, which involves heating a surface and allowing the heat to radiate into nearby areas such as holding cavity. However, some **Muffle Furnaces** use **Convection** heating instead, which involves the circulation of hot air and sometimes **Black Body Radiation**method too.

Applications

Muffle Furnaces are used in a variety of applications

1) **Craft Applications**

- Hardening enamel coating onto clay
- Firing ceramics
- Melting and fusing glass
- Soldering items together
- Brazing

2) **In Science**: A common procedure in chemistry is to burn a sample of particular material to determine **Chemical Composition**, including water content and the proportion of **combustible and non-combustible materials**. The presence of ash after a complete burning indicates certain chemical property and can be used to determine the level of **volatile versus non-volatile** products in the sample.

iii) Used in **Nutritional Analysis**, making it possible to determine the relative proportions of proteins, fat, carbohydrate, and water in food under study.

Fig 5.3

5.3.2 CRUCIBLE

Crucible containers can hold large amounts of molten metal but the vapor flux distribution changes as the level of the molten material changes. Electrically conductive containers can be heated resistively and can be in the form of boats, canoes, dimpled surfaces, crucibles, etc. Typical refractory metals used for containers are tungsten, molybdenum, and tantalum as well as refractory metal alloys such as TZM (titanium and zirconium alloyed with molybdenum for improved high temperature strength) and tungsten with 5–20% rhenium to improved ductility.

Metallic containers are often wetted by the molten material and the material can spread to areas where it is not desired. This spreading can be prevented by having non-wetting areas on the surface. Such non-wetting areas can be formed by plasma spraying Al2O3 or by firing a glass frit on the surface.

Electrically conductive ceramics can be used as crucibles. Carbon (graphite) and glassy carbon are commonly used crucible materials and, when evaporating a carbon-reactive material from such a container, a carbide layer (skull) forms that limits the reaction with the container. These composite ceramics are stable in contact with molten aluminum, whereas most metals react rapidly with the molten aluminum at the vaporization temperature.

A Carbon (graphite) crucible was used for this experiment. The specifications of the crucible are given below.

Specifications of the Crucible used

- Material: Graphite
- Dimensions : Height – 180mm, Outer Dia – 120mm, Inner Dia – 70mm

Fig 5.4

5.3.3 CARBON ROD

During the infiltration process, carbon rods are used to hold the foam inside the molten Aluminium. The applications for carbon are many and include its use as an alloying element with iron in the manufacture of steel, its use as brushes in electrical generators and motors, the use of colloidal graphite or carbon to coat surfaces (e.g. glass), in electrical assemblies to absorb microwaves and inhibit photoelectrons and secondary electrons, and the use of high purity carbon (graphite) in nuclear reactors to moderate neutrons.

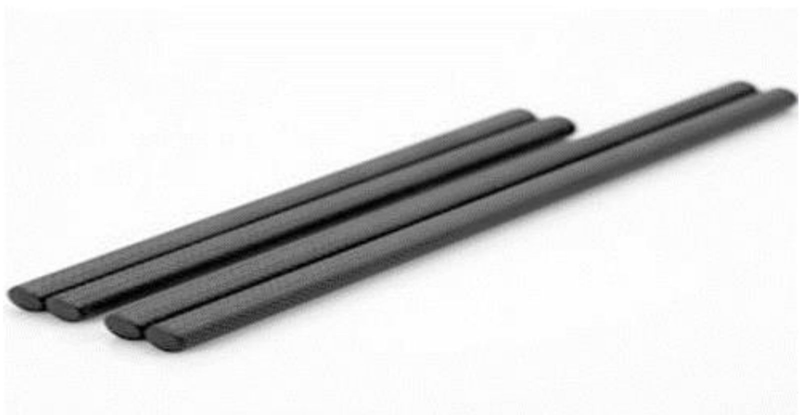


Fig 5.5

The carbon rod was used in the manufacturing process to press the Silicon Carbide foam so that it remains in its original position. This is an important step to be done in order to make sure that we get a sound casting.

With all the necessary equipment ready the manufacturing process is started. The manufacturing process followed is given below.

5.4 MANUFACTURING PROCESS

We chose the gravity infiltration process for the manufacturing of the composite. The Aluminium (2014) is sliced into tiny pieces as shown, before placing them in the set up.

Fig 5.6

The weight of Aluminium used for the infiltration process was 1.086 Kg. The SIC is kept in one crucible and Aluminium in another. The initial weight of the SiC foam before the infiltration process was 57.6 g.

Fig 5.7

Both these setups are placed in two different furnaces. The furnace containing SIC is maintained at temperature of 950 degree centigrade which is less than the MP of SIC. This facilitates the preheating of SiC.

The crucible containing the Aluminium is heated until the Aluminium is completely melted in the crucible. Coveral salt is added in the molten Aluminium in order to remove the oxides that are formed during the melting process. The temperature of the furnace containing the silicon carbide foam is lowered down to 750^0 C after the preheating process. Then the molten Aluminium from the crucible is lifted by the tongs and poured in the crucible containing the preheated silicon carbide foam.

Fig 5.8

The need for carbon rods arises here. The foam floats due to its density and in order to hold the form in such a way that it is well immersed in aluminium, carbon rods are used. This setup is kept intact for 2 hours, so that the molten metal penetrates through every pore inside the foam and an extremely strong bondage is form.

Then it is left inside the furnace for at least for a day so that solidification occurs. Then, the product is removed from the crucible. Some basic machining processes like facing, turning, milling, cutting and grinding are done to obtain surface finish.

Fig 5.9

CHAPTER 6

PROPERTIES OF THE COMPOSITE

The properties like percentage porosity, the amount of aluminium infiltrated into the foam were calculated before machining. The results are shown below.

PROPERTIES	VALUES
Percentage Porosity in SiC Foam	84.18 %
Weight of Aluminium in Casting	998.4 g
Weight of Aluminium Infiltrated into the Foam	267.358 g
Volume of Casting	374.51 cm^3
Theoretical Volume of SiC Foam	113.43 cm^3
Actual Volume of SiC Foam	17.945 cm^3

TABLE 6.1

CHAPTER 7

MACHINING THE CAST

After the infiltration process the silicon foam is completely covered with aluminium. As shown, the Silicon Carbide foam is completely hidden under the aluminium. So it is necessary to remove the excess aluminium on the casting to improve the visibility of the foam.

Fig 7.1

Various machining processes were done to remove the excess aluminium from the casting. The machining processes that were carried out are,

- Face Milling
- Hand Grinding
- Vertical Milling

7.1 FACE MILLING

Face Milling was done to remove the majority of the aluminium on the surface of the casting. The milling cutter is a graphite cutter. A spindle speed of 250 RPM was used during the milling process. The machining parameters used are,

Feed – 50 mm/min

Speed – 45. RPM

Depth of Cut – 0.5 mm

Fig 7.2

The final product after the milling operation is shown below.

Fig 7.3

7.2 HAND GRINDING

The irregularities on the casting were removed by hand grinding with the help of a hand grinding machine. An Aluminium grinding wheel was used for this process.

Fig 7.4

The grinding was done until most of the Aluminium was removed from the casting. At the end of grinding, the silicon carbide foam was visible on all sides of the casting. The casting after the grinding process is shown below.

Fig 7.5

7.3 VERTICAL MILLING

Finally, the casting was milled again to get a cylindrical profile. A vertical machining center was used for this process. A hole was drilled on the cast for holding it on the vertical machining center. The vertical machining center is shown below.

Fig 7.6

7.4 FINAL SPECIMEN

After the machining processes are complete the composite looks as shown below.

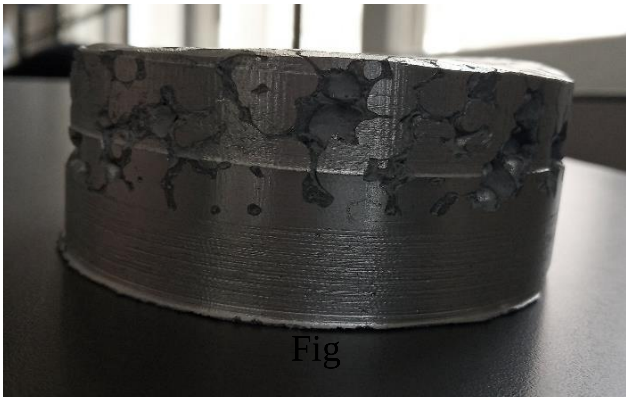


Fig 7.7

Note: A small portion of Aluminium was left below the composite so that the composite can be held in the chuck.

Fig 7.8

DIMENSIONS OF THE COMPOSITE

Height – 20 mm

Diameter – 75 mm

Volume – 88.312 cm^3

WEIGHT OF THE COMPOSITE

Weight of Aluminium in the Sic Foam – 267.358 g

Weight of SiC Foam – 57.6 g

Total Weight of the Composite – 324.958 g

CHAPTER 8

TESTING

After manufacturing the composite, machining is to be done on the composite to find the machinability of the composite. With the help of this test the ease at which at the composite can be found out. Turning operation was done on the composite to find out its machinability properties.

8.1 TURNING

Turning is a machining process in which a cutting tool, typically a non-rotary tool bit, describes a helix toolpath by moving more or less linearly while the workpiece rotates. When turning, the workpiece (a piece of relatively rigid material such as wood, metal, plastic, or stone) is rotated and a cutting tool is traversed along 1, 2, or 3 axes of motion to produce precise diameters and depths.

8.1.1 MACHINE USED

The turning was done using a PSG Trainer Lathe.

8.1.2 OBJECTIVE

The objective of this process is to measure the cutting forces that are developed during turning, the tool wear that develops on the cutting tool and also to measure the surface finish, for different values of speed, feed and the depth of cut. With the help of the results we could arrive at an ideal speed, feed and depth of cut at which the composite could be machined effectively for various operations

8.1.3 CUTTING TOOL USED

A carbide insert was used for carrying out the machining process. The insert was placed in the tool carriage with the help of a tool holder and an Allen key. The cutting tool and the insert is shown below.

Fig 8.1

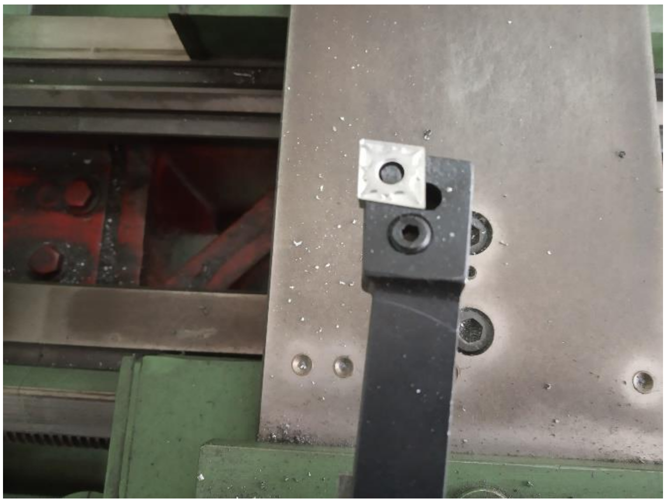


Fig 8.2

8.1.4 VALUES OF SPEED, FEED AND DEPTH OF CUT

Since it is impossible to do the machining for all speed, feed and depth of cuts, three values of speed, feed and depth of cut were chosen. By interchanging these values one at a time the machining is done. The values that were chosen are given below.

Speed (RPM) – 140, 200, 250

Feed (mm/min) – 50, 60, 70

Depth of Cut (mm) – 0.25, 0.5, 0.75

Note: Due to speed limitations on the lathe slow speed machining was done.

Number of readings to be taken

A total of 18 readings of cutting force, surface roughness and tool wear should be taken by interchanging the values of speed, feed and depth of cut for forming the **Taguchi L18** array.

8.1.5 TAGUCHI ARRAY

For this experiment a Taguchi L18 Array was formed. The L18 array has eighteen values of speed, feed and depth of cut and its corresponding values of cutting force, surface roughness and tool wear. An L18 array was used instead of L9 or L12 to improve the accuracy of the results.

With the help of the values from the Taguchi table other values of cutting force, surface roughness and tool wear can be found for different values of Speed, Feed and Depth of Cut. This is the significance of using a Taguchi table analysis.

8.2 CUTTING FORCE

The forces in a turning operation are important for the design of machine tools. The machine tool and its components must be able to withstand these forces without causing any significant deflections, vibrations, or chatter during the operation. The three principal forces during a turning process are,

- **Cutting or Tangential Force**
- **Axial or Feed Force**
- **Radial or Thrust Force**

8.2.1 CUTTING OR TANGENTIAL FORCE

This force acts downward on the tool tip allowing deflection of the workpiece upward. It supplies the energy required for the cutting operation. The specific cutting force required to cut the material is called specific cutting force. Cutting force depends on the material.

8.2.2 AXIAL OR FEED FORCE

This Force acts in the longitudinal direction. It is also called the feed force because it is in the feed direction of the tool. This force tends to push the tool away from the chuck.

8.2.3 RADIAL OR THRUST FORCE

This force acts in the radial direction and tends to push the tool away from the workpiece.

Note: During turning operation, only the feed force and the radial force play a dominant role so during the calculation of resultant force the cutting force component is neglected.

8.3 EQUIPMENT USED FOR MEASUREMENT

The following are the equipment used for various purposes.

- Cutting Force – Lathe tool dynamometer
- Surface Roughness – Roughness Tester
- Tool Wear – Profile Projector

8.3.1 LATHE TOOL DYNAMOMETER

Lathe Tool Dynamometer is a cutting force measuring instrument used to measure the cutting forces coming on the tool tip on the Lathe Machine. The sensor is designed in such a way that it can be rigidly mounted on the tool post, and the cutting tool can be fixed to the sensor directly. This feature will help to measure the forces accurately.

The sensor is made of single element with three different Wheatstone's Strain Gauge Bridge. Provision is made to fix 1/2" size Tool bit at the front side of the sensor. The tool tip of the tool bit can be grind to any angle required. Forces in X - Y - Z directions will be shown individually & simultaneously in three Digital Indicators Supplied. It gives the value of force in KgF (Kilogram Force) which is then converted into Newton (N).

Fig 8.3

8.3.2 ROUGHNESS TESTER

A roughness tester is used to quickly and accurately determine the surface texture or surface roughness of a material. A roughness tester shows the measured roughness depth (Rz) as well as the mean roughness value (Ra). The measured values are in micrometres or microns (μm).

Fig 8.4

8.3.3 PROFILE PROJECTOR

A Profile Projector is typically used as a measuring device. The projector magnifies the profile of the specimen, and displays this on the built-in projection screen. On this screen there is typically a grid that can be rotated 360°so the X-Y axis of the screen can be aligned with a straight edge of the machined part to examine or measure.

Fig 8.5

8.4 MACHINING PROCEDURE

The following steps are followed for carrying out the experiment

1. The insert is placed on the tool holder and tightened with an Allen key.
2. The tool is then placed in the tool carriage on the lathe and the position is set in such a way that the tool holder is perpendicular to the axis of the cylindrical composite.
3. The composite is held in position with the help of the chuck.
4. The correct speed, feed and depth of cut is set on the lathe by changing the gears with the help of the instructions given on the lathe.
5. The lathe tool dynamometer is connected to the lathe.
6. The lathe is turned on and turning is done for some distance on the composite.
7. While turning, the cutting force developed on all the three axes is noted down from the lathe tool dynamometer.
8. Then the composite is removed from the chuck and the surface roughness is measured using the roughness tester.
9. Now the insert is removed from the tool holder and the angle of tool wear and the area of worn out portion of the tool is measured.
10. After this the speed feed and depth of cut is changed and steps 1 to 9 are repeated. Like this 18 sets of readings are taken.

Note: After each cycle the carbide tool insert is changed so that the tool wear can be measured using the profile projector.

8.5 CUTTING FORCE MEASUREMENT

The cutting force is measured using a **Lathe Tool Dynamometer**.

8.5.1 PROCEDURE

1. Connect the lathe tool dynamometer to the lathe
2. During turning measure the three values of force that are shown on the display. This corresponds to the force developed along the x, y and z axis (Fx, Fy, Fz) respectively
3. The developed force is in KgF (Kilogram Force), this is then converted into newton.
4. Then finally the resultant force is calculated.

The Cutting Force on the x, y and z axes displayed on the dynamometer during turning operation is shown below

Fig 8.6

8.5.2 MODEL CALCULATION

Converting KgF to Newton

To convert KgF to Newton multiply the respective KgF value by 9.807

Fx = 3 KgF

1 KgF = 9.807 N

Therefore, 3 KgF = 3*9.807 = 29.421 N

Fz = 4 KgF = 4*9.807 = 39.228 N

Resultant Force

The resultant is calculated using the formula given below. The force Fy is neglected for ease of calculation as it does not play any significant role during turning

Resultant Force = $\sqrt{(Fx^2 + Fz^2)}$

Fx = 29.421 N

Fz = 39.228 N

Fx^2= 865.595 N^2

Fz^2= 1538.835 N^2

Resultant force = 49.035 N

8.6 SURFACE ROUGHNESS MEASUREMENT

The Surface roughness is measured using a **Roughness Tester**.

8.6.1 `PROCEDURE

1. The composite is placed on a flat surface.
2. The roughness tester is turned on and the lambda value is set at 0.08µm
3. The probe of the tester is made to touch the surface of the composite
4. The start button is pressed and the probe starts to move along the surface. After a few seconds the value of surface roughness is given. The unit is micron or micrometre.

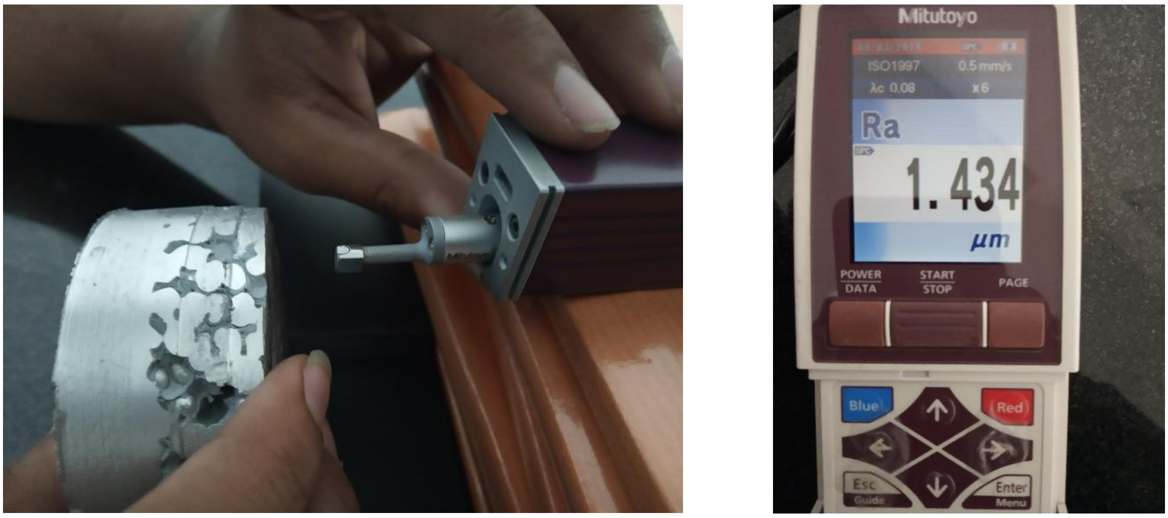


Fig 8.7

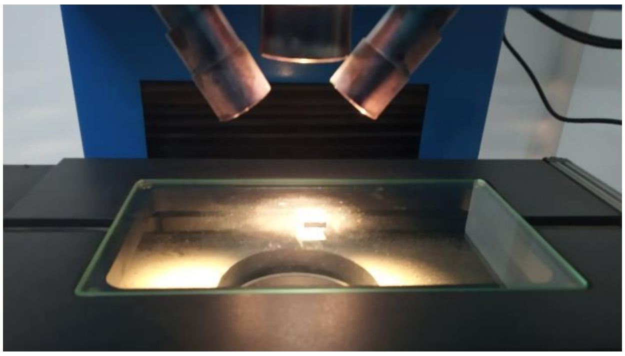
Note: The surface roughness is measured on different places of the turned surface and an average of the values is taken as the final Surface Roughness.

8.7 TOOL WEAR MEASUREMENT

Tool Wear is measured using a **Profile Projector**.

8.7.1 PROCEDURE

1. The profile projector is turned on.
2. The carbide insert is placed on the platform of the profile projector.
3. The side of the tool is made to coincide with the crosshair of the instrument and values of angles of x, y and z axes shown on the display is set to zero.
4. Now the crosshair is adjusted such that it lies on the worn out surface of the tool.
5. The angle between the initial and final position is noted. Also the breadth and height of the worn out portion of the tool is noted
6. The area of the worn out portion of the tool is a direct measure of the tool wear.



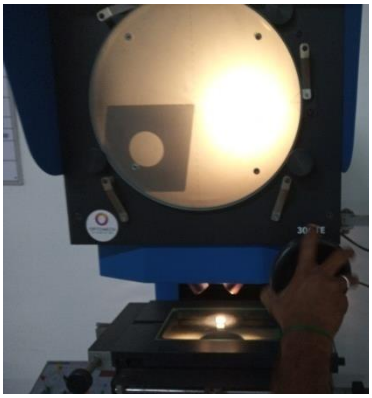


Fig 8.8

Fig 8.9

8.7.2 MODEL CALCULATION

Angle Measured θ = 0°52’06”

Breadth = 0.05 mm

Height = 0.152 mm

Area = (Breadth * Height)/2

Tool Wear Area = (0.05*0.152)/2 = 0.0038 mm^2

Note: The worn out area of the carbide tool insert is considered as tool wear to simplify the calculation, because as tool wear increases the area of the worn out portion increases.

CHAPTER 9

ANALYSIS AND RESULTS

9.1 RESULTS OBTAINED

The results that we obtained from the experiment is given in the form of an excel sheet. The different values of speed, feed and depth of cut and heir corresponding values of cutting force, tool wear and surface roughness is shown in this table.

Feed(mm/min)	Speed(RPM)	Depth of Cut(mm)	Fx(N)	Fy(N)	Fz(N)	Resultant Force(N)	Tool Wear(Theta)	Tool Wear(mm^2)	Surface Roughness(um)
50	140	0.25	9.807	29.421	19.614	21.929	0'52'06'	0.0038	0.501
50	200	0.5	19.614	39.228	29.421	35.359	2'06'27'	0.0075	0.671
50	250	0.75	29.421	68.649	29.421	41.607	2'56'29'	0.0285	0.828
50	140	0.5	19.614	49.035	39.228	43.858	1'12'57'	0.015	0.701
50	200	0.75	29.421	68.649	39.228	49.035	2'16'52'	0.0092	0.724
50	250	0.25	19.614	58.842	49.035	52.512	2'38'25'	0.0049	0.427
60	140	0.25	9.807	39.228	39.228	40.435	1'18'30'	0.0053	0.61
60	200	0.5	19.614	49.035	49.035	52.812	3'38'09'	0.0101	0.81
60	250	0.75	39.228	88.263	49.035	62.795	7'39'59'	0.0652	0.973
60	140	0.5	19.614	49.035	39.228	43.858	1'59'30'	0.0195	0.822
60	200	0.75	39.228	78.456	49.035	62.795	5'05'40'	0.0212	0.973
60	250	0.25	9.807	39.228	39.228	40.435	3'38'52'	0.0064	0.597
70	140	0.25	9.807	29.421	39.228	40.435	2'43'17'	0.0062	1.231
70	200	0.5	19.614	58.842	39.228	43.858	6'33'56'	0.0175	1.174
70	250	0.75	69.649	88.263	49.035	85.178	8'48'44'	0.0834	1.655
70	140	0.5	19.614	58.842	39.228	43.858	2'56'29'	0.0216	1.346
70	200	0.75	39.228	78.456	49.035	62.795	6'11'09'	0.0231	1.434
70	250	0.25	9.807	29.421	39.228	40.435	4'58'03'	0.015	0.981

Fig 9.1

The final step of the project is to perform statistical analysis on the results obtained from experimentation. Response Surface Methodology has been used in this case to understand the relationship among the variables and establish the significance of the model.

9.2 RESPONSE SURFACE METHODOLOGY

Response Surface Methodology (RSM) explores the relationship between several explanatory variables and a few response variables. It is a statistical process that was introduced by George E.P. Box and K.B. Wilson in 1951. The core idea of Response Surface Methodology is to use a sequence of designed experiments to obtain an optimal response. Basically it determines how explanatory variables affect response variables.

9.3 SOFTWARE USED

Design Expert is the software used to perform the Response Surface Methodology.

9.3.1 DESIGN EXPERT

Design- Expert is a statistical software package from Stat-Ease Inc. that is specifically dedicated to performing design of experiments. Design Expert offers optimization and establishes the significance of the model. It also provides the 3D graphs that show the relationship among various factors. Statistical Significance of these factors is established with Analysis of Variance (ANOVA).

9.3.2 BOX-BEHNKEN DESIGN

Box-Behnken designs are used in the software to effect Response Surface Methodology. Box-Behnken designs are experimental designs for Response Surface Methodology (RSM). It is statistical process devised by George E.P. Box and Donald Behnken in 1960 to achieve the two goals:

- Every factor is placed at one of the three equally spaced values. The values are typically -1, 0 and 1.

- The design should be enough to fit a quadratic model. A quadratic model contains squared terms, product of two factors, linear terms and an intercept.

A Box Behnken design for 3 factors involves three blocks, in each of which 2 factors are varied through the 4 possible combinations of high and low.

9.3.3 METHODOLOGY

Response Surface Methodology is done for each output factor separately using Design Expert Software. The Taguchi Table results obtained from experimentation is used as the input in the software to employ Box Behnken design type of analysis. Each output factor needed to be analyzed is separately dealt with to analyze its relationship with the input factors.

9.4 PROCEDURE

1. The Design Expert Software is opened
2. Response Surface Methodology (RSM) is selected.
3. Box-Behnken design analysis is chosen.
4. Now, the parameters to be inputted are chosen.
5. The appropriate notation for each input parameters is entered.
6. The output parameter is chosen.
7. The notation for the output factor is entered.
8. The respective units of the input and the output factors are entered.
9. The number of iterations is chosen.
10. Now, values of input parameters of all the iterations are entered from the Taguchi table results obtained from experiments.
11. The values of output parameter for the respective combination of the input values are also entered.
12. Now optimization is done by including or excluding various parameters to find the model that is most significant and the model that has the R-square value closest to unity.
13. The final equation in terms of coded factors is obtained.
14. The final equation in terms of actual factors is also obtained.
15. The graphs showing variation of an output parameter with two of the input parameters are obtained to draw reference from them.
16. The same procedure is repeated for all other factors.

9.4.1 R^2SIGNIFICANCE

$R^2$is termed coefficient of determination. The coefficient of determination $R^2$is a measure of closeness of the response data to the fitted regression model. The closer the value of $R^2$is to unity, the better the response equations fit the measured data. The optimization is done to find the equation that presents the closest R^2value to unity.

9.4.2 PREDICTED R^2 VALUE

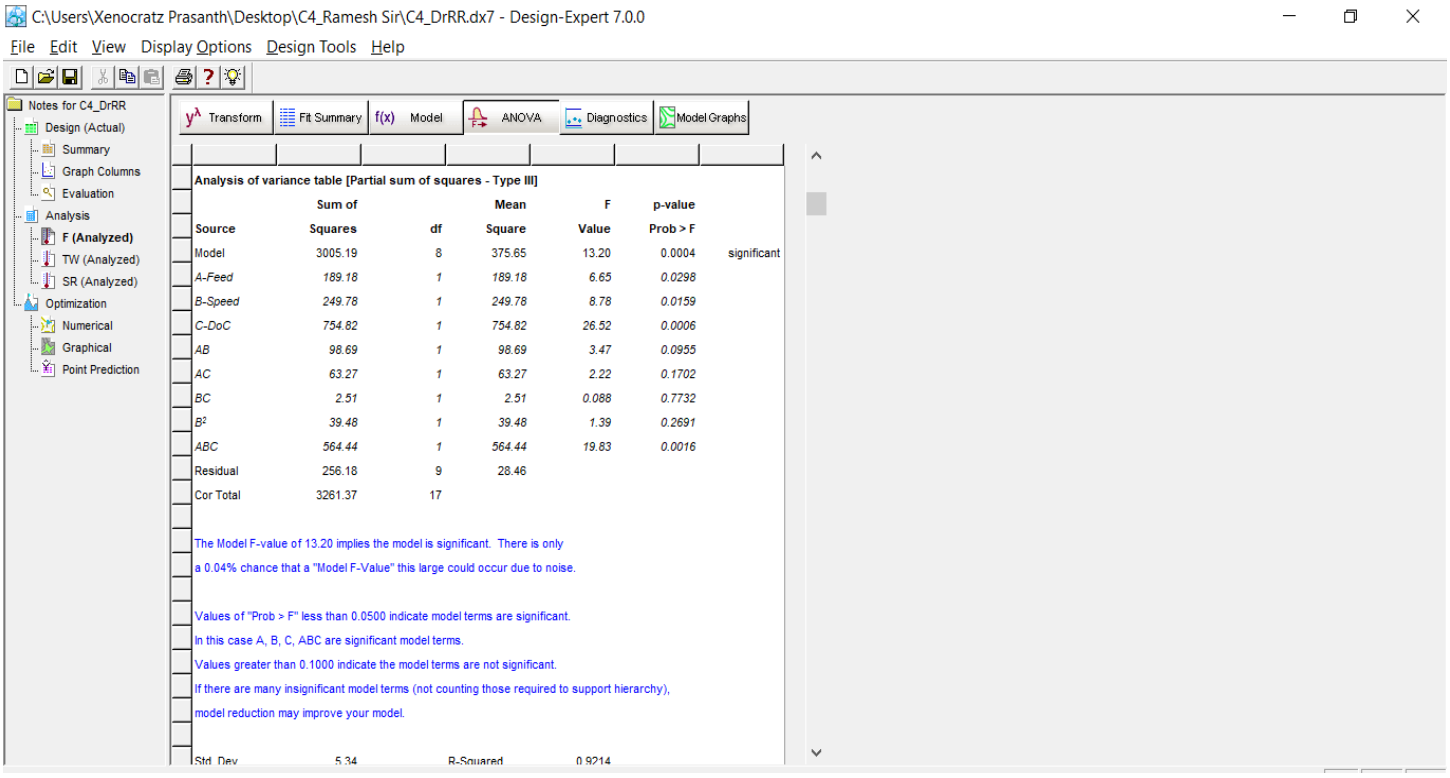
The Predicted R^2value indicates the ability of the fitted regression model to predict responses for new observations. The degree of correctness of the values obtained when new input factors are fitted in the equation to obtain

9.4.3 PREDICTED R^2 AND ADJUSTEDR^2

The close proximity of Predicated $R^2$with the value of Adjusted R^2indicates the ability of the regression model to predict new observation results.

9.5 CUTTING FORCE

First the cutting force parameter is analyzed. The results obtained are as follows:



Analysis of variance table [Partial sum of squares - Type III]

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	3005.19	8	375.65	13.20	0.0004	significant
A-Feed	189.18	1	189.18	6.65	0.0298	
B-Speed	249.78	1	249.78	8.78	0.0159	
C-DoC	754.82	1	754.82	26.52	0.0006	
AB	98.69	1	98.69	3.47	0.0955	
AC	63.27	1	63.27	2.22	0.1702	
BC	2.51	1	2.51	0.088	0.7732	
B^2	39.48	1	39.48	1.39	0.2691	
ABC	564.44	1	564.44	19.83	0.0016	
Residual	256.18	9	28.46			
Cor Total	3261.37	17				

The Model F-value of 13.20 implies the model is significant. There is only
a 0.04% chance that a "Model F-Value" this large could occur due to noise.

Values of "Prob > F" less than 0.0500 indicate model terms are significant.
In this case A, B, C, ABC are significant model terms.
Values greater than 0.1000 indicate the model terms are not significant.
If there are many insignificant model terms (not counting those required to support hierarchy),
model reduction may improve your model.

Std. Dev. 5.34 R-Squared 0.9214

Fig 9.2

ANOVA results indicate that the model with a p-value of 0.0004 indicates that the model is significant. It shows that there is only a 0.04% chance that a "Model F-value this large could occur due to noise. The significance of the model indicates the degree of conformance of the measured values as per ANOVA.

The next important result is the values of R^2, Predicted R^2 and AdjustedR^2. In this case, the value of R^2 is found to be 0.9214 which is close to unity. As mentioned earlier the coefficient of determination R^2 value's closeness to unity indicates generation of good response equations.

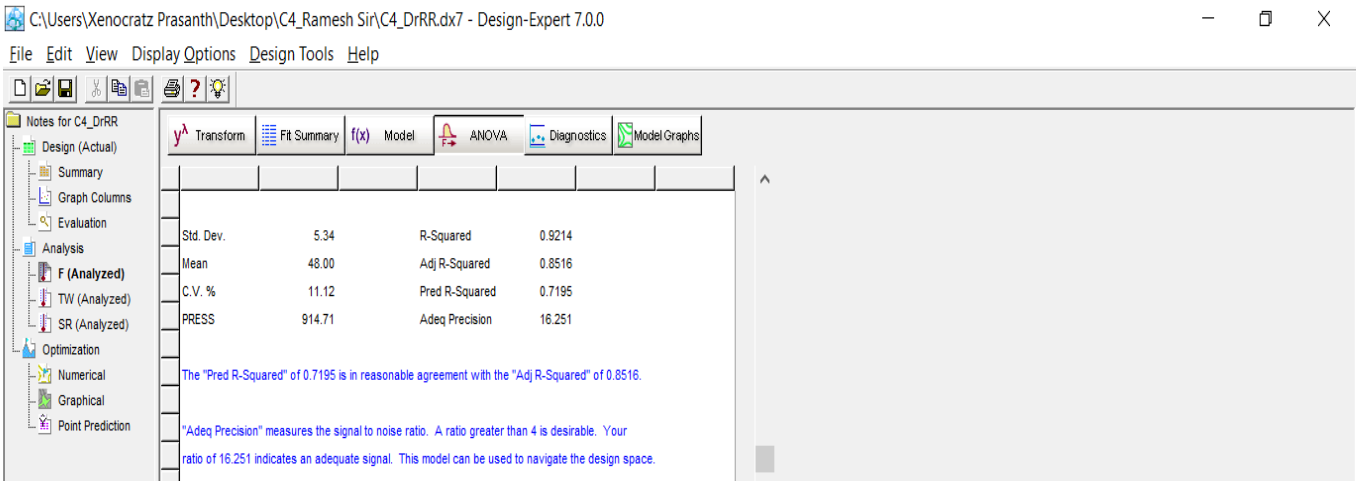


Fig 9.3

The value of Predicted R^2 is found to be 0.7195 and Adjusted R^2 is found to be 0.8516.

The "Predicted R-Squared" of 0.7195 is found to be in reasonable agreement with the "Adjusted R-Squared" of 0.8156.

All these results indicate that the model is not only significant but is also capable of predicting the values of cutting force for various combinations of Speed, Feed and Depth of Cut.

9.5.1 FINAL EQUATION IN TERMS OF CODED AND ACTUAL FACTORS

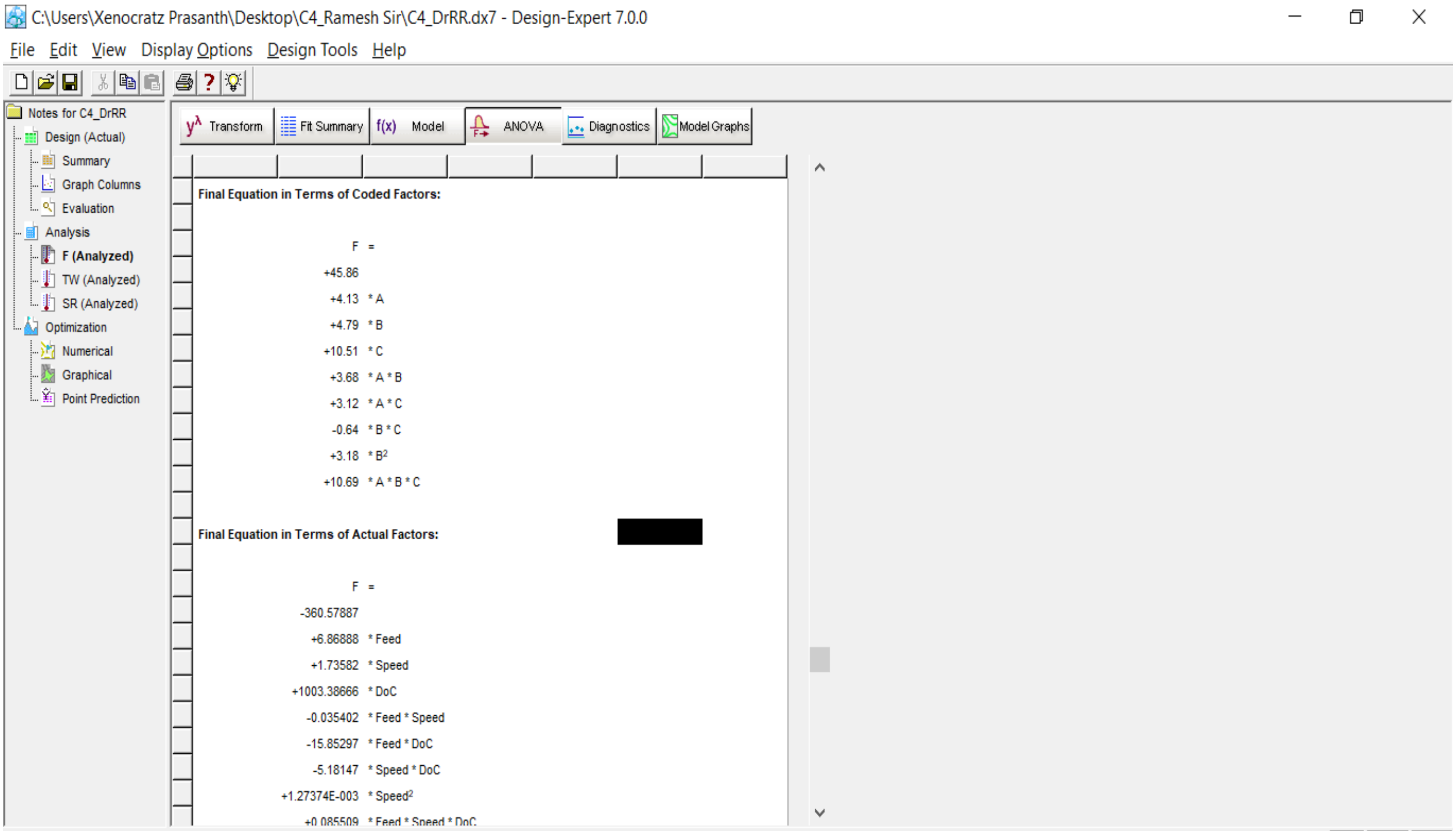


Fig 9.4

These equations are helpful in finding the value of cutting force for any combination of feed (A), speed (B) and depth of cut (C). The equation in terms of coded factors gives an approximate value but is easier to calculate. The equation with actual factors will provide the actual value for the combinations. It is to be noted that these general equations are suitable and applicable only to the experiments that has similar conditions, tools and machines as the experiment performed to obtain the values in the first place.

9.5.2 GRAPHICAL RESULTS AND INTERPRETATION

9.5.2.1 FEED (A) vs SPEED (B) vs CUTTING FORCE (F)

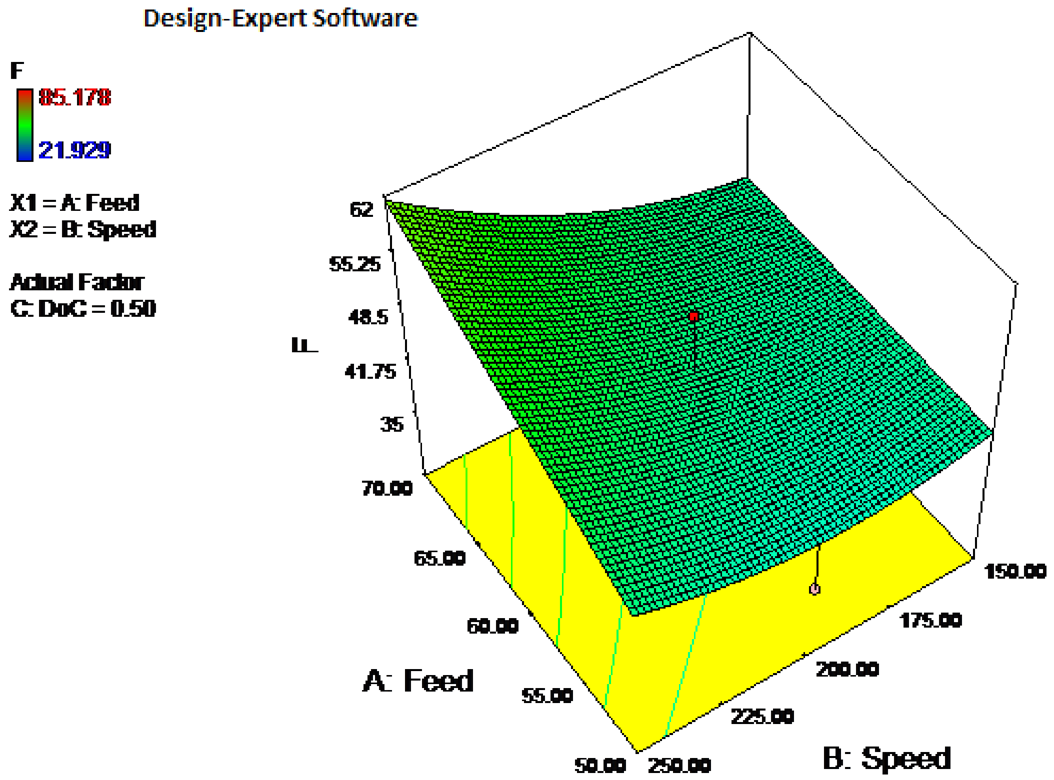


Fig 9.5

This graph indicates that the Cutting force is maximum at maximum speed and at maximum feed. The minimum cutting force corresponds to minimum feed and minimum speed. It is also inferred that the cutting force increases linearly with increase in the feed. And it is to be noted that cutting force increases gradually with the increase in speed. At higher speeds, there is a sharp increase in cutting force with increasing feeds than at lower speeds. At higher feeds, cutting speed increases more gradually with speed than at lower feeds. All these conform to the accepted changes with increase in feeds and speeds.

9.5.2.2 FEED (A) vs DEPTH OF CUT (B) vs CUTTING FORCE (F)

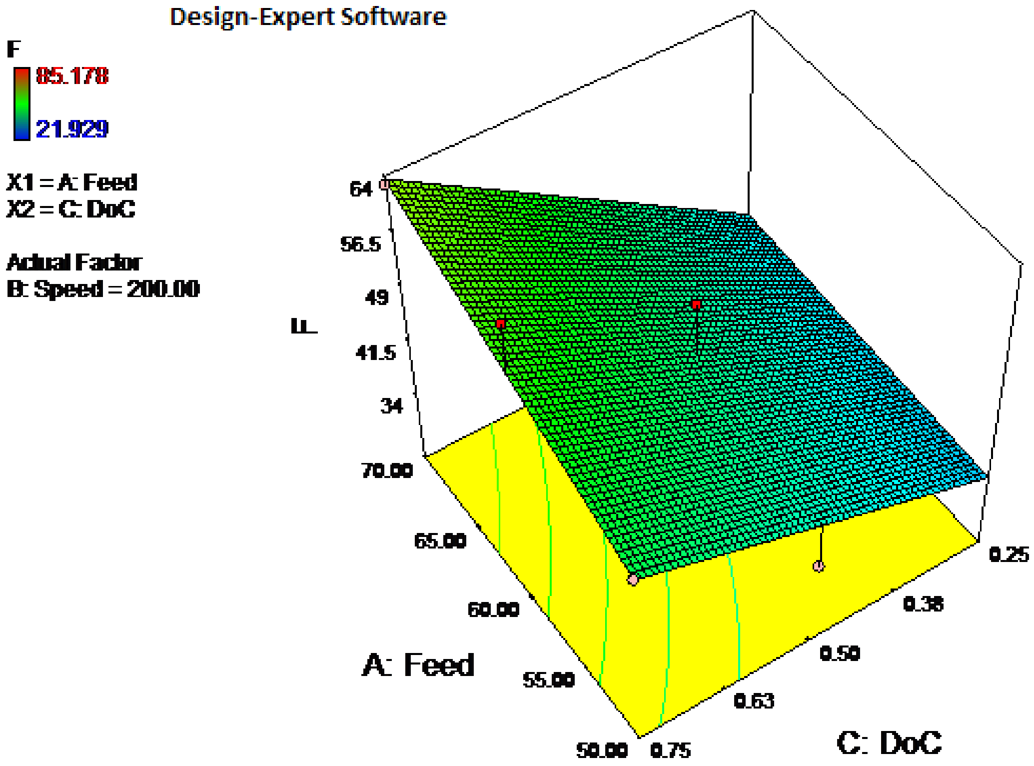


Fig 9.6

This graph shows that maximum cutting force occurs at maximum Depth of Cut and at maximum feed. And also the minimum cutting force occurs at a point when the Depth of Cut and feed are at their minimum. The cutting force increases linearly with increase in feed. It also shows that Cutting force increases linearly with increase in Depth of cut. At higher Depth of Cuts, there is a sharp increase in the cutting force with increase in Feed in comparison to lower DOC's. At higher feeds, cutting force increases appreciably with increase in DOC's as when compared to lower feeds.

9.5.2.3 SPEED (B) vs DEPTH OF CUT (C) vs CUTTING FORCE (F)

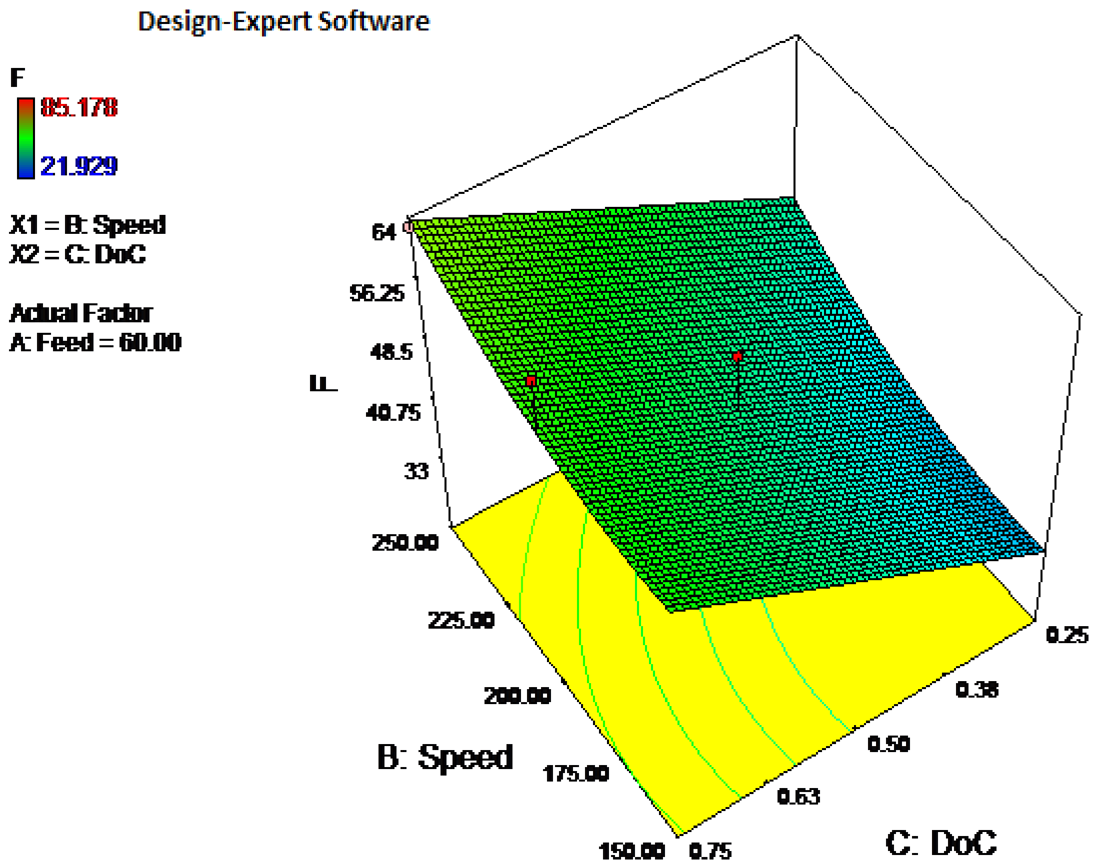
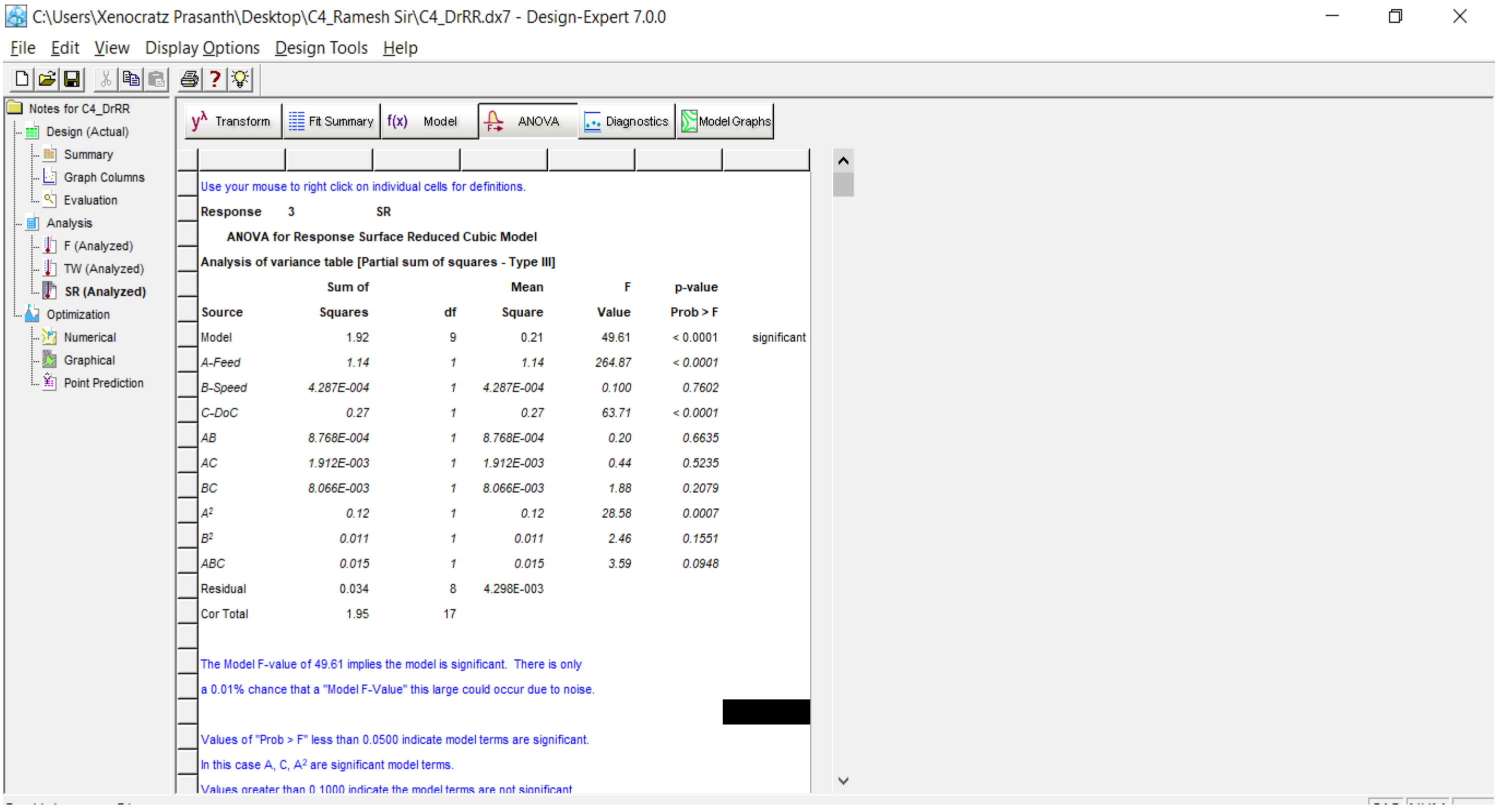


Fig 9.7

This graph indicates that the Cutting force is maximum at maximum speed and at maximum Depth of Cut. The minimum cutting force corresponds to minimum DOC and minimum speed. It is also inferred that the cutting force increases linearly with increase in the DOC. And it is to be noted that cutting force increases gradually with the increase in speed. All these conform to the accepted changes with increase in feeds and speeds.

9.6 SURFACE ROUGHNESS

Next, the Surface Roughness parameter is chosen and analyzed. The following results are obtained:



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File Edit View Display Options Design Tools Help

Notes for C4_DrRR | Design (Actual) | Summary | Graph Columns | Evaluation | Analysis | F (Analyzed) | TW (Analyzed) | SR (Analyzed) | Optimization | Numerical | Graphical | Point Prediction

Transform | Fit Summary | f(x) Model | ANOVA | Diagnostics | Model Graphs

Use your mouse to right click on individual cells for definitions.

Response 3 SR

ANOVA for Response Surface Reduced Cubic Model

Analysis of variance table [Partial sum of squares - Type III]

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	1.92	9	0.21	49.61	< 0.0001	significant
A-Feed	1.14	1	1.14	264.87	< 0.0001	
B-Speed	4.287E-004	1	4.287E-004	0.100	0.7602	
C-DoC	0.27	1	0.27	63.71	< 0.0001	
AB	8.768E-004	1	8.768E-004	0.20	0.6635	
AC	1.912E-003	1	1.912E-003	0.44	0.5235	
BC	8.066E-003	1	8.066E-003	1.88	0.2079	
A^2	0.12	1	0.12	28.58	0.0007	
B^2	0.011	1	0.011	2.46	0.1551	
ABC	0.015	1	0.015	3.59	0.0948	
Residual	0.034	8	4.298E-003			
Cor Total	1.95	17				

The Model F-value of 49.61 implies the model is significant. There is only a 0.01% chance that a "Model F-Value" this large could occur due to noise.

Values of "Prob > F" less than 0.0500 indicate model terms are significant.
In this case A, C, A^2 are significant model terms.
Values greater than 0.1000 indicate the model terms are not significant

Fig 9.8

ANOVA results indicate that the model with a p-value of <0.0001 indicates that the model is significant. It shows that there is only a 0.01% chance that a “Model F-value” this large could occur due to noise. The significance of the model indicates the degree of conformance of the measured values as per ANOVA.

The next important result is the values of R^2, Predicted $R^2$and Adjusted R^2. In this case, the value of R^2 is found to be 0.9824 which is close to unity. As mentioned earlier the coefficient of determination R^2 value's closeness to unity indicates generation of good response equations.

The value of Predicated R^2 is found to be 0.8822 and Adjusted R^2 is found to be 0.9626. The "Predicted R-Squared" of 0.8822 is found to be in reasonable agreement with the "Adjusted R-Squared" of 0.9626.

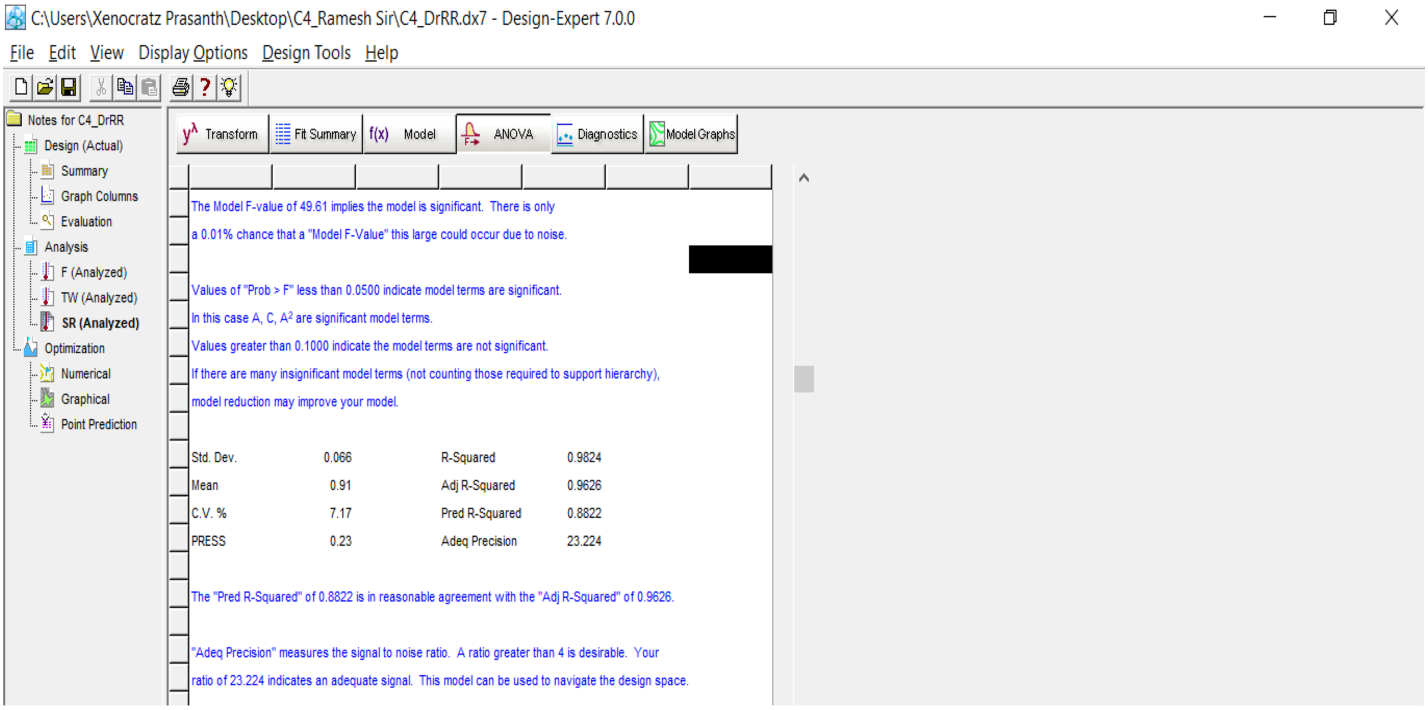
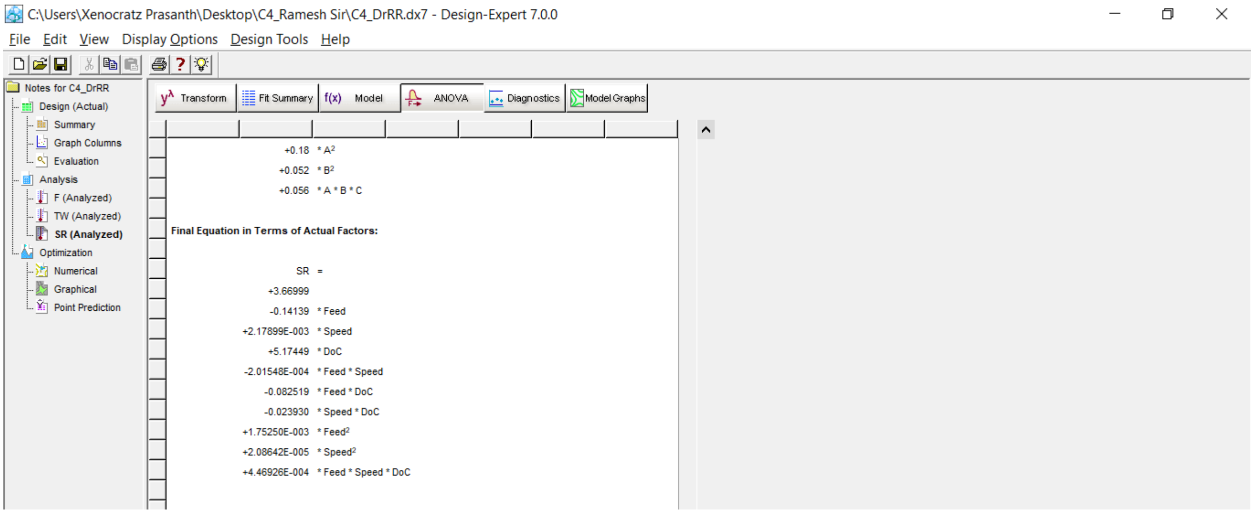


Fig 9.9

All these results indicate that the model is not only significant but is also capable of predicting the values of Surface Roughness for various combinations of Speed, Feed and Depth of Cut.

9.6.1 FINAL EQUATION IN TERMS OF CODED AND ACTUAL FACTORS



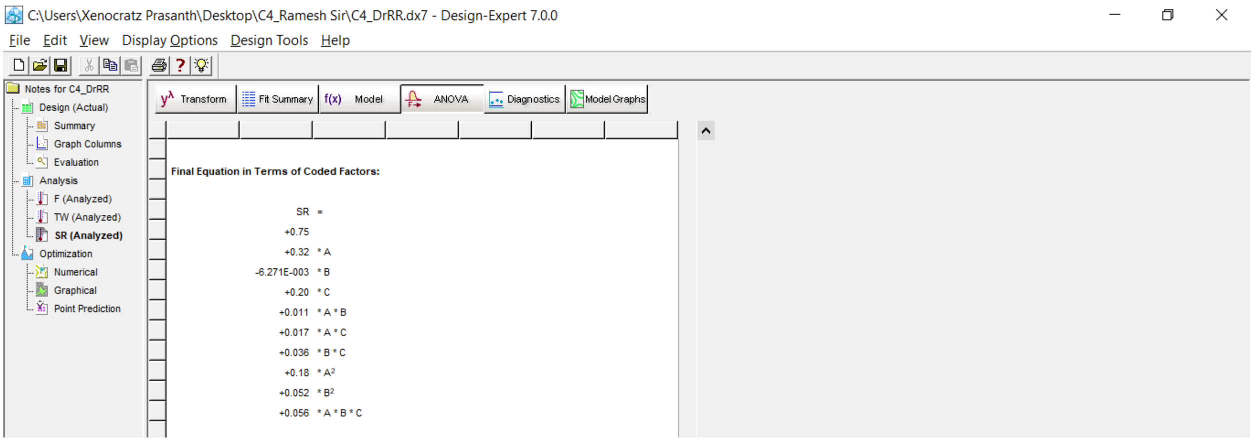


Fig 9.10

These equations are helpful in finding the value of Surface Roughness for any combination of feed (A), speed (B) and depth of cut (C). The equation in terms of coded factors gives an approximate value but is easier to calculate. The equation with actual factors will provide the actual value for the combinations. It is to be noted that these general equations are suitable and applicable only to the experiments that has similar conditions, tools and machines as the experiment performed to obtain the values in the first place.

9.6.2 GRAPHICAL RESULTS AND INTERPRETATION

9.6.2.1 FEED (A) vs SPEED (B) vs SURFACE ROUGHNESS (SR)

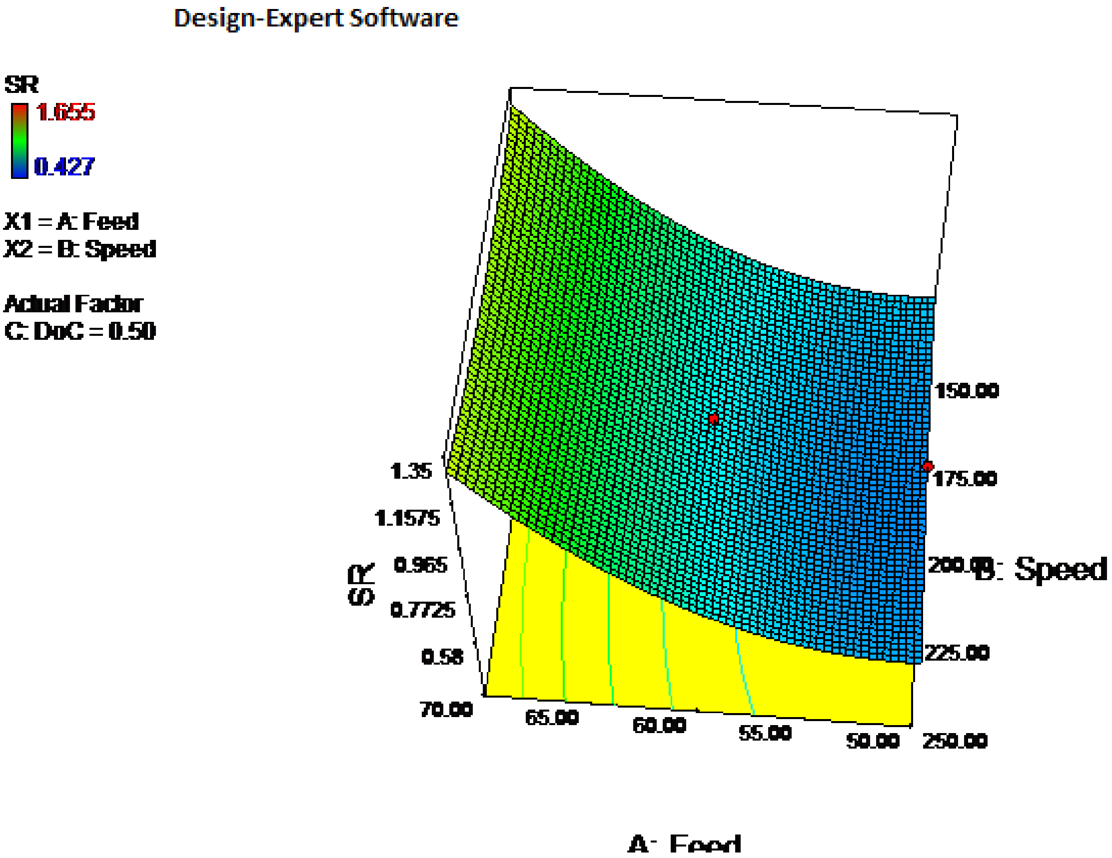


Fig 9.11

This graph indicates that the Surface Roughness is maximum at minimum speed and at maximum feed. The minimum Surface Roughness corresponds to minimum feed and minimum speed. It is also inferred that the Surface Roughness increases in a quadratic fashion with increase in the feed. This shows that feed value has a considerable impact on the Surface Roughness. And it is to be noted that Surface Roughness remains more or less constant with the increase in speed. It indicates that speed doesn't affect surface roughness appreciably compared to feed.

9.6.2.2 FEED (A) vs DEPTH OF CUT (C) vs SURFACE ROUGHNESS (SR)

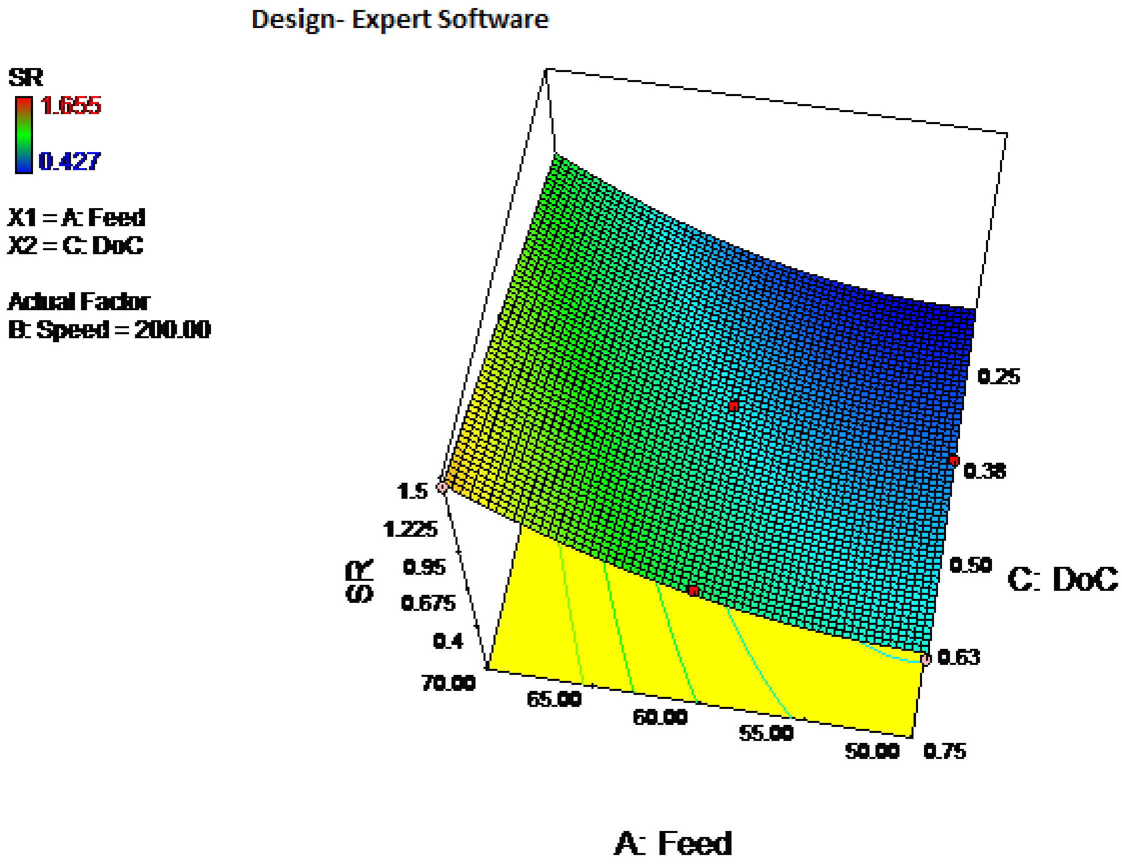


Fig 9.12

This graph shows that maximum Surface Roughness occurs at maximum Depth of cut and at maximum feed. And also the minimum Surface Roughness occurs at a point when the speed and feed are at their minimum. The Surface Roughness increases gradually with increase in feed. It also shows that Surface Roughness increases linearly with increase in Depth of cut but the increase is not too high as observed with Cutting force. At higher feeds, Surface Roughness increases more appreciably with increase in DOC's as when compared to lower feeds.

9.6.2.3 SPEED (B) vs DEPTH OF CUT (C) vs SURFACE ROUGHNESS (SR)

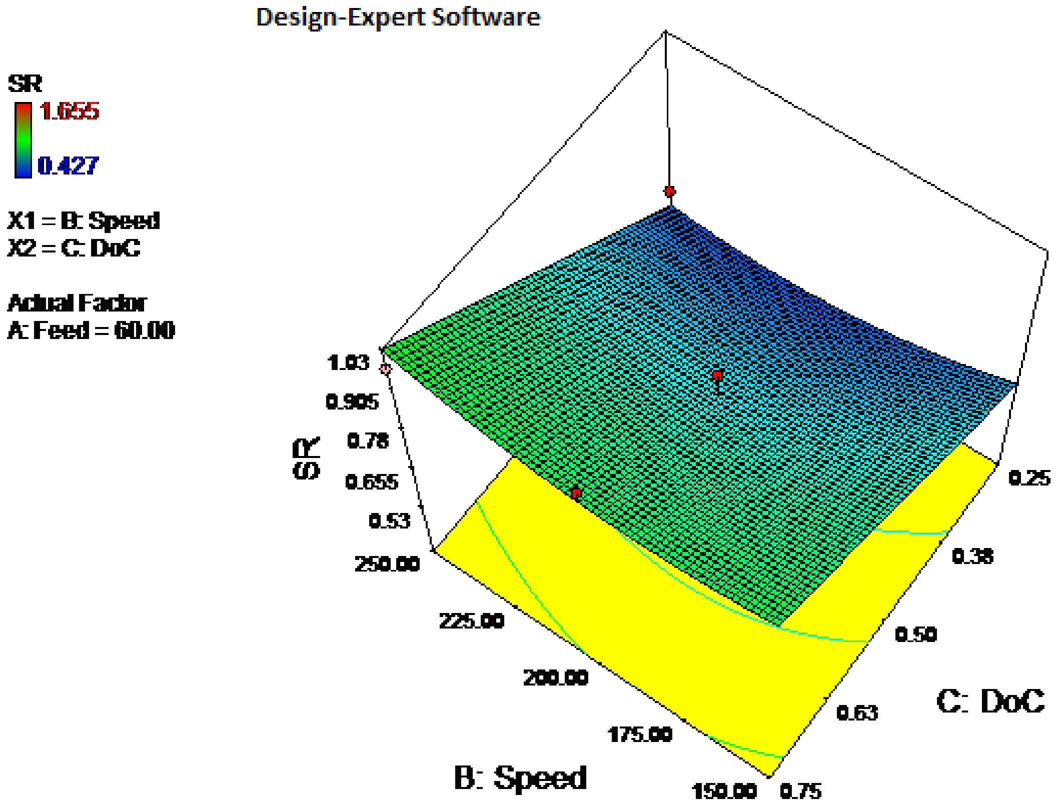
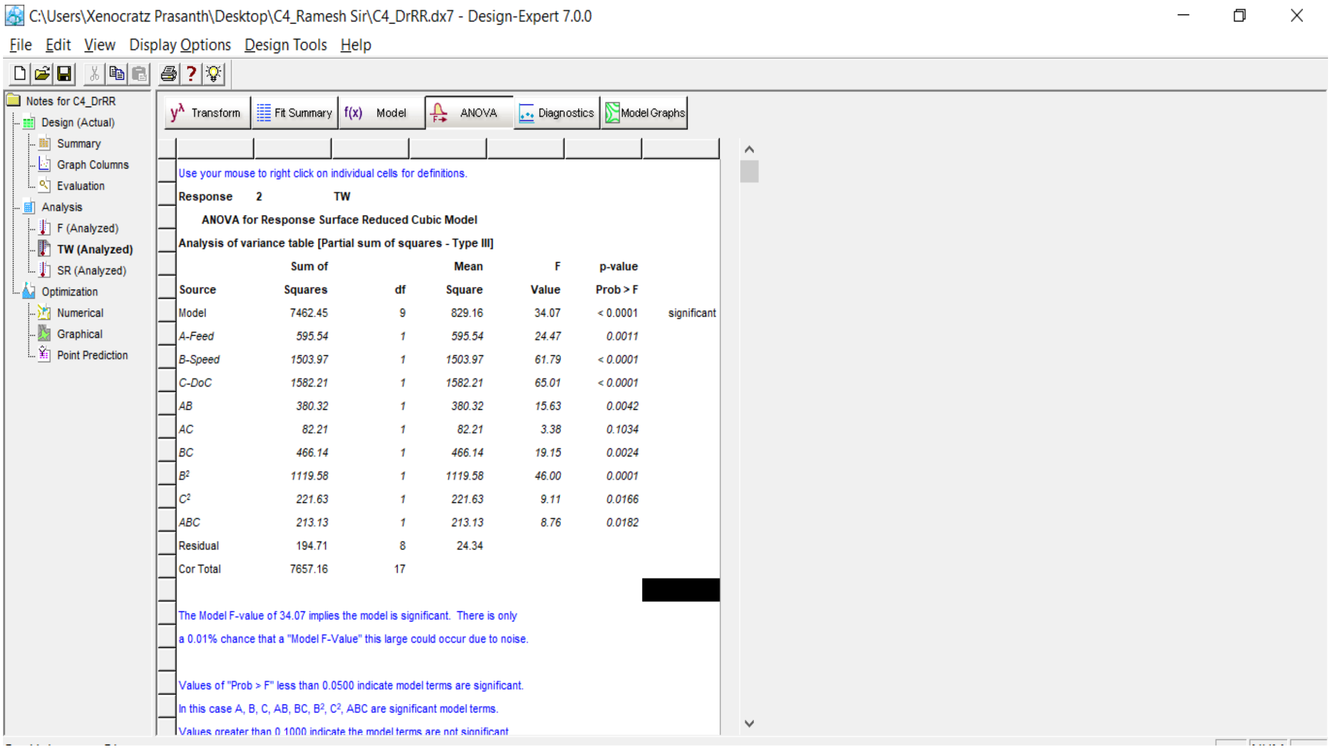


Fig 9.13

The graph indicates that the maximum Surface Roughness occurs at maximum speed and at maximum Depth of cut. The minimum SR value is obtained at maximum speed and at minimum Depth of Cut. The Surface Roughness increases with increase in Depth of cut. This shows that good Surface Finish can be obtained at minimum Depth of cut.

9.7 TOOL WEAR

Now the tool wear parameter is chosen and analyzed. The following results are obtained.



Use your mouse to right click on individual cells for definitions.

Response 2 TW

ANOVA for Response Surface Reduced Cubic Model

Analysis of variance table [Partial sum of squares - Type III]

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	7462.45	9	829.16	34.07	< 0.0001	significant
A-Feed	595.54	1	595.54	24.47	0.0011	
B-Speed	1503.97	1	1503.97	61.79	< 0.0001	
C-DoC	1582.21	1	1582.21	65.01	< 0.0001	
AB	380.32	1	380.32	15.63	0.0042	
AC	82.21	1	82.21	3.38	0.1034	
BC	466.14	1	466.14	19.15	0.0024	
B^2	1119.58	1	1119.58	46.00	0.0001	
C^2	221.63	1	221.63	9.11	0.0166	
ABC	213.13	1	213.13	8.76	0.0182	
Residual	194.71	8	24.34			
Cor Total	7657.16	17				

The Model F-value of 34.07 implies the model is significant. There is only a 0.01% chance that a "Model F-Value" this large could occur due to noise.

Values of "Prob > F" less than 0.0500 indicate model terms are significant.
In this case A, B, C, AB, BC, B^2, C^2, ABC are significant model terms.
Values greater than 0.1000 indicate the model terms are not significant.

Fig 9.14

ANOVA results indicate that the model with a p-value of <0.0001 indicates that the model is significant. It shows that there is only a 0.01% chance that a “Model F-value this large could occur due to noise. The significance of the model indicates the degree of conformance of the measured values as per ANOVA.

The next important result is the values of R^2, Predicted R^2 and Adjusted R^2. In this case, the value of R^2 is found to be 0.9746 which is close to unity. As mentioned earlier the coefficient of determination R^2value's closeness to unity indicates generation of good response equations.

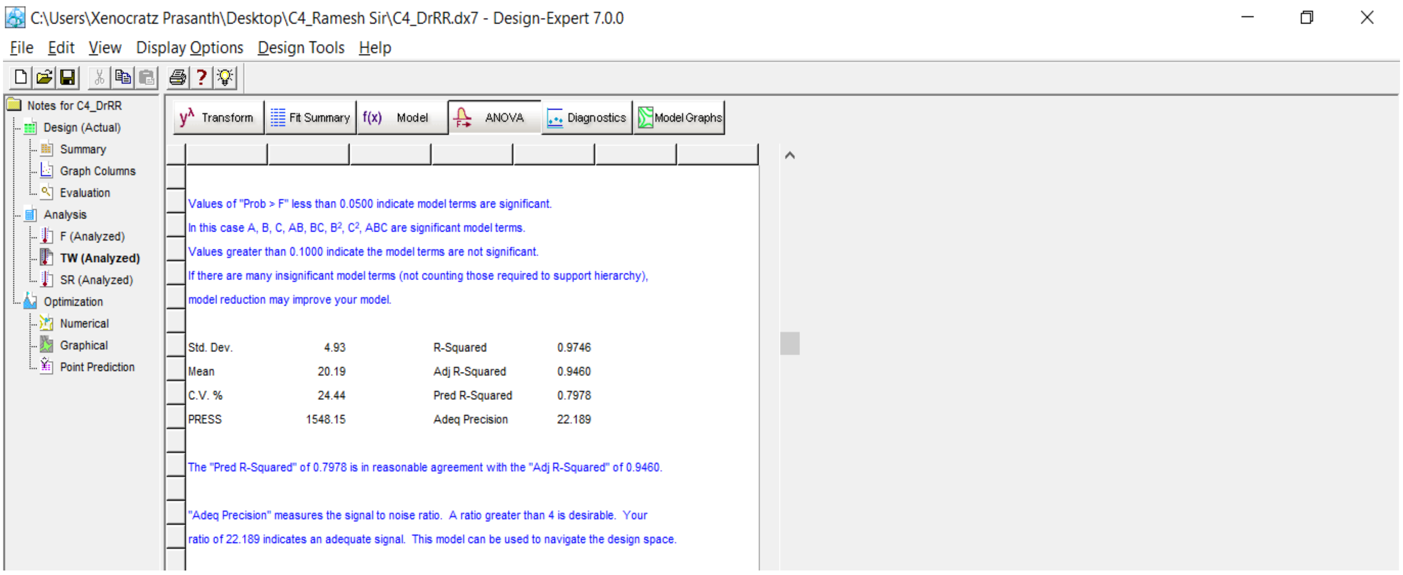


Fig 9.15

The value of Predicated $R^2$is found to be 0.7976 and Adjusted R^2 is found to be 0.9460. The "Predicted R-Squared" of 0.7976 is found to be in reasonable agreement with the "Adjusted R-Squared" of 0.9460.

All these results indicate that the model is not only significant but is also capable of predicting the values of tool wear for various combinations of Speed, Feed and Depth of Cut.

9.7.1 FINAL EQUATION IN TERMS OF CODED AND ACTUAL FACTORS

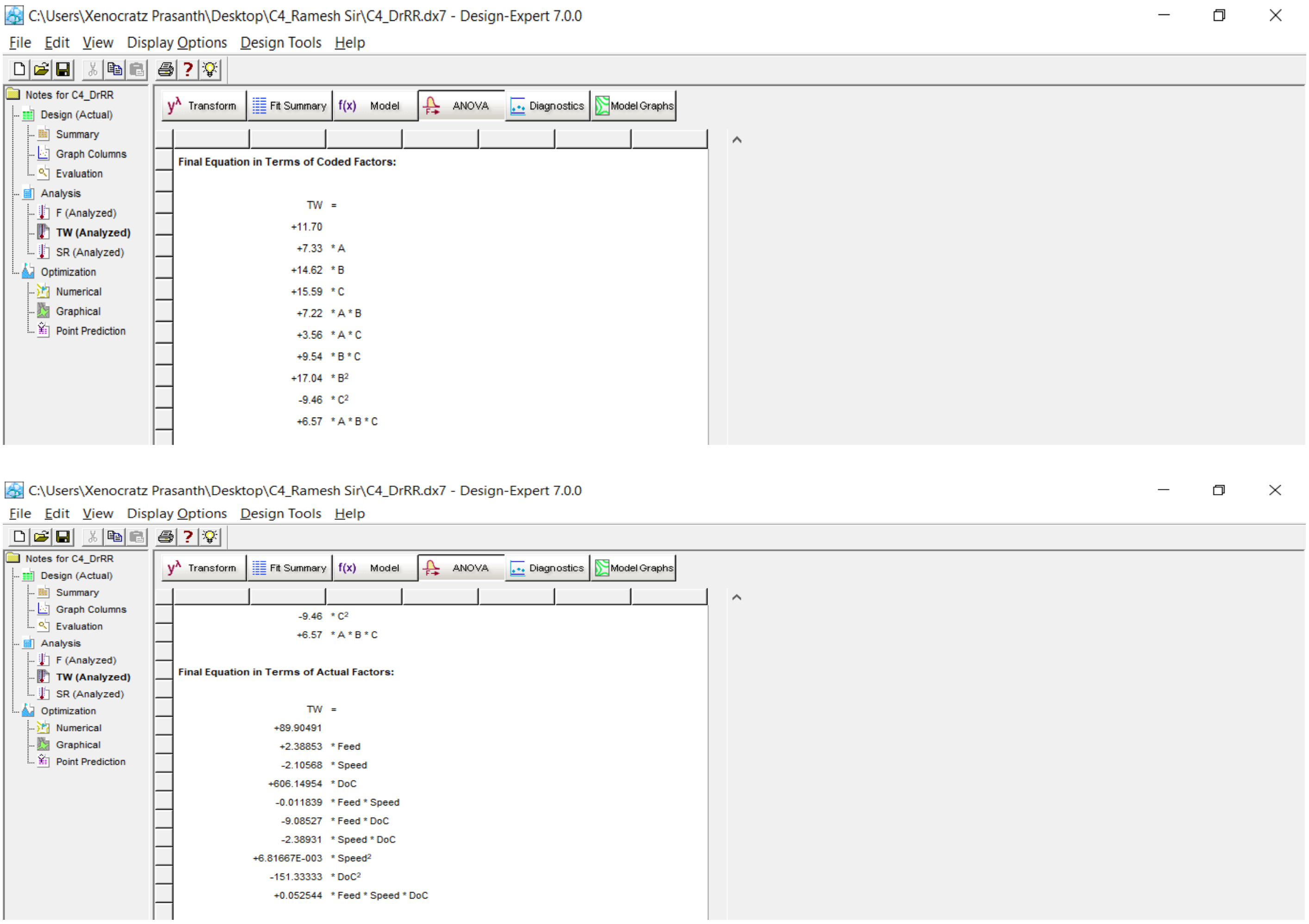


Fig 9.16

These equations are helpful in finding the value of tool wear for any combination of feed (A), speed (B) and depth of cut (C). The equation in terms of coded factors gives an approximate value but is easier to calculate. The equation with actual factors will provide the actual value for the combinations. It is to be noted that these general equations are suitable and applicable only to the experiments that has similar conditions, tools and machines as the experiment performed to obtain the values in the first place.

9.7.2 GRAPHICAL RESULTS AND INTERPRETATION

9.7.2.1 FEED(A) vs SPEED (B) vs TOOL WEAR (TW)

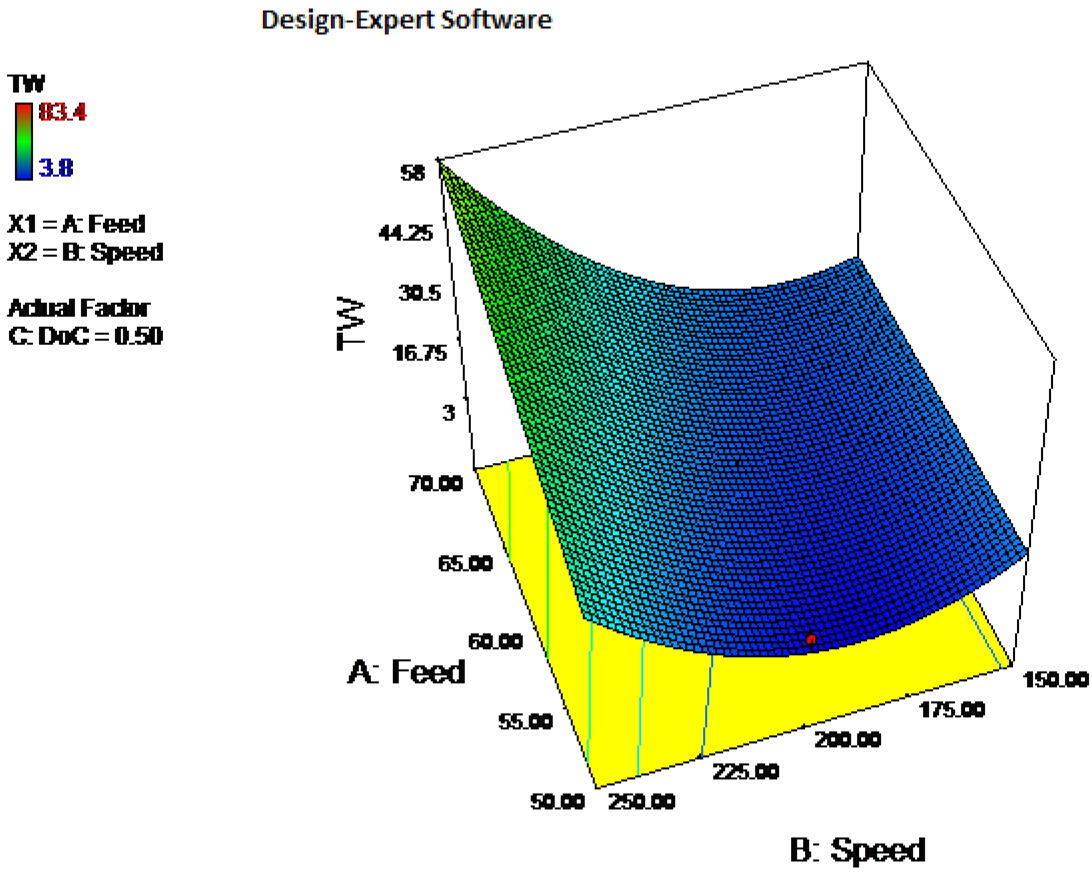


Fig 9.17

This graph indicates that the tool wear remains more or less the same with the increase in the feed and change is minimal. The tool wear initially decreases with increase in speed and then increases and attains the maximum value at maximum speed and at maximum feed. This might indicate a bigger role that the third parameter – Depth of Cut is playing.

9.7.2.2 FEED(A) vs DEPTH OF CUT (C) vs TOOL WEAR (TW)

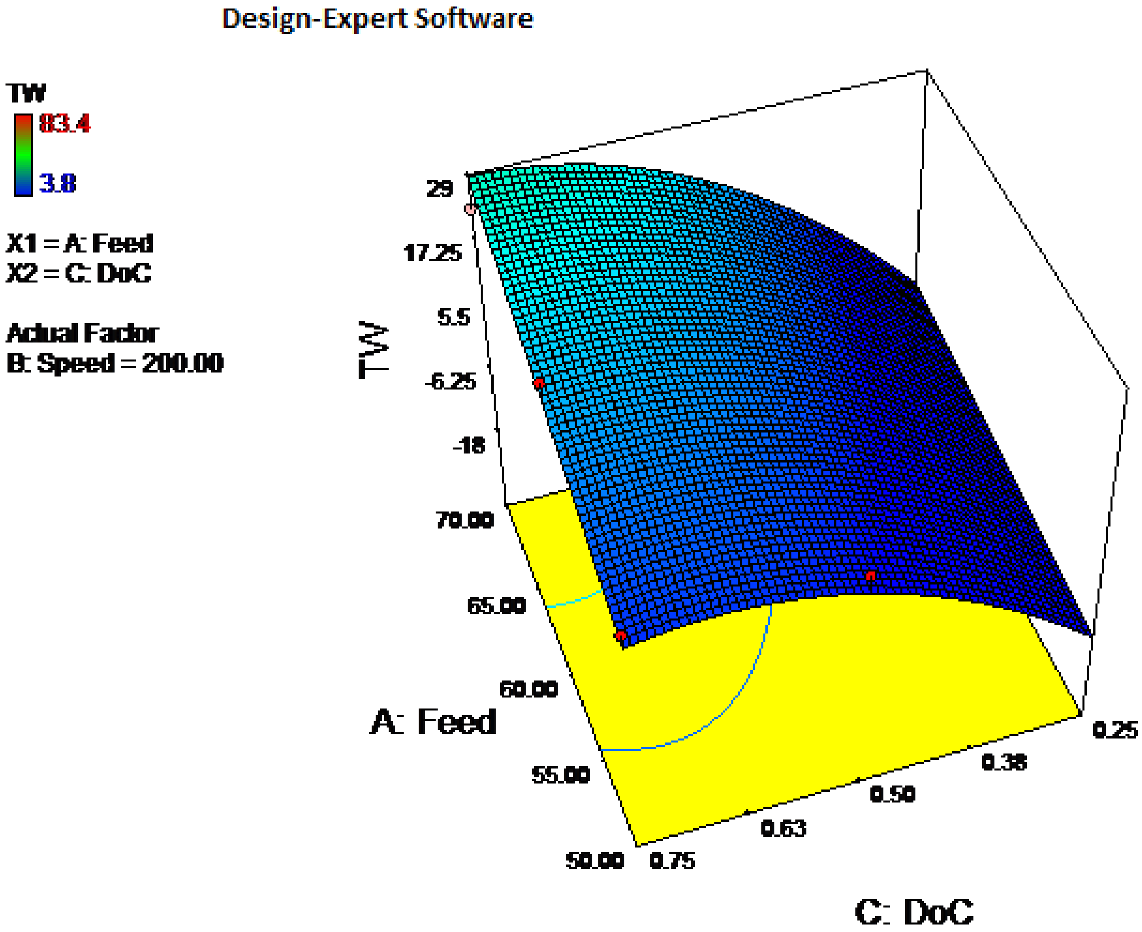


Fig 9.18

This graph indicates that the Tool Wear reflects little change with the increase in feed. But the tools wear increases sharply with increase in Depth of Cut. This shows that Depth of Cut heavily affects the tool wear. The maximum tool wear occurs at maximum feed and at maximum Depth of Cut. So to avoid high tool wear the Depth of Cut should be kept as low as possible.

9.7.2.3 SPEED (B) vs DEPTH OF CUT (C) vs TOOL WEAR (TW)

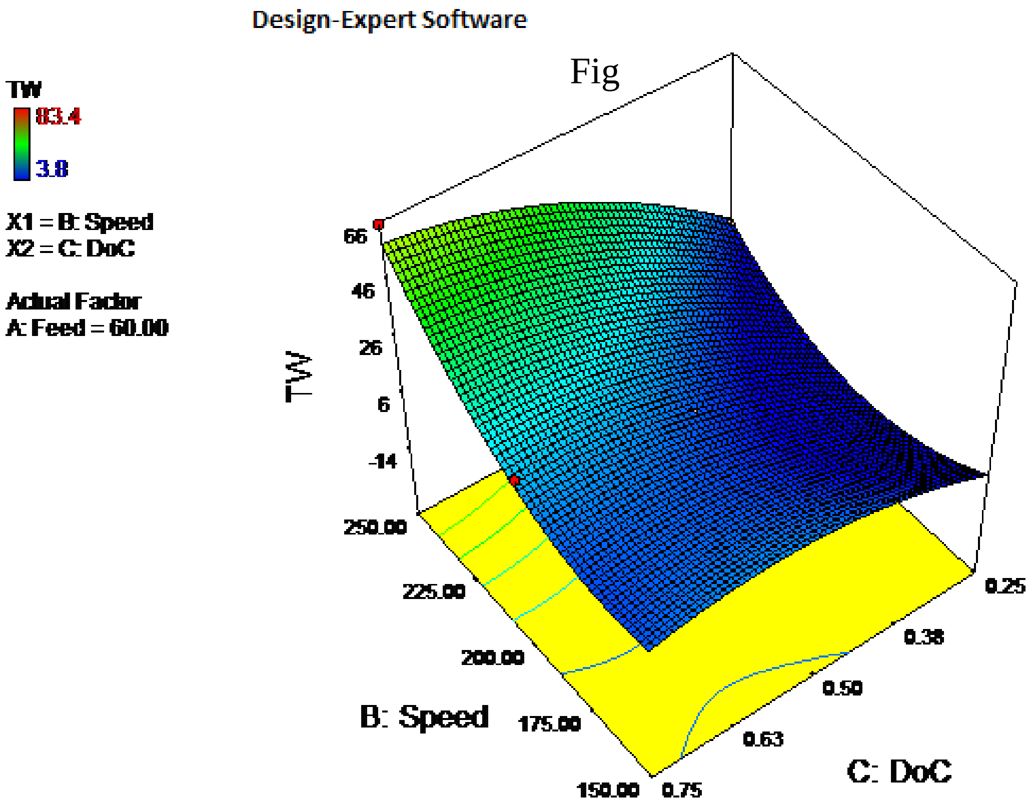


Fig 9.19

This graph indicates that the maximum tool wear occurs at maximum speed and at maximum Depth of Cut. The tool wear increases with increase in speed at higher Depth of Cuts. At lower Depth of Cuts, Tool Wear slightly decreases and then increases with increase in Speed. The tool wear increases more appreciably with increase in Depth of Cut at higher speeds than at lower speeds. Tool Wear is heavily influenced by Depth of Cut and is influenced to an extent by Speed and doesn't get influenced too much by Feed.

CHAPTER 10

CONCLUSION

In this project, the effect of varying three machining parameters namely speed, feed and depth of cut, on surface roughness, cutting force and tool wear during turning operation was studied.Following conclusions are drawn from experimental details.

- As depth of cut increases tangential cutting force acting on material is also increases, and vice-versa. Tangential cutting force acting on material increases with increase in Speed. Tangential cutting force acting on material is increases with increases in feed rate.
- As depth of cut increases Surface roughness of the material also increases, and vice-versa. Surface Roughness increases with increase in feed rate.
- As depth of cut increases Tool Wear increases, and vice-versa. Speed also plays a role in affecting tool wear while feed doesn't reflect any major changes in tool wear.

Thus with the help of the results, equations were developed for cutting force, tool wear and surface roughness, using the Design Expert software. With these equations one can arrive at the value of cutting force, tool wear, or surface roughness that will be developed if the operation is carried at any particular speed, feed and depth of cut and based on the results machining can be done according to the requirements.

CHAPTER 11

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