EFFECT OF CUTTING PARAMETERS ON EN19 STEEL UNDER DRY AND WET CONDITIONS BY USING RESPONSE SURFACE METHODOLOGY

Report submitted for the project

BACHELOR OF TECHNOLOGY IN MECHANICAL ENGINEERING

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CERTIFICATE

This is to certify that the Project Report entitled **"EFFECT OF CUTTING PARAMETERS ON EN19 STEEL UNDER DRY AND WET CONDITIONS BY USING RESPONSE SURFACE METHODOLOGY"** being submitted by PAILA SAI PRANEETH (317126520105), LENKA PRANAY KUMAR (318126520L15), KAMISETTI V V S VIJAY BABU (317126520085), CHITTIMURI ANANDKUMAR (318126520L18), DEVA SWARUP KADIYALA (317126520072) in partial fulfillments for the award of degree of **BACHELOR OF TECHNOLOGY** in **MECHANICAL ENGINEERING**. It is the work of bona-fide, carried out under the guidance and supervision of **MR.B.PRADEEP KUMAR**, Assistant Professor, Department Of Mechanical Engineering, ANITS during the academic year of 2017-2021.

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ABSTRACT

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

While machining a substance, it is desired to obtain maximum material removal rate and a good surface finish (i.e., lowest surface roughness) without generating high temperatures (as they lead to sour surface finish and tool failure). While machining en19 steel, inevitable consequences are arising due to unique properties of the material like low specific heat, tendency to strain harden e. t. c. This study mainly concentrates on comparing various effects of cutting parameters like speed, feed, and depth of cut on EN19 steel under dry and wet conditions. The observations temperature, type of chips formed, chip thickness ratio were made. The behavior of the above output parameters is compared at different input conditions by using response surface methodology(RSM).EN19 steel is widely used in automotive gears and parts, shafts, load-bearing tie rods.

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CHAPTER 1.INTRODUCTION

1.1 TURNING OPERATION

Turning is the removal of metal from the outer diameter of a rotating cylindrical work piece. Turning is used to reduce the diameter of the work piece, usually to a specified dimension, and produce a smooth finish on the metal. Often the work piece will be turned so that adjacent sections have different diameters. Turning is the machining operation that produces cylindrical parts. In its basic form, it can be defined as the machining of an external surface:

• With the work piece rotating.

• With a single-point cutting tool and

• With the cutting tool feeding parallel to the axis of the work piece and at a distance that will remove the outer surface of the work.

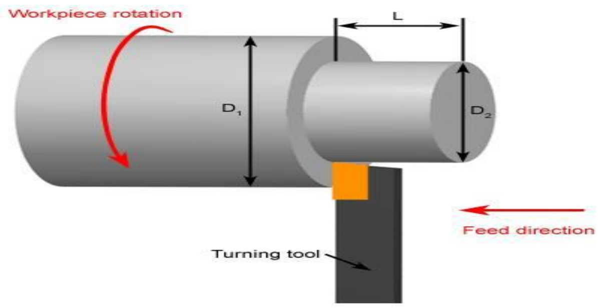


Figure 1.1: Adjustable parameters in turning operation

Taper turning is practically the same, except that the cutter path is at an angle to the work axis. Similarly, in contour turning, the distance of the cutter from the work axis is varied to produce the desired shape. Even though a single-point tool is specified, this does not exclude a multiple-tool setup as a single-point which is often employed in turning. In such setups, each tool will operate independently as a single cutting tool.

1.2 ADJUSTABLE CUTTING PARAMETERS IN TURNING

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

1.2.1 Speed:

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

$$V = \pi DN/1000$$

Here, v is the cutting speed in turning in m/min,

D is the initial diameter of the work piece in mm,

N is the spindle speed in r.p.m.

1.2.2 Feed:

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

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

Here,

F_m is the feed in mm per minute,

f - Feed in mm/rev and

N - Spindle speed in r.p.m.

1.2.3 Depth of Cut:

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

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

D_{cut} - Depth of cut in mm

D - Initial diameter of the work piece

d - Final diameter of the work piece

1.3 CUTTING TOOLS FOR LATHE

1.3.1 Tool Geometry

For cutting tools, geometry depends mainly on the properties of the tool material and the work material. The standard terminology is shown in the following figure1.2. For single-point tools, the most essential angles are the rake angles and the end and side relief angles

1.3.1(a) Flank

A flat surface of a single-point tool that is adjacent to the face of the tool. During turning, the side flank faces the direction that the tool is fed into the work piece, and the end flank passes over the newly machined surface.

1.3.1(b) Face

The flat surface of a single point tool through which the work piece rotates during turning operation. On a typical turning setup, the face of the tool is positioned upwards.

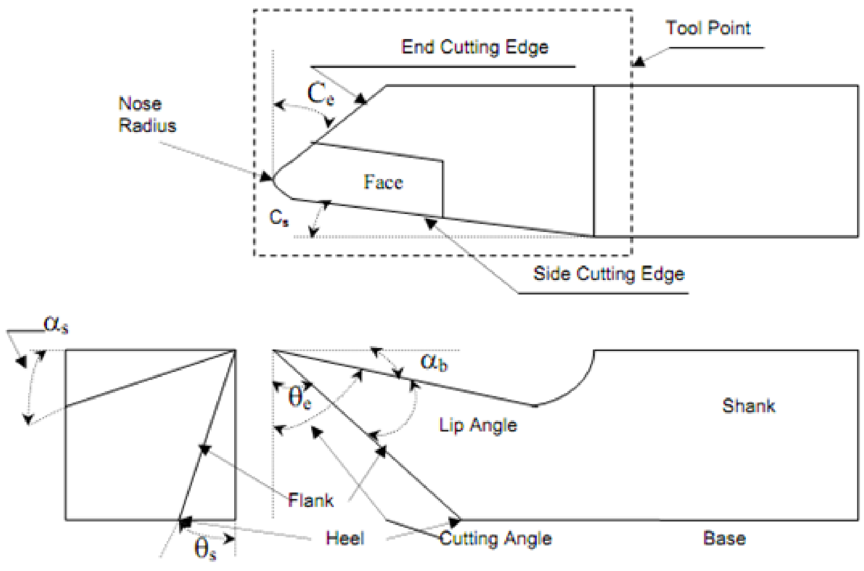


Figure 1.2: Geometry of tool

1.3.1(c) Back rake angle

If viewed from the side facing the end of the work piece, it is the angle formed by the face of the tool and a line parallel to the floor. A positive back rake angle tilts the tool face back, and a negative angle tilts it forward and up

1.3.1(d)Side rake angle

If viewed from behind the tool, looking down the length of the tool holder, it is the angle formed by the face of the tool and the centre line of the work piece. A positive side rake angle tilts the tool face down toward the floor, and a negative angle tilts the face-up and toward the work piece.

1.3.1(e) Side cutting edge angle

If viewed from above looking down on the cutting tool, the angle is formed by the tool's side flank and a line perpendicular to the work piece centreline. A positive side cutting edge angle moves the side flank into the cut, and a negative angle moves the side flank out of the cut.

1.3.1(f) End cutting edge angle

If viewed from above looking down on the cutting tool, it is the angle formed by the end flank of the tool and a line parallel to the work piece centreline. Increasing the end cutting edge angle tilts the far end of the cutting edge away from the work piece.

1.3.1(g) Side relief angle

If viewed from behind the tool, looking down the length of the tool holder, it is the angle formed by the side flank of the tool and a vertical line down to the floor. Increasing the side relief angle tilts the side flank away from the work piece.

1.3.1(h) End relief angle

If viewed from the side facing the end of the work piece, it is the angle formed by the end flank of the tool and a vertical line down to the floor. Increasing the end relief angle tilts the end flank away from the work piece.

1.3.1(i) Nose radius:

It is the rounded tip on the cutting edge of a single-point tool. A zero-degree nose radius creates a sharp point of the cutting tool.

1.3.1(j) Lead angle:

It is the common name for the side cutting edge angle. If a tool holder is built with dimensions that shift the angle of an insert, the lead angle considers this change. The back rake angle affects the ability of the tool to shear the work material and form the chip. It can be positive or negative. Positive rake angles reduce the cutting forces resulting in smaller deflections of the work piece, tool holder, and machine. If the back rake angle is too large, the strength of the tool is reduced and its capacity to conduct heat. In machining hard work materials, the back rake angle must be slight, even harmful for carbide and diamond tools. The higher the hardness, the smaller will be the back rake angle. For high-speed steels, the back rake angle is generally chosen in the positive range.

1.4 CUTTING TOOL MATERIALS

The cutting tool materials currently in use for machining operation are high-speed tool steel, cobalt-base alloys, cemented carbides, ceramic, and polycrystalline cubic boron nitride polycrystalline diamond. Different machining applications require different cutting tool materials. The ideal cutting tool material should have all of the following characteristics:

- Harder than the work it is cutting
- High-temperature stability
- Resists wear and thermal shock

• Impact resistant

• Chemically inert to the work material and cutting fluid

To effectively select tools for machining, a machinist or engineer must have specific information about:

• The starting and finished part shape

• The work piece hardness

• The material's tensile strength

• The material's abrasiveness

• The type of chip generated

• The work holding setup

• The power and speed capacity of the machine tool

Some common cutting tool materials are described below:

1.4.1 Carbon steels

Carbon steels have been used since the 1880s for cutting tools. However, carbon steels start to soften at a temperature of about 180oC. This limitation means that such tools are rarely used for metal cutting operations. Plain carbon steel tools, containing about 0.9% carbon and about 1% manganese, hardened to about 62 Rc, are widely used for Woodworking, and they can be used in a router to machine aluminium sheet up to about 3mm thick.

1.4.2 High-speed steels (HSS)

HSS tools are so named because they were developed to cut at higher speeds. Developed around 1900 HSS are the most highly alloyed tool steels. The tungsten (T series) was developed first and typically contains 12 - 18% tungsten, 4% chromium and 1- 5% vanadium. Most grades contain about 0.5% molybdenum, and most grades contain 4- 12% cobalt. It was soon discovered that molybdenum (smaller proportions) could be substituted for most of the tungsten, resulting in a more economical formulation with better abrasion resistance than the T series and undergoing less distortion during heat treatment. Consequently, about 95% of all HSS tools are made from M series grades. These contain 5 - 10% molybdenum, 1.5 - 10% tungsten, 1 - 4% vanadium, 4% Chromium and many grades contain 5 -

10% cobalt. HSS tools are tough and suitable for interrupted cutting and are used to manufacture tools of complex shape such as drills, reamers, taps, dies, and gear cutters. Tools may also be coated to improve wear resistance. HSS accounts for the largest tonnage of tool materials currently used. Typical cutting speeds: 10 - 60 m/min.

Figure 1.3: High speed steel(HSS) tool

1.4.3 Cast Cobalt alloys

Introduced in the early 1900s these alloys have compositions of about 40 - 55% cobalt, 30% chromium, and 10 - 20% tungsten and are not heat treatable. Maximum hardness values of 55 - 64 Rc. They have good wear resistance but are not as tough as HSS but can be used at somewhat higher speeds than HSS. Now only in limited use.

1.4.4 Carbides

Also known as cemented carbides or sintered carbides were introduced in the 1930s and had high hardness over a wide range of temperatures, high thermal conductivity, high Young's modulus making them an effective tool and die materials for a range of applications. The two groups used for machining are tungsten carbide and titanium carbide; both types may be coated or uncoated. Tungsten carbide particles (1 to 5 micrometres) are bonded together in a cobalt matrix using powder metallurgy. The powder is pressed and sintered to the required insert shape. Titanium and niobium carbides may also be included to impart unique properties. A wide range of grades is available for different applications. Sintered carbide tips are the dominant type of material used in metal cutting. The proportion of cobalt (the usual matrix material) present has a significant effect on the properties of carbide tools. 3 - 6% matrix of cobalt gives greater hardness while 6 - 15% matrix of cobalt gives a more excellent toughness while decreasing the hardness, wear-resistance and strength. Tungsten carbide tools are commonly used for machining steels, cast irons, and abrasive non-ferrous materials. Titanium carbide has a higher wear resistance than tungsten but is not as strict. With a nickel-molybdenum alloy as the matrix, TiC is suitable for machining at higher speeds than those used for tungsten carbide. Typical cutting speeds are 30 - 150 m/min or 100 - 250 when coated.

1.4.4 High Carbide Steels (HCS)

Generally, the high carbon steels contain from 0.60 to 1.00% C with manganese contents ranging from 0.30 to 0.90%. The pearlite has an excellent structure, which makes the steel very hard. Unfortunately, this also makes the steel quite brittle and much less ductile than mild steel.

Figure 1.4:High Carbide Steel (HCS) Single Point Cutting Tool

Medium and high carbon steels are widely used in many typical applications. Increasing carbon as the primary alloy for the higher strength and hardness of steel is usually the most economical approach to improved performance. However, some of the effects of elevated carbon levels include reduced weldability, ductility, and impact toughness. When these reduced properties can be tolerated, the increased strength and hardness of the higher carbon materials can be used to a significant advantage. Typical applications of higher carbon steels include forging grades, rail steels, spring steels (both flat-rolled and round), pre-stressed concrete, wire rope, tire reinforcement, wear resistant steels (plates and forgings), and high strength bar.

1.5 TURNING MACHINES

The turning machines are, of course, every kind of lathes. Lathes used in manufacturing can be classified as engine, turret, automatics, and numerical control, etc. They are heavy duty machine tools and have power drive for all tool movements. They commonly range from 12 to 24 inches swing and from 24 to 48 inches center distance, but swings up to 50 inches, and centre distances up to 12 feet are not uncommon.

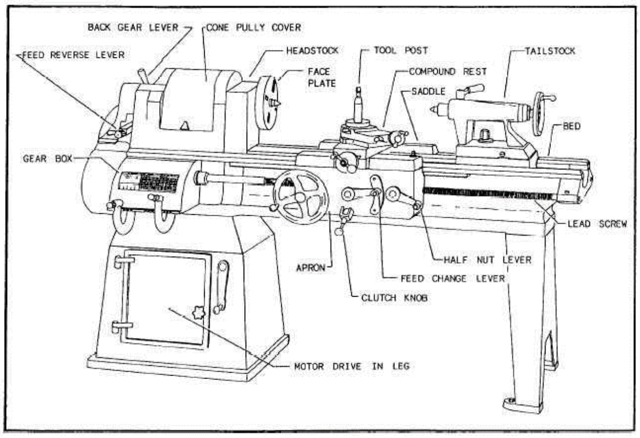


Figure 1.5: Engine lathe

1.5.1 Turret Lathe

In a turret lathe, a longitudinally feed-able, hexagon turret replaces the tailstock. The turret, on which six tools can be mounted, can be rotated about a vertical axis to bring each tool into operating position, and the entire unit can be moved longitudinally, either annually or by power, to provide feed for the tools. When the turret assembly is backed away from the spindle through a capstan wheel; the turret indexes automatically at the end of its movement, thus bringing each of the six tools into operating position. The square turret on the cross slide can be rotated manually about a vertical axis to bring each of the four tools into operating position. On most machines, the turret can be moved transversely, either manually or by power, employing the cross slide, and longitudinally through power or manual operation of the carriage. A fixed tool holder is added to the back end of the cross slide; this often carries a parting tool. Through these basic features of a turret lathe, several tools can be set on the machine and then quickly be brought successively into working position so that a whole part can be machined without the necessity for further adjusting, changing tools, or making measurements.

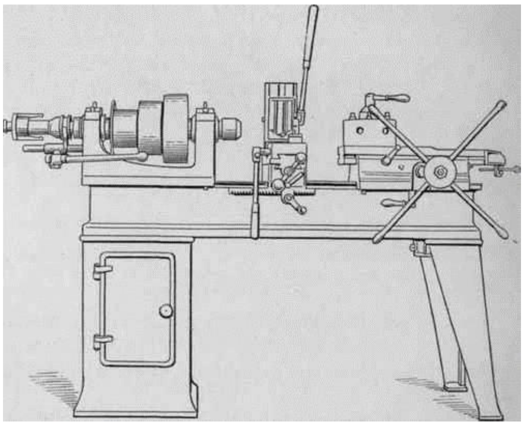


Figure1.6: Turret lathe

1.5.2 Single-Spindle Automatic Screw Machines

There are two common types of single-spindle screw machines, One, an American development commonly called the turret type (Brown & Sharp), is shown in the following figure1.5. The other is of Swiss origin and is referred to as the Swiss-type. The Brown & Sharp screw machine is essentially a tiny automatic turret lathe, designed for bar stock, with the main turret mounted on the cross slide. All motions of the turret, cross slide, spindle, chuck, and stock-feed mechanism are controlled by cams. The turret cam is essentially a program that defines the movement of the turret during a cycle. These machines usually are equipped with an automatic rod feeding magazine that feeds a new length of bar stock into the collection as soon as one rod is wholly used

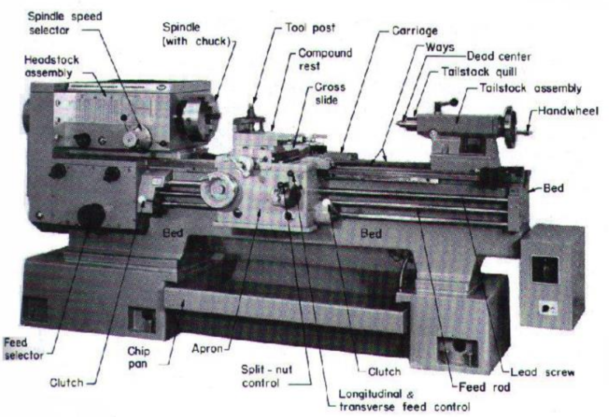


Figure 1.7: Single spindle automatic screw lathe

this speckle image can be related to the surface characteristics. The degree of correlation of two speckle patterns produced from the same surface by two different illumination beams can be used as a roughness parameter. Monochromatic plane wave with an angle of incidence concerning the normal to the surface; multi-scattering and shadowing effects are neglected. The photo-sensor of a CCD camera placed in the focal plane of a Fourier lens is used for recording speckle patterns. Assuming Cartesian coordinates x,y,z, a rough surface can be represented by its ordinates Z (x,y) concerning an arbitrary datum plane having transverse coordinates (x,y,z). Then the rms value of surface roughness can be defined and calculated roughness values.

a. Inductance method: An inductance pickup is used to measure the distance between the surface and the pickup. This measurement gives a parametric value that may be used to give a comparative roughness. However, this method is limited to measuring magnetic materials.

b. Ultrasound: A spherically focused ultrasonic sensor is positioned with a non-normal incidence angle above the surface. The sensor sends out an ultrasonic pulse to the personal computer for analysis and calculation of roughness parameters.

1.6 TEMPERATURE GUN MEASUREMENT

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

Figure 1.8:Temperature gun

There are, however, some basics that you must know to use these temperature guns correctly.

First, the temperature gun uses beams to collect information on the heat energy coming from a given object. Thus, the gun does not state whether the heat comes from the intended object or the surroundings. This means that to collect the correct temperature measurement, you will have to ensure that you point the gun directly at the object whose temperature you intend to measure. You need to be as close as possible to avoid reading other heat waves that may interfere with your reading's accuracy. The gun will only read the heat energy on the area where it is pointing, and for accuracy, you must aim directly at the object whose temperature you intend to measure.

1.7 INTRODUCTION TO MINITAB

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

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

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

1.7.1 Minitab Project and Worksheets

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

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

The Toolbar: Shortcuts to some Minitab commands.

1.7.2 Two windows in MINITAB

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

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

Other windows include:

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

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

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

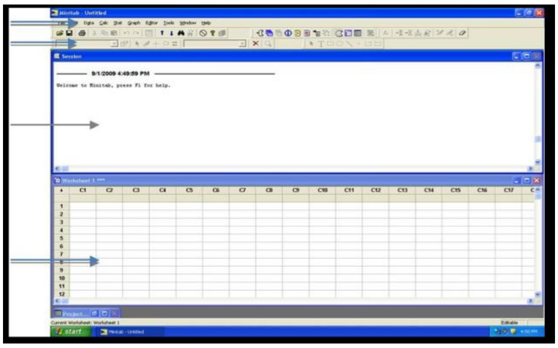


Figure 1.9: Environment in Minitab Software

CHAPTER 2.LITERATURE STUDY

SK Thangarasu, et al [1] identified that Cutting force is highly influenced by the depth of cut (27.72%) and slightly by cutting speed.Surface roughness is highly influenced by the interaction of feed and depth of cut (41.67%), feed (21.33%).Tool wear is highly influenced by feed (61.63%), slightly by the depth of cut and cutting speed.If tool wear increases, then tool work piece contact increases, increasing cutting forces resulting in poor surface finish.

K.G.Nikam, et al[2] studied that The highest surface finish (lowest surface roughness) is obtained at a cutting speed of 200m/min, feed rate of 0.2mm/revolutions, and depth of cut of 0.5 mm.Best surface roughness is obtained from CNMG120412FC insert than the other two types of the insert.The result of ANOVA shows that surface finish is most affected by feed rate. Cutting speed and depth of cut are the least significant parameters.Best surface roughness at high cutting speed (i.e., 250m/min) is obtained from CNMG120412FC insert.

Zulfiqar Ahmad Khan et al [3] Observed That Chip formation for EN8 Steel in dry conditions that showed appropriate heat removal via chips. jagged edge was present inside the helical chip due to the high feed rate.When sampling plane perpendicular with cut similar surface roughness for both wet and dry at 4.899 and 5.119, plane parallel wet conditions considerably out performed dry with 0.874 and 2.218.The reduced feed rate of0.08 mm/rev for the finish cut improved surface roughness for both wet and dry conditions, with 0.559 and 1.139, respectively.On measuring the accuracy of the finishing cut, it is found that there was an overcut of -0.01 mm in dry conditions, while for wet cut conditions, there was an undercut of +0.006 mm.

N. Satheesh Kumar et al [4] Observed That Effect of Spindle speed refers to the rotating speed of the work piece. It was increased from 339 rpm to 980 rpm. The depth of cut was kept at 0.5mm throughout, but feed rate was varied from 0.05mm/rev to 0.15mm/rev in steps of 0.025mm/rev, with single turning operation for each feed rate. The surface roughness decreased with increased spindle speed.Effect of feed rate:Feed rate is the rate at which the tool advances along its cutting path. It was increased from 0.05mm/rev to 0.15mm/rev in steps of 0.025mm/rev by keeping the depth of cut constant at 0.5mm throughout and varying speed from 339rpm to 980rpm with single turning operation for each speed. The surface roughness increased with increased feed rate.From this study of the effect of spindle speed and feed rate on surface roughness of carbon alloy steels, a better surface finish may be achieved by turning carbon alloy steels at low feed rate and high spindle speeds.

Roopa K Rao et al [5] Observed That MRR- For En19 steel without heat treatment, Speed is the significant factor influencing MRR by 63.97%, followed by feed which contributes by 16.06% and contribution of the depth of cut is 3.50%.Maximum MRR of 249.73 mm3/min for a given range can be obtained at 1000 rpm speed,0.054 mm/rev feed,0.12 mm depth of cut. MRR- For EN19 steel subjected to heat treatment, Speed is the significant factor that affects MRR by 69.38%, followed by feed which contributes by 13.76% and contribution of the depth of cut is 3.94%.Maximum MRR of 200.72 mm3/min for a given range can be obtained at 1000 rpm speed,0.054 mm/rev feed,0.12 mm depth of cut.

Amol N. Varade et al [6] studied that. As per review of research papers, we can see that researcher work on material AISI52100 grade steel, EN19, AISI 304 austenitic SS, AISI 1030 steel, MDN250 steel, SAE8620, EN8, EN24, and EN47, and various composite materials which possess high hardness. As per selecting the machining parameter, there is increase the surface roughness and decrease the MRR, the aim of the paper is decided on an approach of performance measurement of high material removal rate (MRR), low surface roughness (Ra), and low tool tip temperature during hard turning of EN19 material.

B.Madhu Sudan et al [7] studied that:

The experimental investigation of EN 19 alloy steel by using surface grinding operation is done. The following conclusions are made, which are1) Main effect plot for GR Grade indicates that nanofluid type AL2O3 has high GR Grdae than CuO.2) ANOVA shows that Nanofluid Type has significant factor, because its p-value less than 0.05.3) CuO 2% concentration has better surface roughness than AL2O3.4) Percentage contribution of nanofluid type is 16.95%, nanofluid concentration is 15.71%, depth of cut 9.90%, feed rate is 3.96%.

Dhiraj Kumar et al [8] studied that 1. The optimal setting of process parameters is found to be electrolytic concentration (A)=20%, voltage (B)=12V, feed rate (C)=0.32 mm/min and inter-electrode gap (D)=0.2mm from Taguchi based TOPSIS. 2. Confirmatory tests reveal that the improvement of preference values in the experimental and initial setting using Taguchi based TOPSIS are 0.572242, which is satisfactory. 3. ANOVA was carried out to find out the significance of machining parameters affecting process characteristics at 95% confidence interval. Electrolytic concentration, Voltage, Feed rate, and Inter-electrode gap are parameters that contribute to improvement in the value of preference solution.

Abhishek S Shetty et al [9] concluded that the MRR increases with increasing spindle speed, feed rate and depth of cut. The optimal input parameters for en19 steel is (1200rpm,0.75mm/rev,0.6mm)depth of cut is the most influencing parameter, followed by single speed and feed rate(via ANOVA).

T.RAJAPRABU et al [10] concluded that Taguchi method is a powerful tool for optimization, which provides a systematic and effective methodology for the design optimization of cutting parameters. The Feed has greater influence on the surface roughness followed by depth of cut.The depth of cut has a more significant influence on the MRR followed by cutting speed and Feed. Surface roughness is minimum at cutting speed of 180 m/min, feed of 0.2 mm/rev, and depth of cut of 2 mm. MRR is maximum at cutting speed of 220 m/min, feed of 0.1mm/rev, and depth of cut of 1.5 mm.

N.Baskar et al [11] observed that En8:-feed rate and cutting speed plays an essential role on the machining process of MRR If the feed rate increases, the MRR increases if the cutting speed increases, the MRR increases if the DOC increases, the MRR increases

CHAPTER 3.DESIGN OF EXIPERIMENTS

3.1 DESIGN OF EXPERIMENTS (DOE) OVERVIEW

In industry, designed experiments can systematically investigate the process or product variables that influence product quality. After identifying the process conditions and product components that influence product quality, direct improvement efforts enhance a product's manufacturability, reliability, quality, and field performance. As the resources are limited, it is essential to get the most information from each experiment performed. Well-designed experiments can produce significantly more information and often require fewer runs than haphazard or unplanned experiments. A well-designed experiment identifies the essential effects. If there is an interaction between two input variables

They should be included in the design rather than a "one factor at a time" experiment. An interaction occurs when the effect of one input variable is influenced by the level of another input variable.

Designed experiments are often carried out in four phases: planning, screening (also called process characterization), optimization, and verification.

3.1.1 Planning

Careful planning help in avoiding the problems that can occur during the execution of the experimental plan. For example, personnel, equipment availability, funding, and the mechanical aspects of system may affect the ability to complete the experiment. The preparation required before beginning experimentation depends on the problem. Here are some steps need to go through:

• Define the problem. Developing a good problem statement helps in studying the right variables.

• Define the objective. A well-defined objective will ensure that the experiment answers the right questions and yields practical, usable information. At this step, define the goals of the experiment.

• Develop an experimental plan that will provide meaningful information. Review relevant background information, such as theoretical principles and knowledge gained through observation or previous experimentation.

Make sure the process and measurement systems are in control. Ideally, both the process and the measurements should be in statistical control as measured by a functioning statistical process control (SPC) system. Minitab provides numerous tools to evaluate process control and analyze your measurement system.

3.1.2 Screening

In many process development and manufacturing applications, potentially influential variables are numerous. Screening reduces the number of variables by identifying the key variables that affect product quality. This reduction allows focusing process improvement efforts on the crucial variables. Screening suggests the “best" optimal settings for these factors.

The following methods are often used for screening:

• Two-level full and fractional factorial designs are used extensively in industry

• Plackett-Burman designs have low resolution, but they are helpful in some screening experimentation and robustness testing.

• General full factorial designs (designs with more than two levels) may also be helpful for small screening experiments.

3.1.3 Optimization

After identifying the vital variables by screening, there is a need to determine the "best" or optimal values for these experimental factors. Optimal factor values depend on the process objective.

The optimization methods available in Minitab include general full factorial designs (designs with more than two levels), response surface designs, mixture designs, and Taguchi designs.

• Factorial Designs Overview describes methods for designing and analyzing general full factorial designs.

• Response Surface Designs Overview describes methods for designing and analyzing central composite and Box-Behnken designs.

• Mixture Designs Overview describes designing and analyzing simplex centroid, simplex lattice, and extreme vertices designs. Mixture designs are a particular class of response surface designs where the proportions of the components (factors), rather than their magnitude, are essential.

• Response Optimization describes methods for optimizing multiple responses. Minitab provides numerical optimization, an interactive graph, and an overlaid contour plot to help to determine the "best" settings to simultaneously optimize multiple responses.

• Taguchi Designs Overview describes methods for analyzing Taguchi designs. Taguchi designs may also be called orthogonal array designs, robust designs, or inner-outer array designs. These designs are used for creating products that are robust to conditions in their expected operating environment.

3.1.4 Verification

Verification involves performing a follow-up experiment at the predicted "best" processing conditions to confirm the optimization results.

3.2 ADVANTAGES & DISADVANTAGES OF DOE

DOE became a more widely used modeling technique superseding its predecessor one-factor-at- time (OFAT) technique. One of the main advantages of DOE is that it shows the relationship between parameters and responses. In other words, DOE shows the interaction between variables which in turn allows us to focus on controlling essential parameters to obtain the best responses. DOE also can provide us with the most optimal set of parametric values to find the best possible output characteristics. Besides that, the mathematical model generated can be used as a prediction model to predict the possible output response based on the input values. Another main reason DOE is used because it saves time and cost in terms of experimentation. DOE functions so that the number of experiments or the number of runs is determined before the actual experimentation is done. This way, time and cost can be saved as we do not have to repeat unnecessary experiment runs. Most usually, experiments will have an error occurring. Some of them might be predictable, while some errors are just out of control. DOE allows us to handle these errors while continuing with the analysis. DOE is excellent when it comes to predicting linear behavior. However, when it comes to nonlinear behavior, DOE does not always give the best results.

3.3 FACTORIAL DESIGNS

3.3(a) Factorial Designs Overview

Factorial designs allow for the simultaneous study of the effects that several factors may have on a process. When experimenting, varying the factors simultaneously rather than one at a time is efficient in terms of time and cost and allows for studying interactions between the factors. Interactions are the driving force in many processes. Without the use of factorial experiments, essential interactions may remain undetected.

3.3(b) Screening designs

In many process development and manufacturing applications, the number of potential input variables (factors) is significant. Screening (process characterization) reduces the number of input variables by identifying the key input variables or process conditions that affect product quality. This reduction allows focusing process improvement efforts on the few crucial variables. Screening may also suggest the "best" or optimal settings for these factors. Optimization experiments can then be done to determine the best settings. In industry, two-level full and fractional factorial designs and Plackett-Burman designs are often used to "screen" for the significant factors that influence process output measures or product quality. General full factorial designs (designs with more than two levels) may be used with small screening experiments.

3.3.1 Full factorial designs

In a complete factorial experiment, responses are measured at all combinations of the experimental factor levels. The combinations of factor levels represent the conditions at which responses will be measured. Each experimental condition is called a "run," and the response measurement an observation. The entire set of runs is the "design."

3.3.1(a) Two-level full factorial designs

In a two-level complete factorial design, each experimental factor has only two levels. The experimental runs include all combinations of these factor levels. Although two-level factorial designs cannot fully explore a broad region in the factor space, they provide helpful information for relatively few runs per factor. Because two-level factorials can indicate significant trends, which are used to provide direction for further experimentation.

3.3.1(b) General full factorial designs

In a general complete factorial design, the experimental factors can have any number of levels. For example, Factor A may have two levels, Factor B may have three levels, and Factor C may have five levels. The experimental runs include all combinations of these factor levels. General full factorial designs may be used with small screening experiments or in optimization experiments.

3.3.2 Fractional factorial designs

In a full factorial experiment, responses are measured at all combinations of the factor levels, which may result in a prohibitive number of runs. For example, a two-level full factorial design with 6 factors requires 64 runs; a design with 9 factors requires 512 runs.

To minimize time and cost, can use designs that exclude some of the factor level combinations. Factorial designs in which one or more level combinations are excluded are called fractional factorial designs. Minitab generates two-level fractional factorial designs for up to 15 factors.

Fractional factorial designs are helpful in factor screening because they reduce the number of runs to a manageable size. The runs that are performed are a selected subset or fraction of the complete factorial design.

3.3.3 Plackett-Burman designs

Plackett-Burman designs are a class of resolution III, two-level fractional factorial designs often used to study the main effects. In a resolution III design, the main effects are aliased with two-way interactions. Minitab generates designs for up to 47 factors. Each design is based on the number of runs, from 12 to 48, and is always a multiple of 4. The number of factors must be less than the number of runs.

3.4 Choosing a Factorial Design

The design, or layout, provides the specifications for each experimental run. It includes the blocking scheme, randomization, replication, and factor level combinations. This information defines the experimental conditions for each test run. While experimenting, need to measure the response (observation) at the predetermined settings of the experimental conditions. Each experimental condition that is employed to obtain a response measurement is a run. Minitab provides two-level full and fractional factorial designs, Plackett-Burman designs, and full factorials for more than two levels. While choosing a design, there is a need to

• identify the number of factors that are of interest.

Determine the number of runs you can perform Factorial Designs.

• determine the impact that other considerations (such as cost, time, or the availability of facilities) have on the choice of a design.

3.5 DESIGN OF EXPERIMENTS

3.5.1 Creating Full Factorial Designs

Use Minitab's general full factorial design option when any factor has more than two levels. Using this can create designs with up to 15 factors. Each factor must have at least two levels, but not more than 100 levels.

To create a general full factorial design

1 Choose Stat > DOE > Factorial > Create Factorial Design.

2 Choose General full factorial designs.

3 From the Number of factors, choose a number from 2 to 15.

4 Click Designs.

5 Click in the Number of Levels in the row for Factor A and enter a number from 2 to 100. Use the arrow key to move down

The column and specify the number of levels for each factor

6 Click OK. This selects the design and brings it back to the main dialog box.

7 click Options or Factors and use any dialog box options, then click OK to create the design.

Factorial Design − Available Designs

Stat > DOE > Factorial > Create Factorial Design >choose General full factorial design > Display Available Designs

This dialog box does not take any input.

Factorial Design − Designs

Stat > DOE > Factorial > Create Factorial Design >choose General full factorial design > Design

Allows naming factors, specifying the number of levels for each factor, adding replicates, and blocking the design.

Dialog box items

Factor: This shows the number of factors that are chosen for the design. This column does not take any input.

Name: Enter text to change the name of the factors. By default, Minitab names the factors alphabetically.

Number of Levels: Enter a number from 2 to 100 for each factor. Use the arrow keys to move up or down the column.

The number of replicates: Enter a number up to 50.

Block on replicates: Check to block the design on replicates. Each set of replicate points will be placed in a separate block.

Factorial Design − Factors

Stat > DOE > Factorial > Create Factorial Design >choose General full factorial design > Designs > Factors

Allows naming or renaming the factors and assigning values for factor levels. If factors are continuous, use numeric levels; if factors are categorical, use text levels. Continuous variables can take on any value on the measurement scale being used (for example, length of reaction time). In contrast, categorical variables can only assume a limited number of possible values (for example, type of catalyst).

Use the arrow keys to navigate within the table, moving across rows or down columns.

3.5.2 Dialog box items

Factor: This shows the number of factors is chosen for the design. This column does not take any input.

Name: Enter text to change the name of the factors.

Type: Choose to specify whether the levels of the factors are numeric or text.

Levels: This shows the number of levels for each factor. This column does not take any input.

Level Values: Enter numeric or text values for each level of the factor. Can have up to 100 levels for each factor.

To name factors

1 In the Create Factorial Design dialog box, click Factors.

2 Under Name, click in the first row and type the name of the first factor. Then, use the arrow key to move down the column and enter the remaining factor names.

To assign factor levels

1 In the Create Factorial Design dialog box, click Factors.

2 Under Level Values click in the factor row to assign values and enter any numeric or text value. Enter numeric levels from lowest to highest.

3 Use the arrow key to move down the column and assign levels for the remaining factors. Click OK.

3.5.3 Create Design − Options

Stat > DOE > Factorial > Create Factorial Design >choose General full factorial design > Options

Allows to randomize the design and store the design (and design object) in the worksheet.

Dialog box items

Randomize runs: Check to randomize the runs in the data matrix. If blocks are specified, randomization is done separately within each block, and then the blocks are randomized.

The base for random data generator: Enter a base for the random data generator. By entering a base for the random data generator, can control the randomization so that can obtain the same pattern every time.

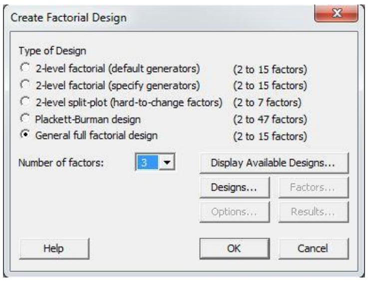


Figure 3.1:Creating factorial Design

CHAPTER 4.EXPERIMENTAL SETUP AND MACHINING

The project was done in 3 stages.

• Design of experiments was done using the full factorial method.

• Cycle time was calculated by machining the workpiece on lathe machine

• Analysis of results was done using MINITAB 17.1.30.

4.1 SELECTION OF PROCESS VARIABLES

• A total of three process variables and three levels are selected for the experimental procedure.

• The deciding process variables are

▪ Speed

▪ Feed

▪ Depth of cut

• Speed of the spindle, i.e. the speed at which the spindle rotates the tool.

• Feed is the rate at which the material is removed from the work piece.

• Depth of cut is the depth up to which the tool is emerged in one cycle.

4.2 SELECTION OF LEVELS:

• Since it is a twolevel design by observing the parameters taken in various projects, the levels of the factors are designed as follows

FACTORS	LEVEL1	LEVEL2
SPPED(RPM)	200	500
FEED(MM/REV)	0.5	1.0
D.O.C(MM)	1.0	1.5

Table 4.1: Selection of process variables

4.3 DESIGN OF EXPERIMENTS

• Design of experiments was done using the whole factorial method.

Design of experiments (DOE) or experimental design is the design of any information-gathering exercises where variation is present, whether under the complete control of the experimenter or not.

4.4 SELECTION OF MATERIAL

By studying various projects, EN 19 is selected for machining operation. The composition of EN 19 is:

- Carbon:0.35-0.45%
- Manganese:0.50-0.80%
- Silicon:0.10-0.35%
- Molybdenum:0.20-0.40%
- Chromium:0.90-1.50%
- Sulfur:0.05%
- Phosphorous:0.05%

The dimensions of the workpiece used are length 50mm*16mmdia

4.5 CLAMPING OF THE WORK PIECE

The work piece is clamped to the machine by using standard 3 jaw chuck.

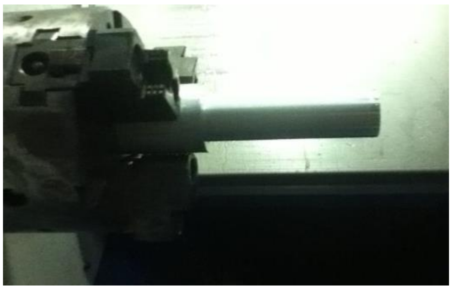


Figure 4.1: Clamping of the work piece

The tool used for turning is High Speed Steel. Initially these tool is fixed in the tool turret using tool holding fixture.

4.6. CHIP THICKNESS RATIO

Chip thickness ratio (r_c) = a_1/a_2

a1= chip thickness before cutting

a2= chip thickness after cutting

4.7.SHEAR ANGLE

$$\tan\theta = \frac{(r_c cos\alpha)}{(1 - r_c sin\alpha)}$$

$$\theta = \tan^{-1}\left(\frac{(r_c cos\alpha)}{(1 - r_c sin\alpha)}\right)$$

θ= shear angle

r_c= chip thickness ratio

α= rake angle(i.e $14°30'$)[tool maker's microscope]

SAMPLE CALCULATION:

$a_1 = 0.5 \times \sin 60 = 0.43\text{mm}$

$a_2 = 8\text{mm}$

$r_c = \frac{0.43}{8} = 0.053$

$$\theta = \tan^{-1}\left(\frac{(r_c cos\alpha)}{(1 - r_c sin\alpha)}\right) = \tan^{-1}\left(\frac{0.053\cos(14°30')}{(1 - 0.053\sin(14°30'))}\right) = \tan^{-1}\left(\frac{0.051}{0.98}\right)$$
$$= 79.09°$$

CHAPTER 5.ANALYSIS OF VARIANCE

5.1 ANALYSIS OF VARIANCE (ANOVA) USING MINITAB

ANOVA was developed by the English statistician R.A. Fisher (1890-1962). Though initially dealing with agricultural data, this methodology has been applied to various other fields for data analysis. Despite its widespread use, some practitioners fail to recognize the need to check the validity of several vital assumptions before applying an ANOVA to their data. It is the hope that this article may provide specific usage guidelines for performing fundamental analysis using such a software package. Analysis of variance (ANOVA) is a collection of statistical models used to analyze the differences between group means and their associated procedures (such as "variation" among and between groups), in which the observed variance in a particular variable is partitioned into components attributable to different sources of variation. In its simplest form, ANOVA provides a statistical test of whether or not the means of several groups are all equal, and therefore generalizes t-test to more than two groups. Doing multiple two-sample t-tests would result in an increased chance of committing a type I error.

For this reason, ANOVAs are helpful in comparing (testing) three or more means (groups or variables) for statistical significance. ANOVA is a particular form of statistical hypothesis testing heavily used in the analysis of experimental data. A statistical hypothesis test is a method of making decisions using data. A test result (calculated from the null hypothesis and the sample) is called statistically significant if it is deemed unlikely to have occurred by chance, assuming the truth of the null hypothesis. A statistically significant result (when a probability (p-value) is less than a threshold (significance level)) justifies the rejection of the null hypothesis. The terminology of ANOVA is mainly from the statistical design of experiments. The experimenter adjusts factors and measures responses in an attempt to determine an effect. Factors are assigned to experimental units by a combination of randomization and blocking to ensure the validity of the results. Blinding keeps the weighing impartial. Responses show a variability that is partially the result of the effect and is partially random error. ANOVA is the synthesis of several ideas, and it is used for multiple purposes. As a consequence, it is difficult to define concisely or precisely.

5.2 CHARACTERISTICS OF ANOVA

ANOVA is used to analyze comparative experiments, those in which only the difference in outcomes is of interest. The statistical significance of the experiment is determined by a ratio of two variances. This ratio is independent of several possible alterations to the experimental observations: Adding a constant to all observations does not alter significance. Multiplying all observations by a constant does not alter significance. So ANOVA statistical significance results are independent of constant bias and scaling errors and the units used in expressing observations. In the era of mechanical calculation, it was common to subtract a constant from all observations (when equivalent to dropping leading digits) to simplify data entry. This is an example of data coding.

Classical ANOVA for balanced data does three things at once:

1. As exploratory data analysis, an ANOVA is an organization of additive data decomposition, and its sums of squares indicate the variance of each component of the decomposition (or, equivalently, each set of terms of a linear model).

2. Comparisons of mean squares and F-tests allow testing of a nested sequence of models.

3. Closely related to the ANOVA is a linear model fit with coefficient estimates and standard errors. In short, ANOVA is a statistical tool used in several ways to develop and confirm an explanation for the observed data. Additionally: It is computationally elegant and relatively robust against violations of its assumptions.

4. ANOVA provides industrial-strength (multiple sample comparison) statistically.

5. It has been adapted to the analysis of a variety of experimental designs.

5.3 ANALYSIS OF VARIANCE USING FACTORIAL METHOD

The purpose of this handout is to assist the burgeoning statistician in analyzing and interpreting the meaning of a statistically significant interaction in the context of factorial analysis of variance (ANOVA). We shall assume that the reader is already familiar with the results obtained when factorial ANOVA is the chosen analytic technique. However, just to be on the safe side, we will review the basics as we go through two examples demonstrating two methods that can be used as a follow-up to a statistically significant interaction effect. The two approaches that we will discuss are: 1. tests of simple main effects, and 2. statistical comparison of cells

Steps involved in the Factorial method

Step 1: Create a design using the General factorial method

Stat – DOE – Factorial – Create Factorial design

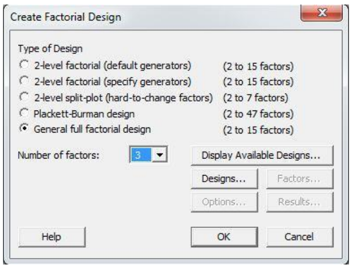


Figure 5.1: Factorial design model

Step 2: Define Response Surface Design by selecting Speed, Feed, and Depth of cut as Input para meters.

Stat – DOE – Factorial – Define Response Surface Design

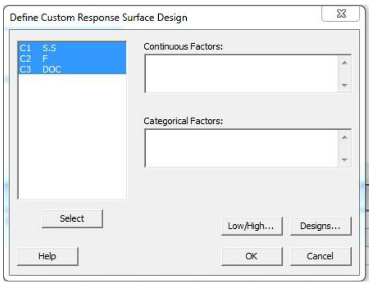


Figure 5.2: Custom Response Surface Design

Step 3: Analyse the Custom Response design

Stat – DOE – Response Surface – Analyse Response Design

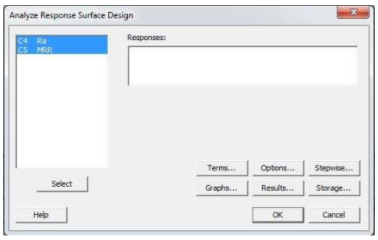


Figure 5.3: Analyse Response Surface Design

CHAPTER 6.RESULT AND DISCUSSION

6.1 DEVELOPMENT OF MATHEMATICAL MODELS

A Second-order polynomial is employed for developing the mathematical model for predicting weld pool geometry. If the response is well modelled by a linear function of the independent variables, then the approximating function is the first order model, as shown in Equation.

$$\mathbf{Y = \beta + \beta 1\ x1 + \beta 2\ x2 + \ldots .\_\ \beta x\ xx + \in}$$

A mathematical regression equation is developed for cycle time in every tool path, and the graphs are plotted.

$$\mathbf{Y = \beta 0} + \sum_{i=1}^{k} \beta_{o} x_{o} + \sum_{i=1}^{k} \beta ii \quad i2 + \sum \quad \sum_{i<j} \beta ij \ i \ \ j \ \text{€} \qquad x\,x\ +$$

- Y is the corresponding response
- Xi is the cutting parameters
- (1,2,…….k) are code levels of quantitative process variables
- The terms are the second-order regression coefficients
- The second term is the attribute to linear effect
- Third term corresponds to higher order effects
- Fourth term includes the interactive effects of the process parameters.
- And the last term indicates the experimental error.
- All the estimated coefficients were used to construct the models for the response parameter, and these models were used to construct the models for the response parameter. These models were tested by applying the Analysis Of Variance (ANOVA)technique F-ratio was calculated and compared, with the normal values for 95% confidence level. If the calculated value is less than the F-table values the model is considered==adequate.

6.2.Different Terms used in Response Surface Methodology Regression table

1. **P-values**: P- Values (P) are used to determine which of the effects in the model are statistically significant.

- If the p-value is less than or equal to 0.5, conclude that the effect is significant.
- If the p-value is greater than 0.5, conclude that the effect is not significant.

2. **Coefficients**: Coefficients are used to construct an equation representing the relationship between the response and the factors.

3. **R-squared:** R and adjusted R represent the proportion of variation in the response that is explained by the model.

- R (R-Sq) describes the amount of variation in the observed responses that is explained by the model.
- Predicted R reflects how well the model will predict future data.
- Adjusted R is a modified R that has been adjusted for the number of terms in the model. If we include unnecessary terms, R can be artificially high. Unlike R , adjusted R may get smaller when we add terms to the model.

4. **Analysis of variance table*:*** P-values (P) are used in the analysis of variance table to determine which of the effects in the model are statistically significant. The interaction effects in the model are observed first because a significant interaction will influence the main effects.

5.Estimated coefficients using uncoded units

- Minitab displays the coefficients in uncoded units in addition to coded units if the two units differ.

- For each term in the model, there is a coefficient. These coefficients are helpful to construct an equation representing the relationship between the response and the factors.

6.3. GRAPHS OBTAINED

6.3.1 Contour Plots,Surface Plots

- Contour and surface plots are helpful for establishing desirable response values and operating conditions.
- A contour plot provides a two-dimensional view where all points that have the same response are connected to Produce contour lines of constant responses.
- A surface plot provides a three-dimensional view that may provide a clearerpicture of the response surface.

Contour/Surface Plots − Contour – Setup

Stat > DOE > Factorial > Contour/Surface Plots >check Contour > Setup

- Generates a response surface contour plot for a single pair of factors or separate contour plots for all possible pairs of factors.
- Contour plots show that as the lines are diverging towards spindle speed andfeed, these two parameters have a stimulating effect on the machining process.
- The main effect occurs when the mean response changes across the levels of a factor.Main effect plots are used to compare the relative strength of the effects across factors.

6.4. OBSERVATION TABLE FOR EN19 DRY:

S.no	Speed	Feed	D.O.C	Temperature	Chip thickness ratio	Shear angle	Chip formation
1	200	0.5	1	54	0.00716	81.76	Discontinuous
2	200	0.5	1.5	56	0.047	88.75	Discontinuous
3	200	1	1	65	0.0081	82.8	Discontinuous
4	200	1	1.5	73.6	0.0455	88.71	Discontinuous
5	500	0.5	1	127.4	0.0091	83.53	Continuous with built up edge
6	500	0.5	1.5	217	0.0083	82.9	Continuous with built up edge
7	500	1	1	72.4	0.015	86.05	Continuous
8	500	1	1.5	63	0.0866	89.1	Discontinuous

6.5.RESULTS FOR EN19 DRY CONDITION:

Response Surface Regression: temperature (°C) versus Speed(rpm), feed(mm), depth of cut(mm)

```
The following terms cannot be estimated and were removed:
   Speed(rpm)*Speed(rpm), feed(mm)*feed(mm), depth of cut(mm)*depth of cut(mm)


Analysis of Variance

Source                             DF   Seq SS  Contribution   Adj SS  Adj MS  F-Value
P-Value
Model                               6  20509.7        93.64%  20509.7  3418.3     2.45
0.453
  Linear                            3  11780.3        53.78%  11780.3  3926.8     2.82
0.407
    Speed(rpm)                      1   6681.7        30.50%   6681.7  6681.7     4.79
0.273
    feed(mm)                        1   4068.0        18.57%   4068.0  4068.0     2.92
0.337
    depth of cut(mm)                1   1030.6         4.71%   1030.6  1030.6     0.74
0.548
  2-Way Interaction                 3   8729.5        39.85%   8729.5  2909.8     2.09
0.461
    Speed(rpm)*feed(mm)             1   7056.7        32.22%   7056.7  7056.7     5.06
0.266
    Speed(rpm)*depth of cut(mm)    1    605.5         2.76%    605.5   605.5     0.43
0.629
    feed(mm)*depth of cut(mm)      1   1067.2         4.87%   1067.2  1067.2     0.77
0.542
Error                             1   1393.9        6.36%   1393.9  1393.9
Total                             7  21903.7      100.00%
```

```
Model Summary

      S    R-sq  R-sq(adj)    PRESS  R-sq(pred)
37.3352  93.64%     55.45%  89210.9       0.00%


Coded Coefficients

Term                             Effect    Coef  SE Coef        95% CI        T-Value  P-Value
VIF
Constant                                   91.0     13.2  ( -76.7, 258.8)      6.90    0.092
Speed(rpm)                         57.8    28.9     13.2  (-138.8, 196.6)      2.19    0.273
1.00
feed(mm)                          -45.1   -22.6     13.2  (-190.3, 145.2)     -1.71    0.337
1.00
depth of cut(mm)                   22.7    11.4     13.2  (-156.4, 179.1)      0.86    0.548
1.00
Speed(rpm)*feed(mm)               -59.4   -29.7     13.2  (-197.4, 138.0)     -2.25    0.266
1.00
Speed(rpm)*depth of cut(mm)        17.4     8.7     13.2  (-159.0, 176.4)      0.66    0.629
1.00
feed(mm)*depth of cut(mm)         -23.1   -11.5     13.2  (-179.3, 156.2)     -0.88    0.542
1.00


Regression Equation in Uncoded Units

temperature (°C) = -245 + 0.497 Speed(rpm) + 418 feed(mm) + 103 depth of cut(mm)
                   - 0.792 Speed(rpm)*feed(mm) + 0.232 Speed(rpm)*depth of cut(mm)
                   - 185 feed(mm)*depth of cut(mm)
```

Figure 6.1: Normal plot of Residuals for temperature (°C)

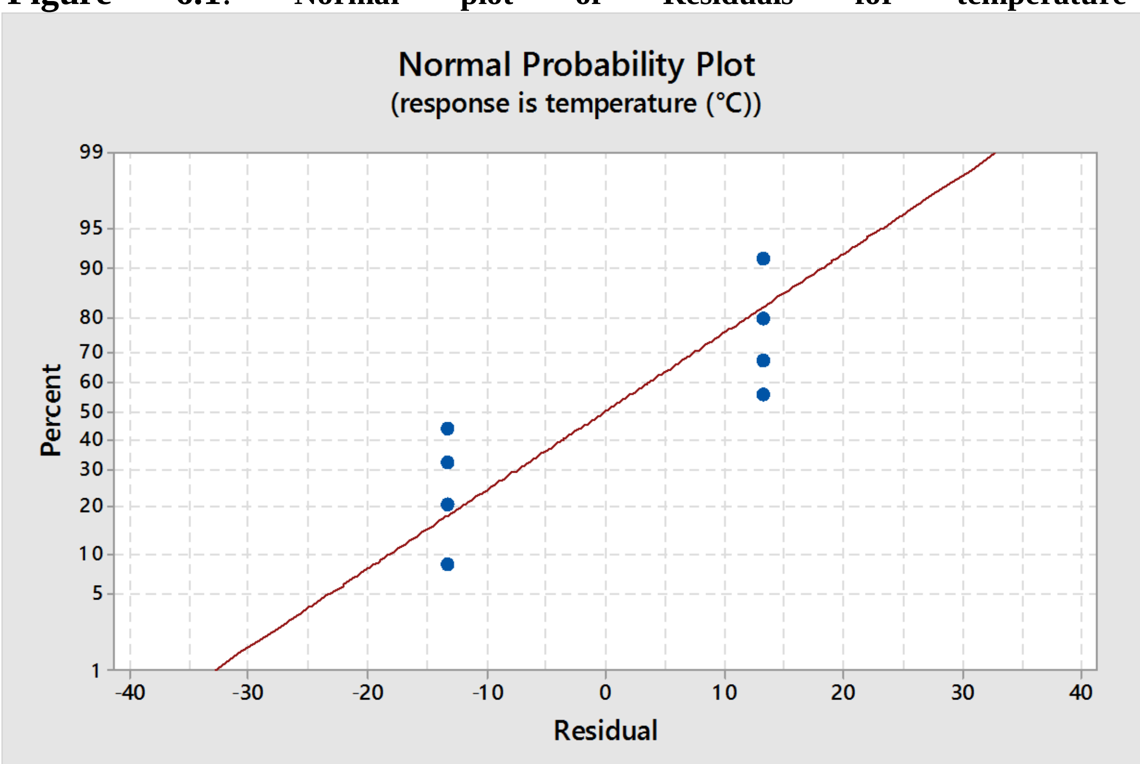


Figure 6.2: Residuals vs Fits for temperature (°C)

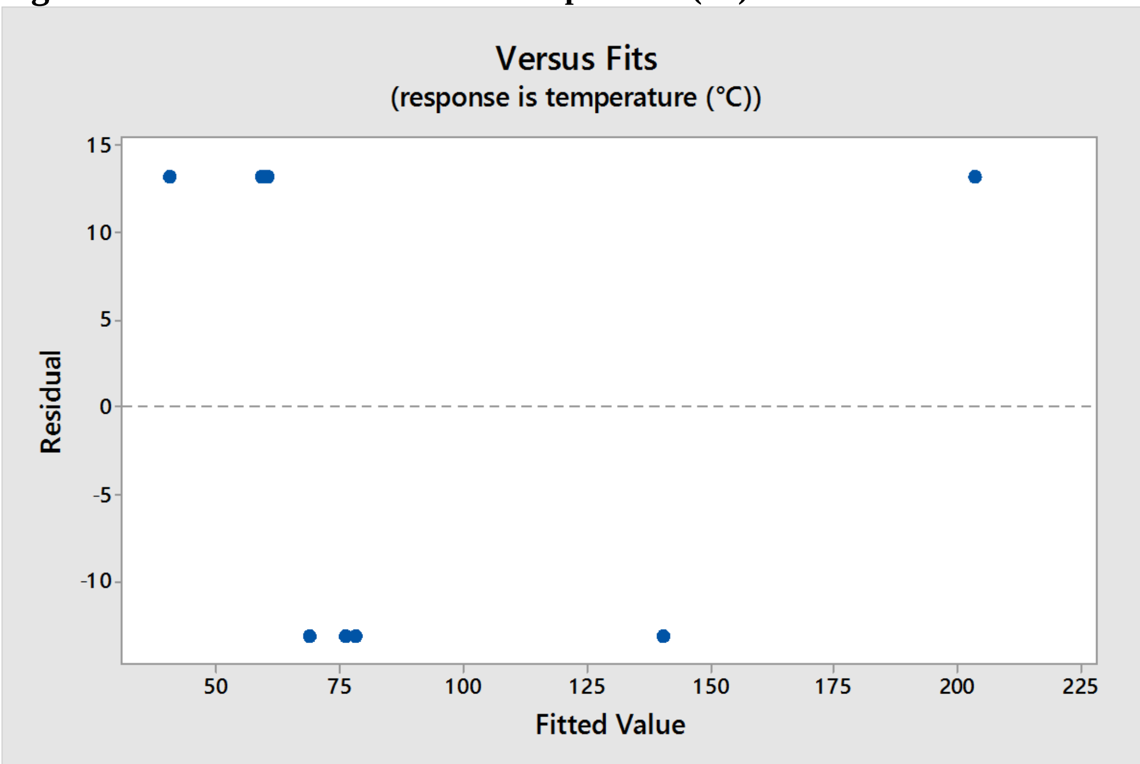


Figure 6.3: Residual Histogram for temperature (°C)

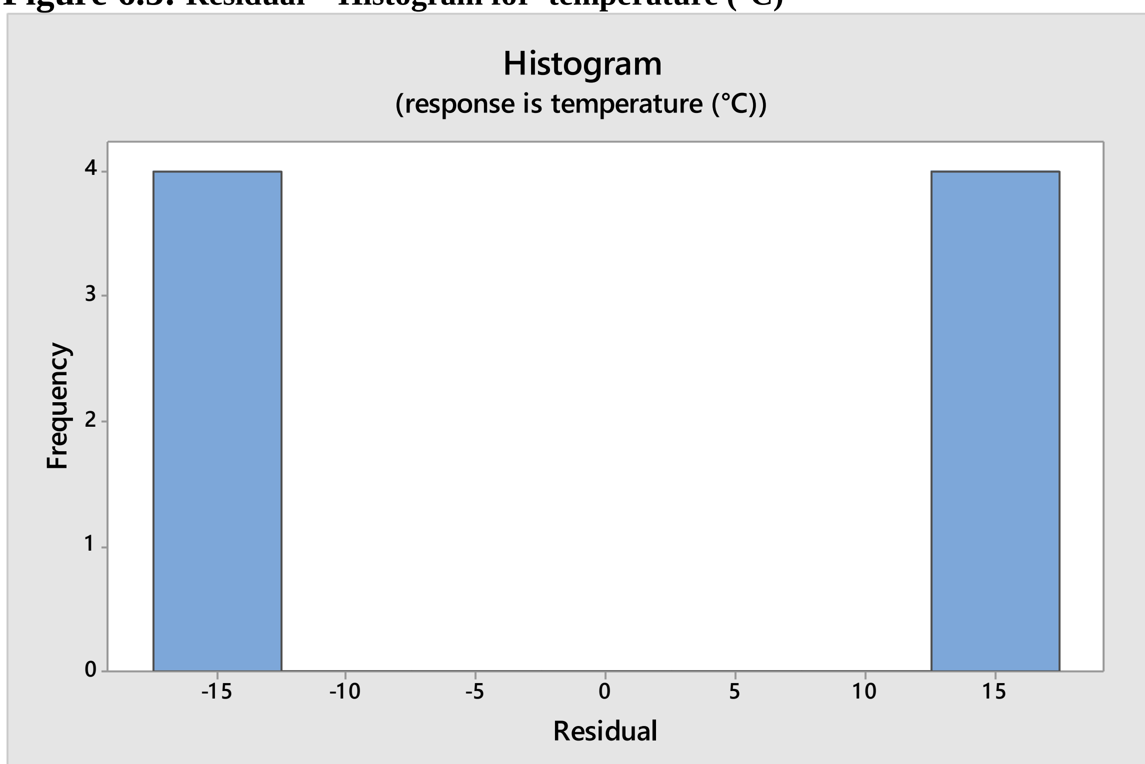


Figure 6.4: Contour Plot of temperature (°C) vs feed(mm), Speed(rpm)

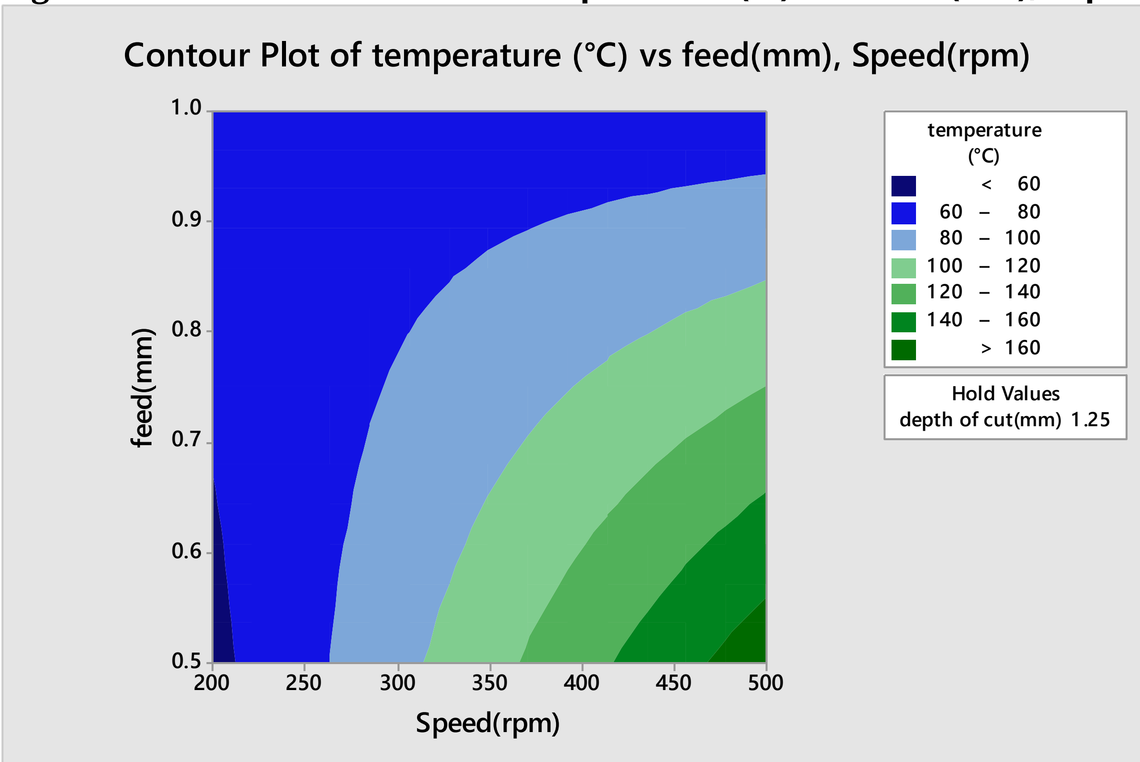


Figure 6.5: Contour Plot of temperature (°C) vs. depth of cut(mm), Speed(rpm)

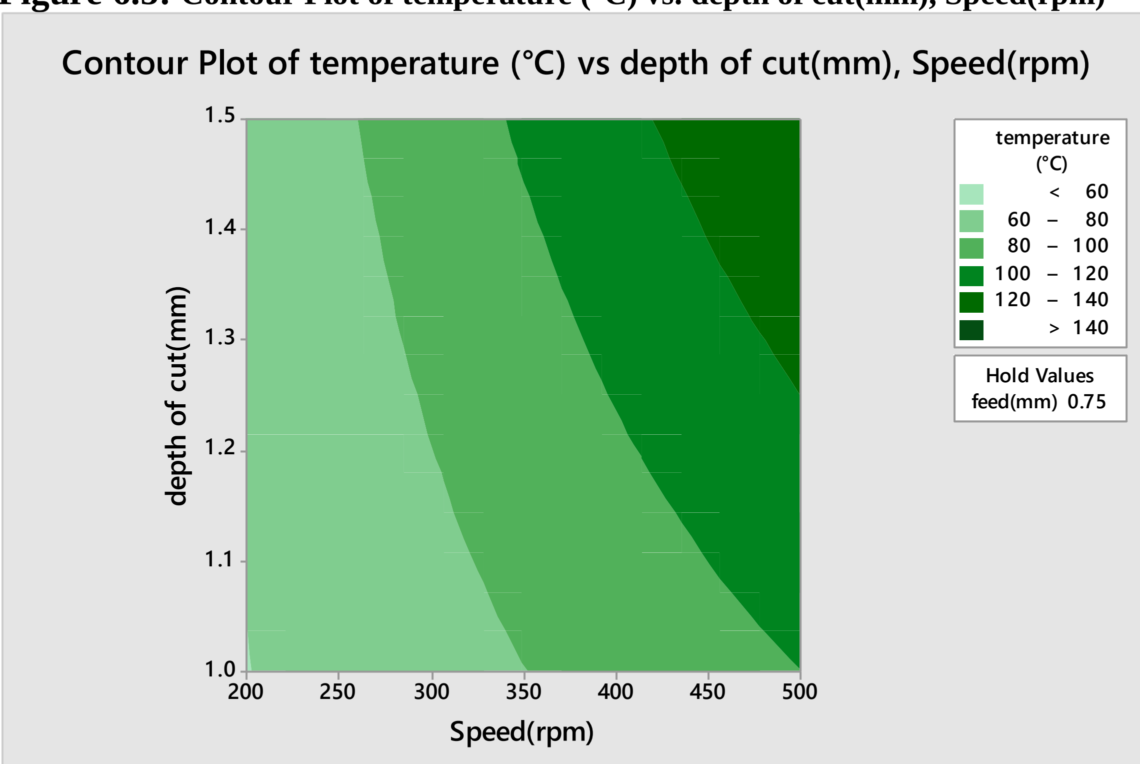


Figure 6.6: Contour Plot of temperature (°C) vs. depth of cut(mm), feed(mm)

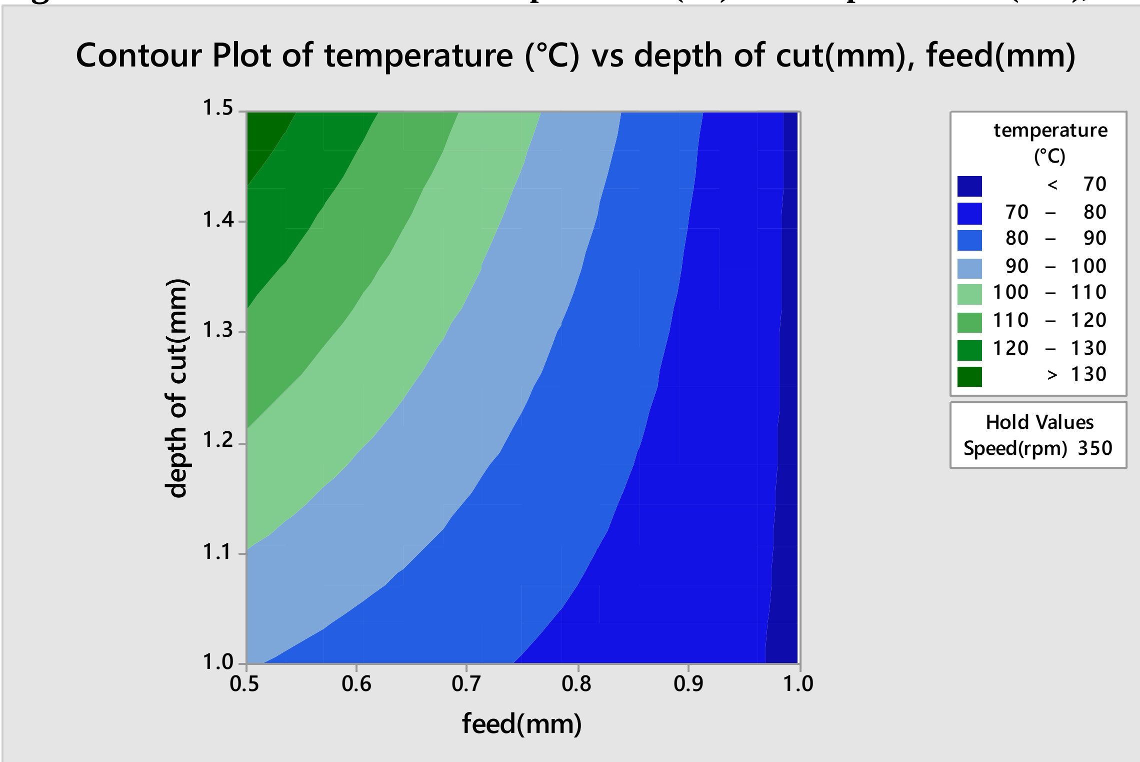


Figure 6.7: Surface Plot of temperature (°C) vs feed(mm), Speed(rpm)

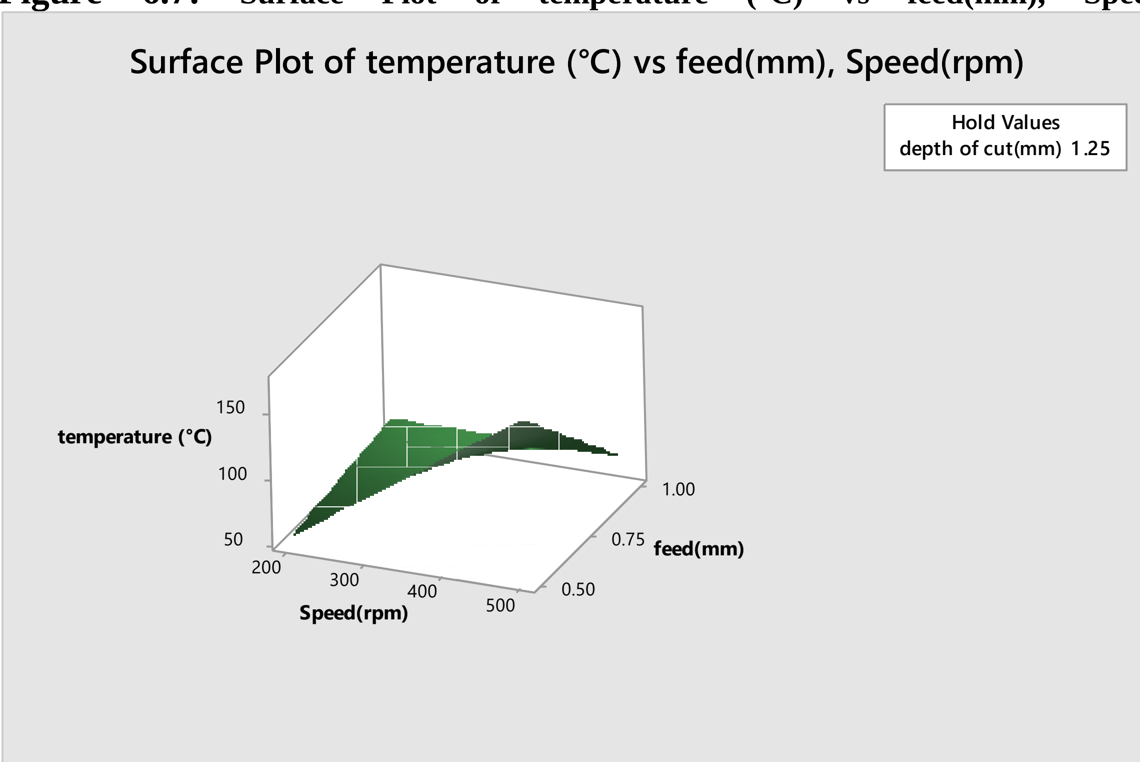


Figure 6.8: Surface Plot of temperature (°C) vs. depth of cut(mm), Speed(rpm)

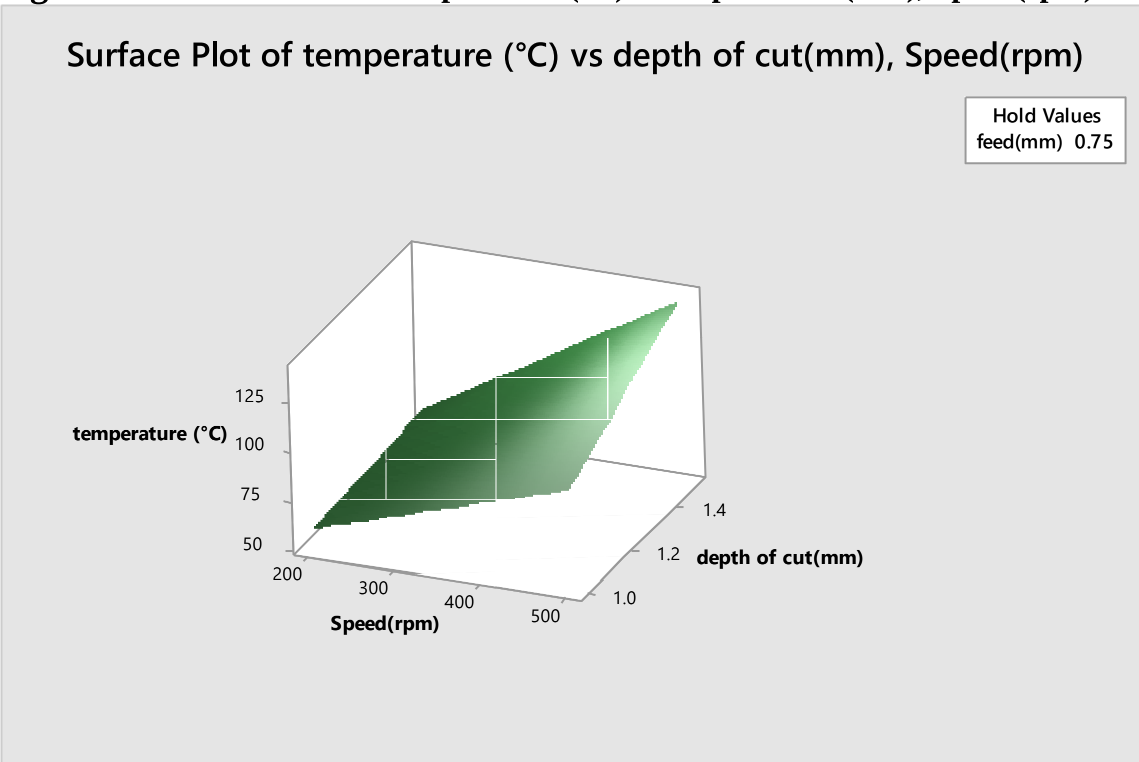
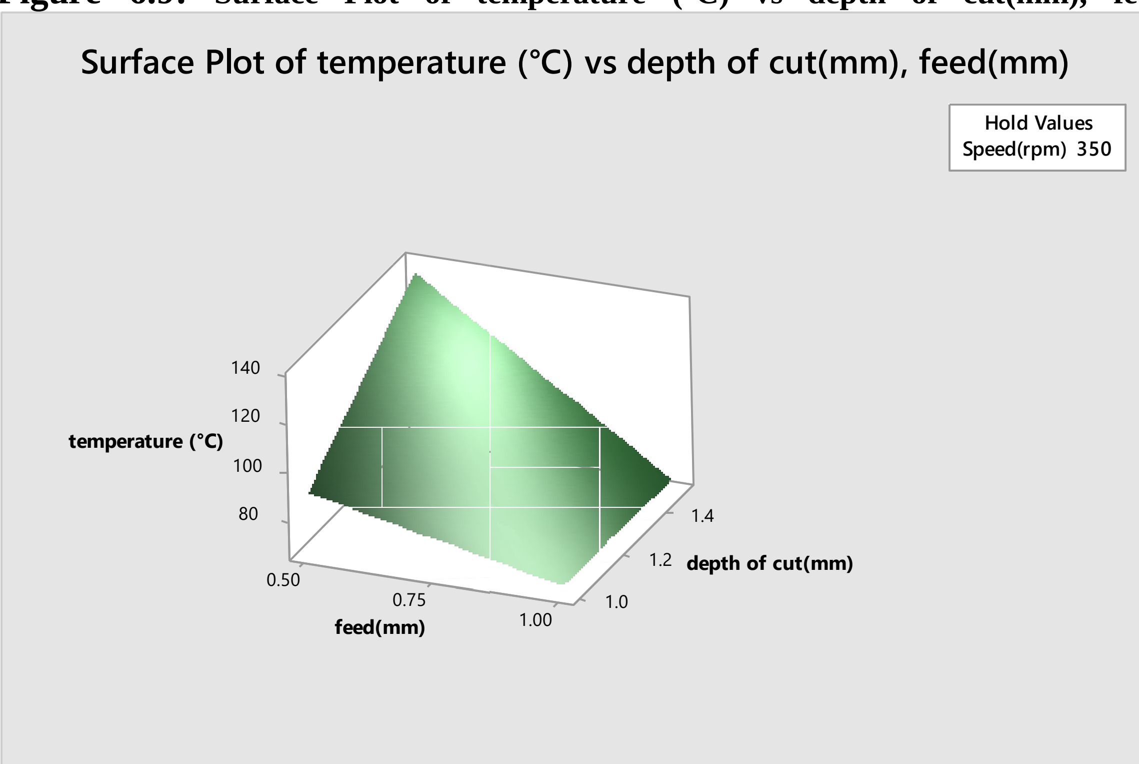


Figure 6.9: Surface Plot of temperature (°C) vs depth of cut(mm), feed(mm)



Response Surface Regression: chip thickness r versus Speed(rpm), feed(mm), depth of cut(mm)

The following terms cannot be estimated and were removed:
Speed(rpm)*Speed(rpm), feed(mm)*feed(mm), depth of cut(mm)*depth of cut(mm)

Analysis of Variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value
Model	6	0.005145	88.02%	0.005145	0.000857	1.22
Linear	3	0.003630	62.10%	0.003630	0.001210	1.73
Speed(rpm)	1	0.000016	0.27%	0.000016	0.000016	0.02
feed(mm)	1	0.000874	14.96%	0.000874	0.000874	1.25
depth of cut(mm)	1	0.002739	46.87%	0.002739	0.002739	3.91
2-Way Interaction	3	0.001515	25.92%	0.001515	0.000505	0.72
Speed(rpm)*feed(mm)	1	0.000898	15.36%	0.000898	0.000898	1.28
Speed(rpm)*depth of cut(mm)	1	0.000005	0.09%	0.000005	0.000005	0.01
feed(mm)*depth of cut(mm)	1	0.000612	10.47%	0.000612	0.000612	0.87
Error	1	0.000700	11.98%	0.000700	0.000700	
Total	7	0.005845	100.00%			

Source	P-Value
Model	0.599
Linear	0.498
Speed(rpm)	0.905
feed(mm)	0.465
depth of cut(mm)	0.298
2-Way Interaction	0.676
Speed(rpm)*feed(mm)	0.460
Speed(rpm)*depth of cut(mm)	0.945
feed(mm)*depth of cut(mm)	0.521
Error	
Total	

Model Summary

S	R-sq	R-sq(adj)	PRESS	R-sq(pred)
0.0264599	88.02%	16.15%	0.0448082	0.00%

Coded Coefficients

Term	Effect	Coef	SE Coef	95% CI	T-Value
Constant		0.02835	0.00935	(-0.09052, 0.14721)	3.03
Speed(rpm)	0.00281	0.00140	0.00936	(-0.11746, 0.12027)	0.15
feed(mm)	0.02091	0.01046	0.00935	(-0.10841, 0.12932)	1.12
depth of cut(mm)	0.03701	0.01850	0.00935	(-0.10036, 0.13737)	1.98
Speed(rpm)*feed(mm)	0.02119	0.01059	0.00935	(-0.10827, 0.12946)	1.13
Speed(rpm)*depth of cut(mm)	-0.00161	-0.00080	0.00936	(-0.11967, 0.11806)	-0.09
feed(mm)*depth of cut(mm)	0.01749	0.00874	0.00936	(-0.11012, 0.12761)	0.93

Term	P-Value	VIF
Constant	0.203	
Speed(rpm)	0.905	1.00
feed(mm)	0.465	1.00
depth of cut(mm)	0.298	1.00
Speed(rpm)*feed(mm)	0.460	1.00
Speed(rpm)*depth of cut(mm)	0.945	1.00
feed(mm)*depth of cut(mm)	0.521	1.00

Regression Equation in Uncoded Units

```
chip thickness ratio = 0.097 - 0.000176 Speed(rpm) - 0.232 feed(mm) -
 0.023 depth of cut(mm)
                       + 0.000283 Speed(rpm)*feed(mm) -
 0.000021 Speed(rpm)*depth of cut(mm)
                       + 0.140 feed(mm)*depth of cut(mm)
```

Figure 6.10: Normplot of Residuals for chip thickness ratio

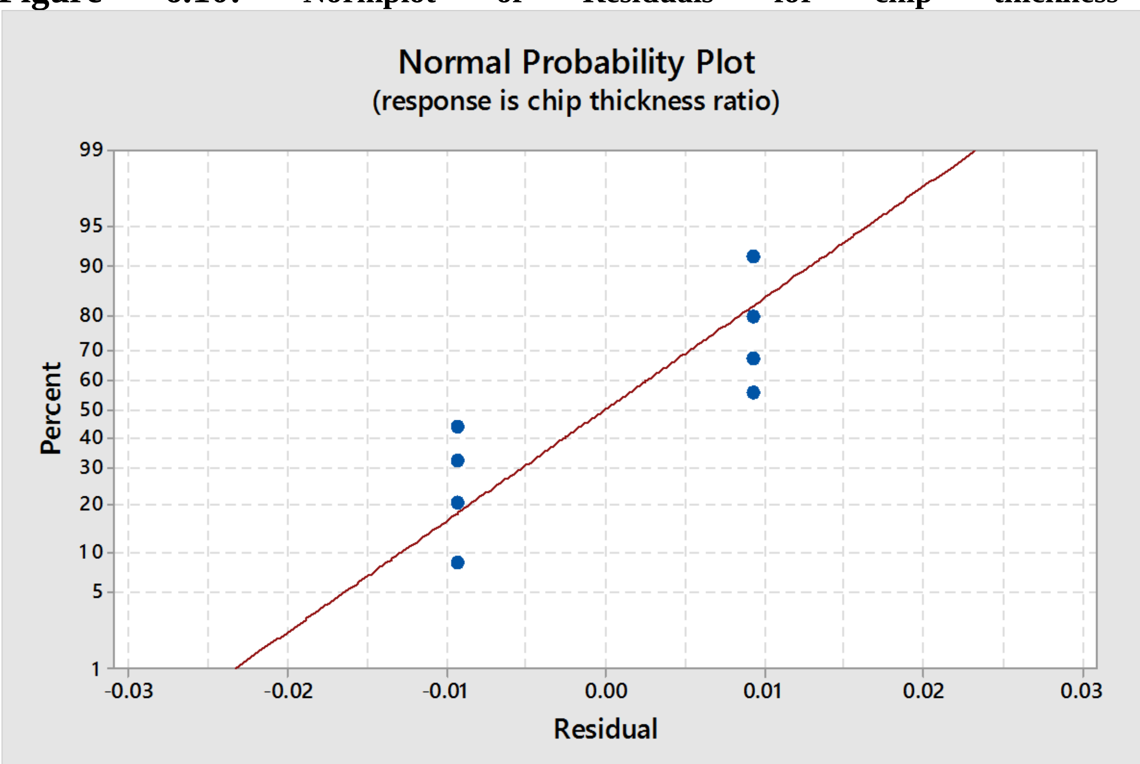


Figure 6.11: Residuals vs. Fits for chip thickness ratio

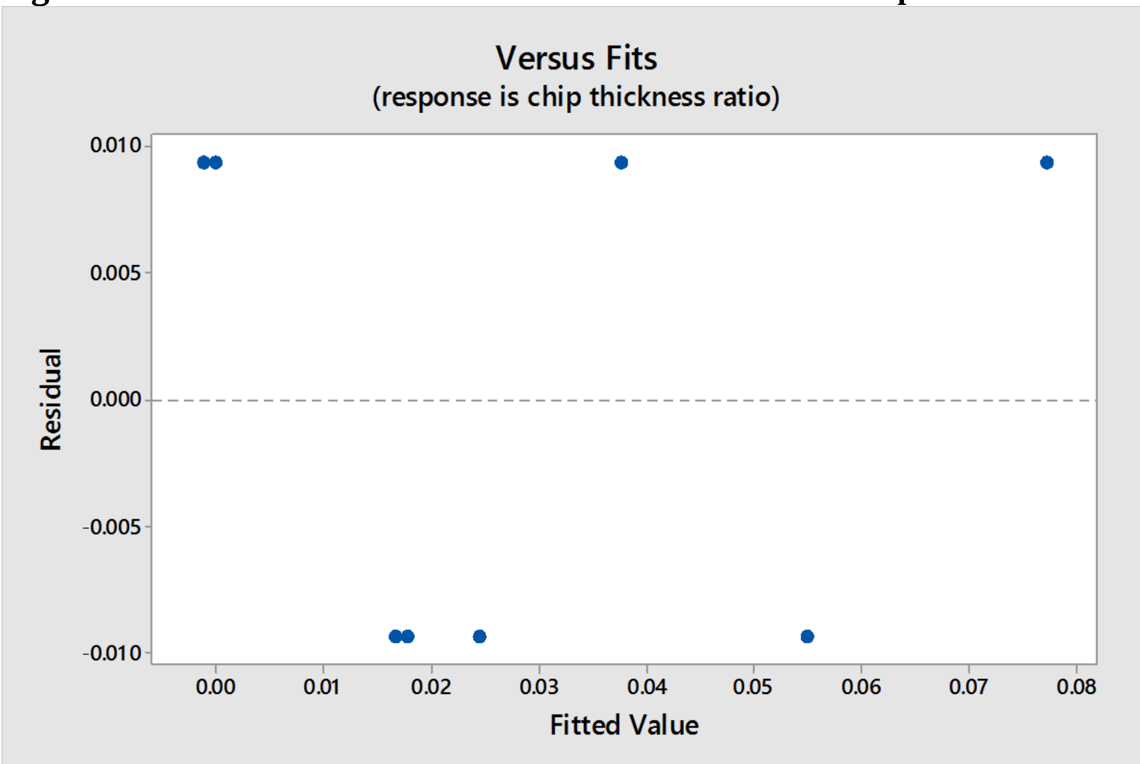


Figure 6.12: Residual Histogram for chip thickness ratio

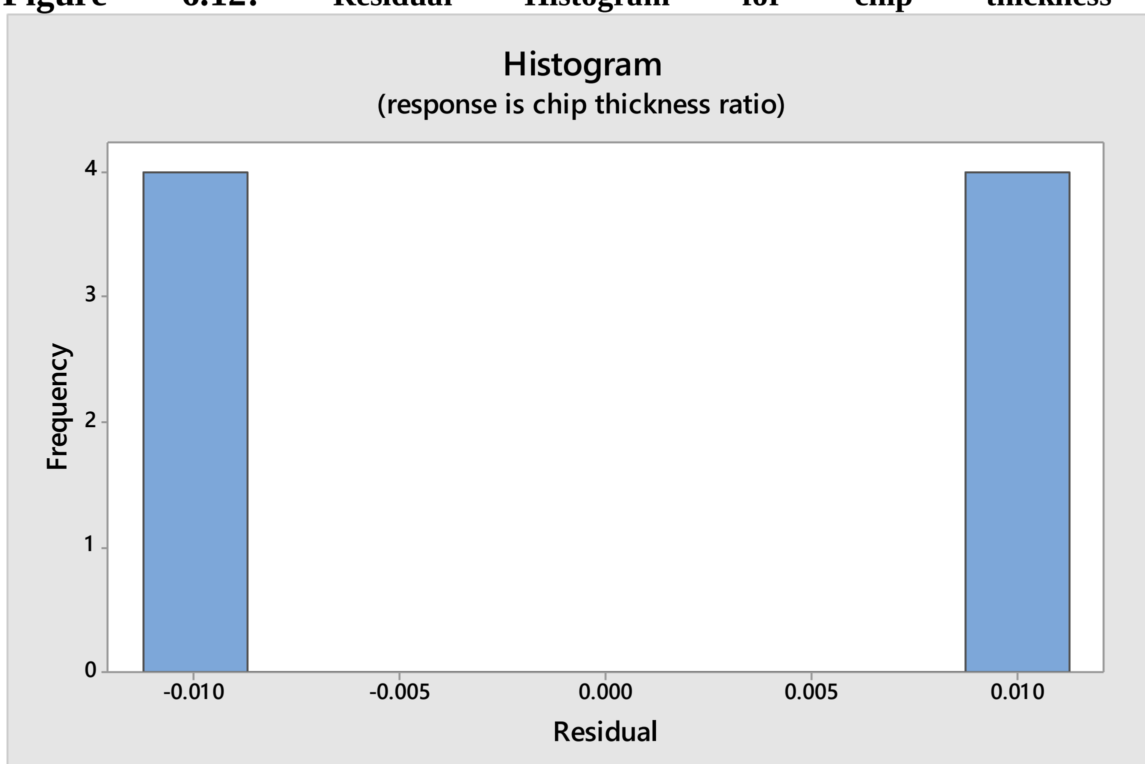


Figure 6.13: Contour Plot of chip thickness ratio vs. feed(mm), Speed(rpm)

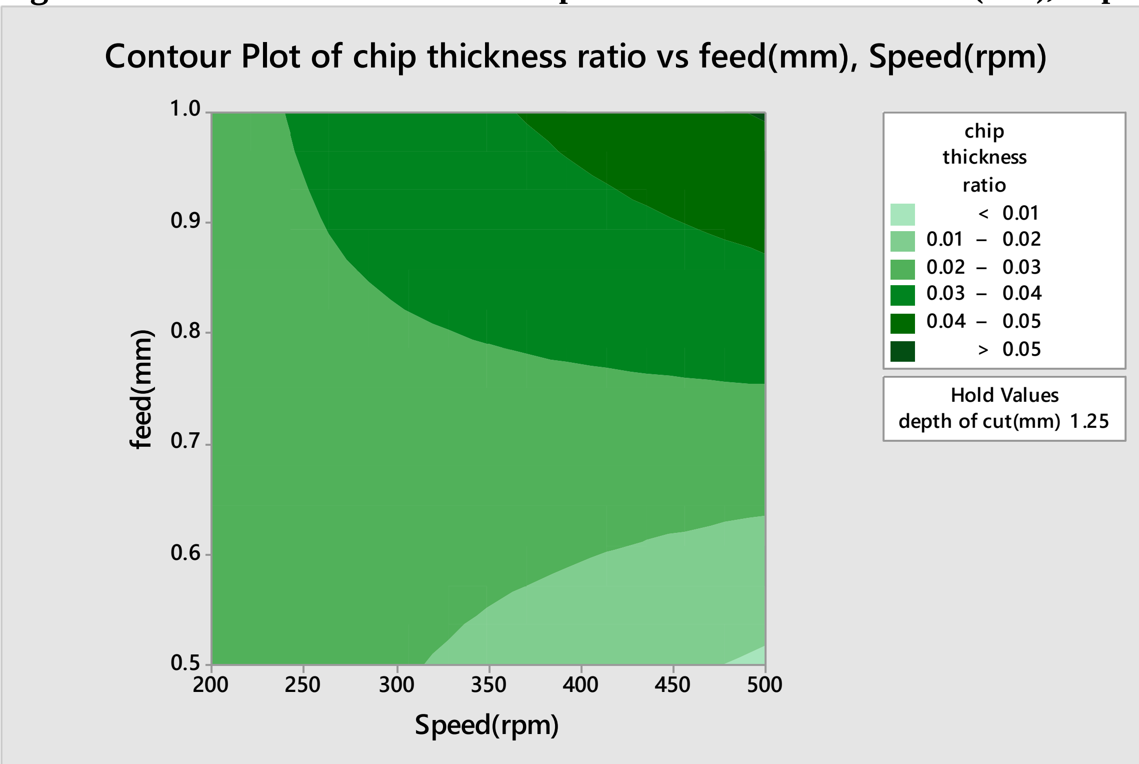


Figure 6.14: Contour Plot of chip thickness ratio vs. depth of cut(mm), Speed(rpm)

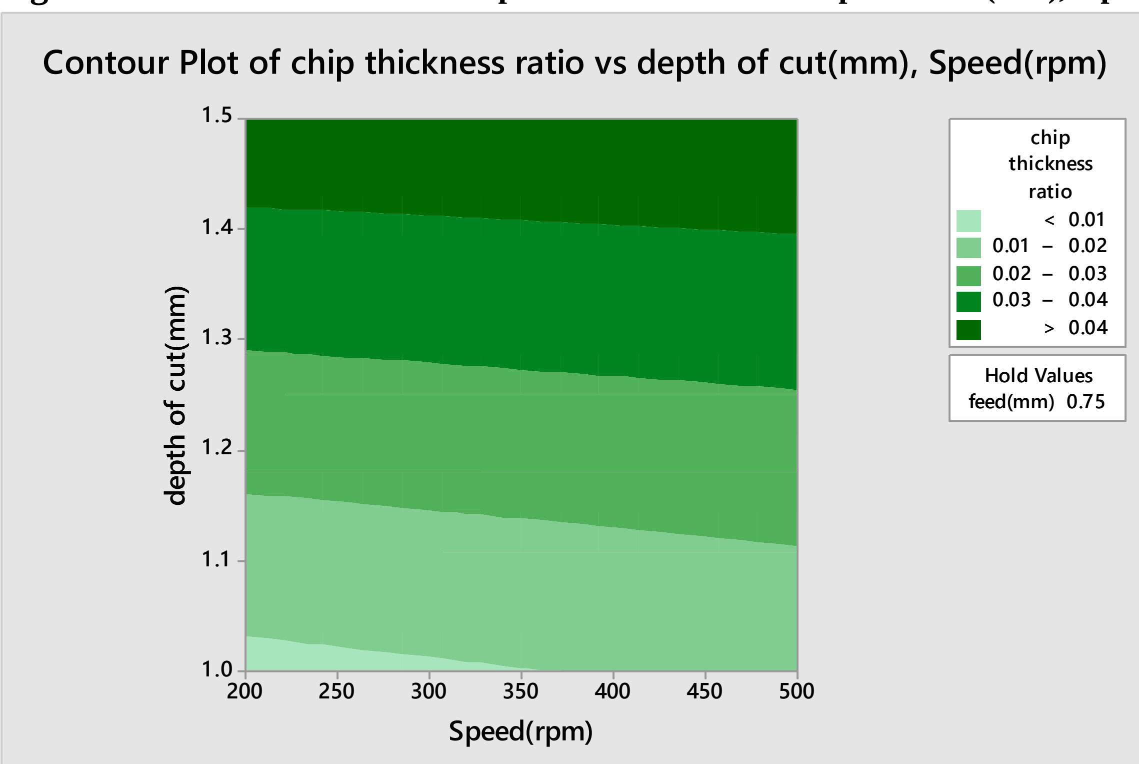


Figure 6.15: Contour Plot of chip thickness ratio vs. depth of cut(mm), feed(mm)

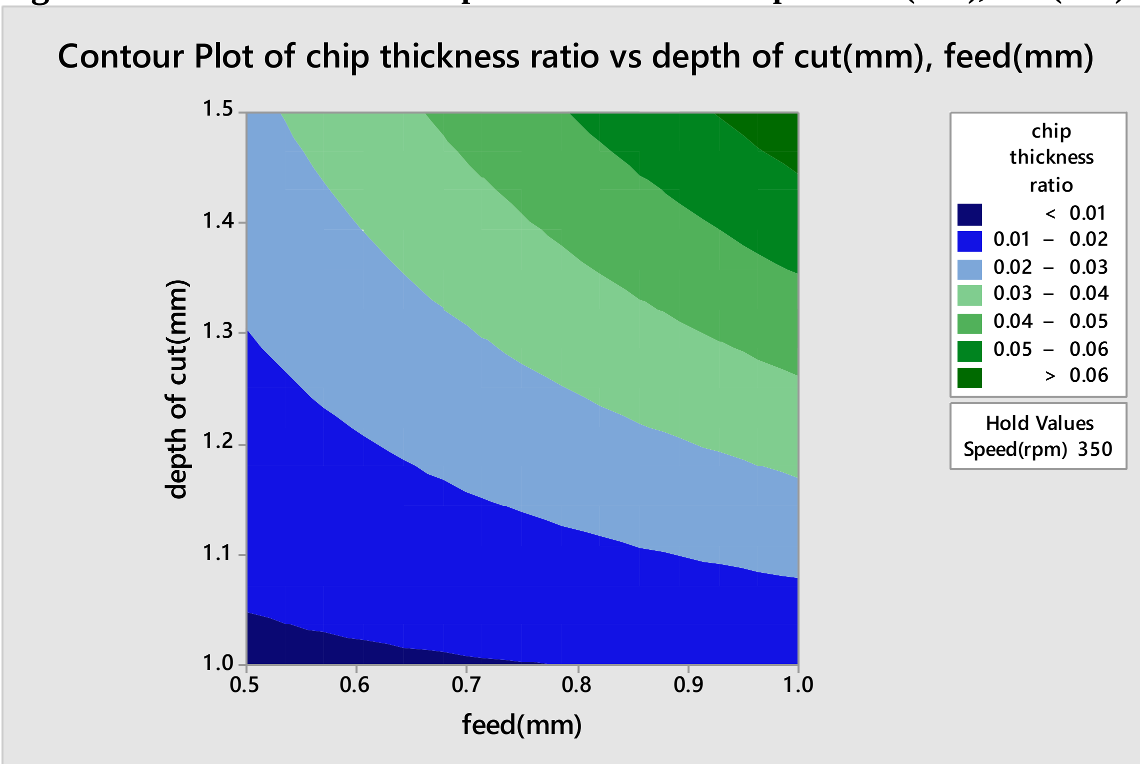


Figure 6.16: Surface Plot of chip thickness ratio vs. feed(mm), Speed(rpm)

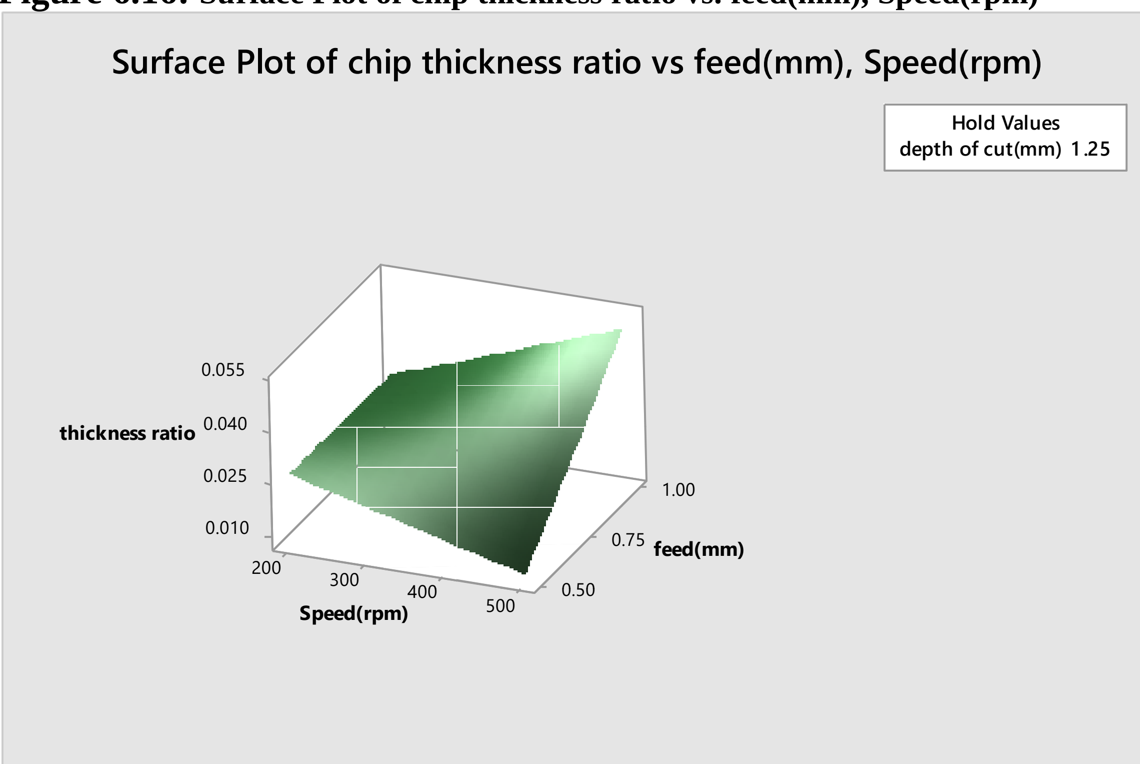


Figure 6.17: **Surface Plot of chip thickness ratio vs depth of cut(mm), Speed(rpm)**

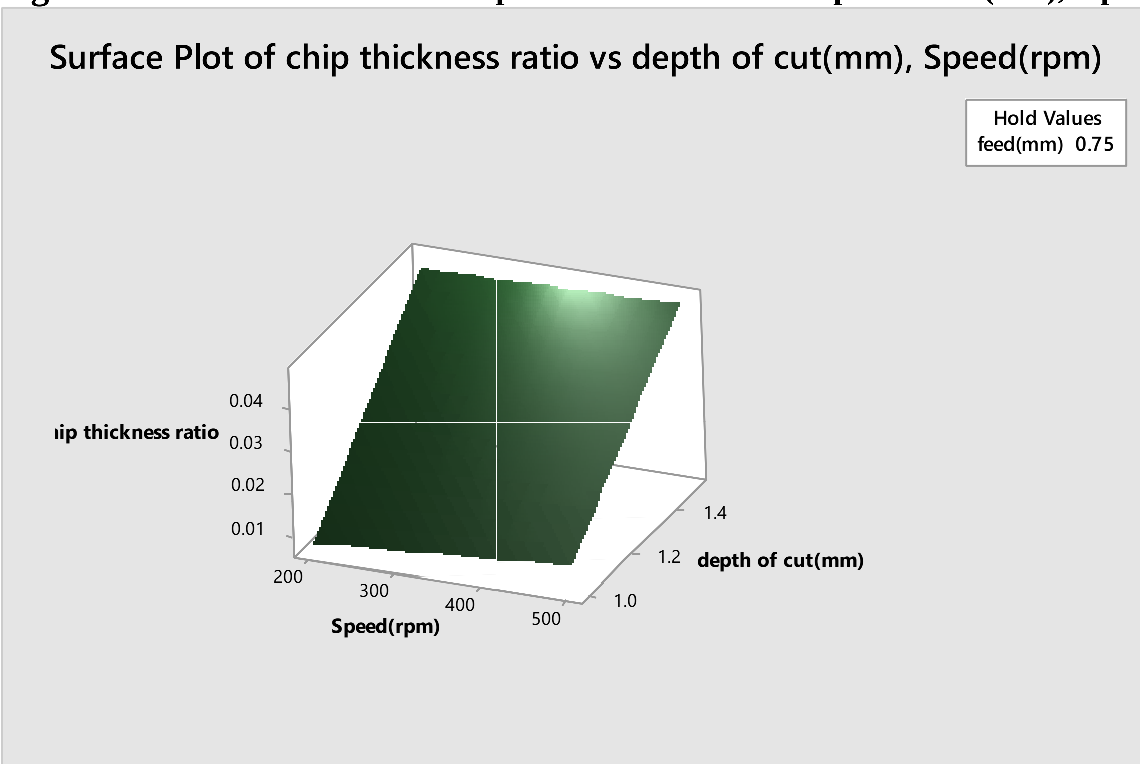
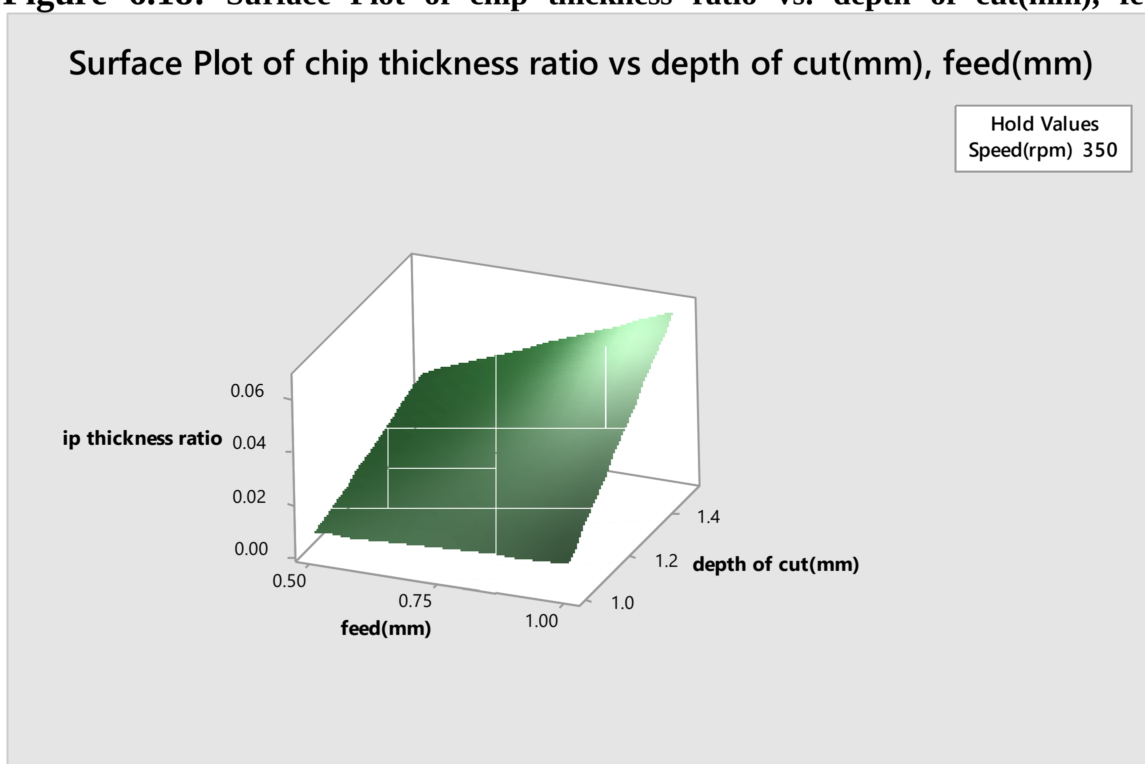


Figure 6.18: **Surface Plot of chip thickness ratio vs. depth of cut(mm), feed(mm)**



Response Surface Regression: shear angle versus Speed(rpm), feed(mm), depth of cut(mm)

The following terms cannot be estimated and were removed:
Speed(rpm)*Speed(rpm), feed(mm)*feed(mm), depth of cut(mm)*depth of cut(mm)

Analysis of Variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value
Model	6	63.1954	95.71%	63.1954	10.5326	3.72
Linear	3	41.1718	62.36%	41.1718	13.7239	4.85
Speed(rpm)	1	0.0242	0.04%	0.0242	0.0242	0.01
feed(mm)	1	11.8098	17.89%	11.8098	11.8098	4.17
depth of cut(mm)	1	29.3378	44.43%	29.3378	29.3378	10.36
2-Way Interaction	3	22.0236	33.36%	22.0236	7.3412	2.59
Speed(rpm)*feed(mm)	1	7.4498	11.28%	7.4498	7.4498	2.63
Speed(rpm)*depth of cut(mm)	1	13.7288	20.79%	13.7288	13.7288	4.85
feed(mm)*depth of cut(mm)	1	0.8450	1.28%	0.8450	0.8450	0.30
Error	1	2.8322	4.29%	2.8322	2.8322	
Total	7	66.0276	100.00%			

Source	P-Value
Model	0.377
Linear	0.320
Speed(rpm)	0.941
feed(mm)	0.290
depth of cut(mm)	0.192
2-Way Interaction	0.421
Speed(rpm)*feed(mm)	0.352
Speed(rpm)*depth of cut(mm)	0.271
feed(mm)*depth of cut(mm)	0.682
Error	
Total	

Model Summary

S	R-sq	R-sq(adj)	PRESS	R-sq(pred)
1.68291	95.71%	69.97%	181.261	0.00%

Coded Coefficients

Term	Effect	Coef	SE Coef	95% CI	T-Value	P-Value
Constant		85.450	0.595	(77.890, 93.010)	143.61	0.004
Speed(rpm)	-0.110	-0.055	0.595	(-7.615, 7.505)	-0.09	0.941
feed(mm)	2.430	1.215	0.595	(-6.345, 8.775)	2.04	0.290
depth of cut(mm)	3.830	1.915	0.595	(-5.645, 9.475)	3.22	0.192
Speed(rpm)*feed(mm)	1.930	0.965	0.595	(-6.595, 8.525)	1.62	0.352
Speed(rpm)*depth of cut(mm)	-2.620	-1.310	0.595	(-8.870, 6.250)	-2.20	0.271
feed(mm)*depth of cut(mm)	0.650	0.325	0.595	(-7.235, 7.885)	0.55	0.682

Term	VIF
Constant	

```
Speed(rpm)                    1.00
feed(mm)                      1.00
depth of cut(mm)              1.00
Speed(rpm)*feed(mm)           1.00
Speed(rpm)*depth of cut(mm)   1.00
feed(mm)*depth of cut(mm)     1.00


Regression Equation in Uncoded Units

shear angle = 68.7 + 0.0240 Speed(rpm) - 10.6 feed(mm) + 15.99 depth of cut(mm)
              + 0.0257 Speed(rpm)*feed(mm) - 0.0349 Speed(rpm)*depth of cut(mm)
              + 5.20 feed(mm)*depth of cut(mm)
```

Figure 6.19: Normplot of Residuals for shear angle

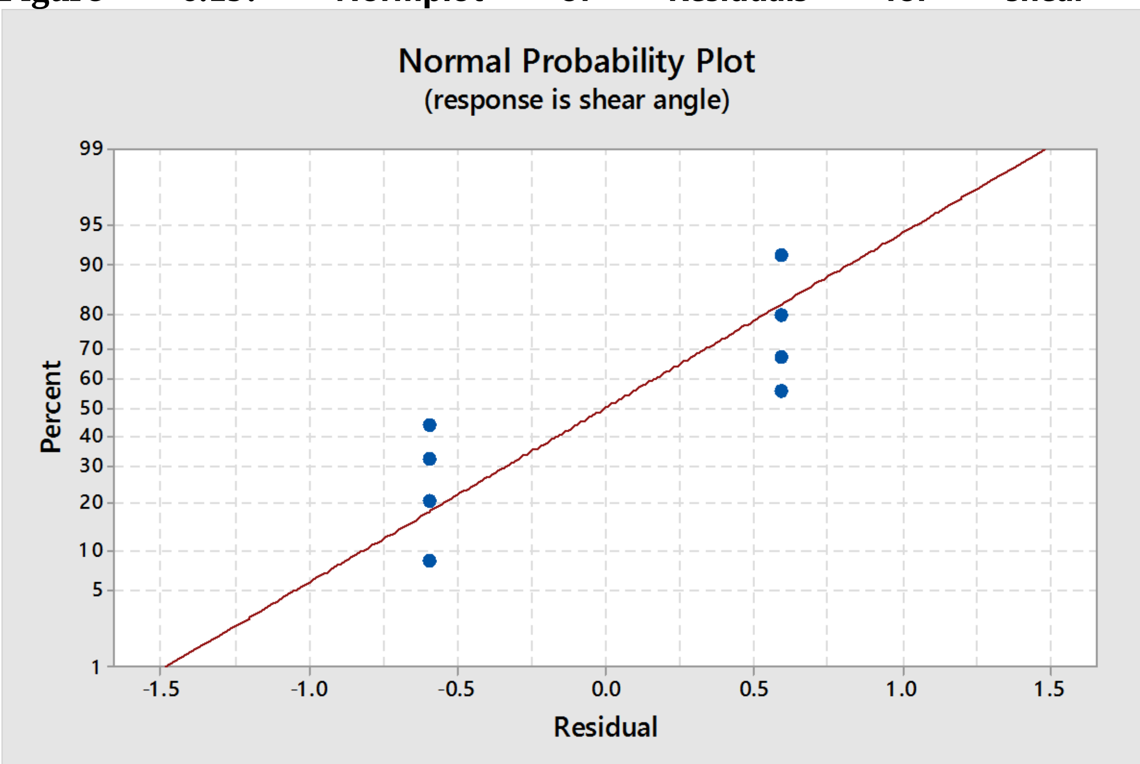


Figure 6.20: Residuals vs. Fits for shear angle

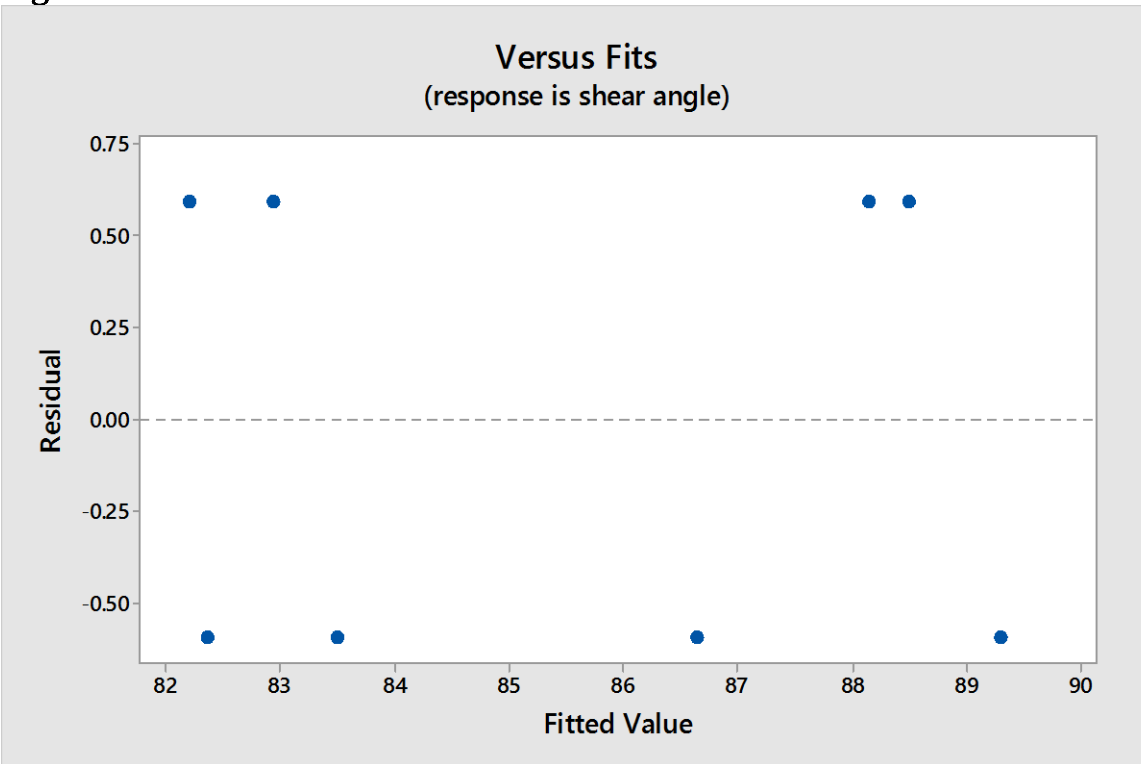


Figure 6.21: Residual Histogram for shear angle

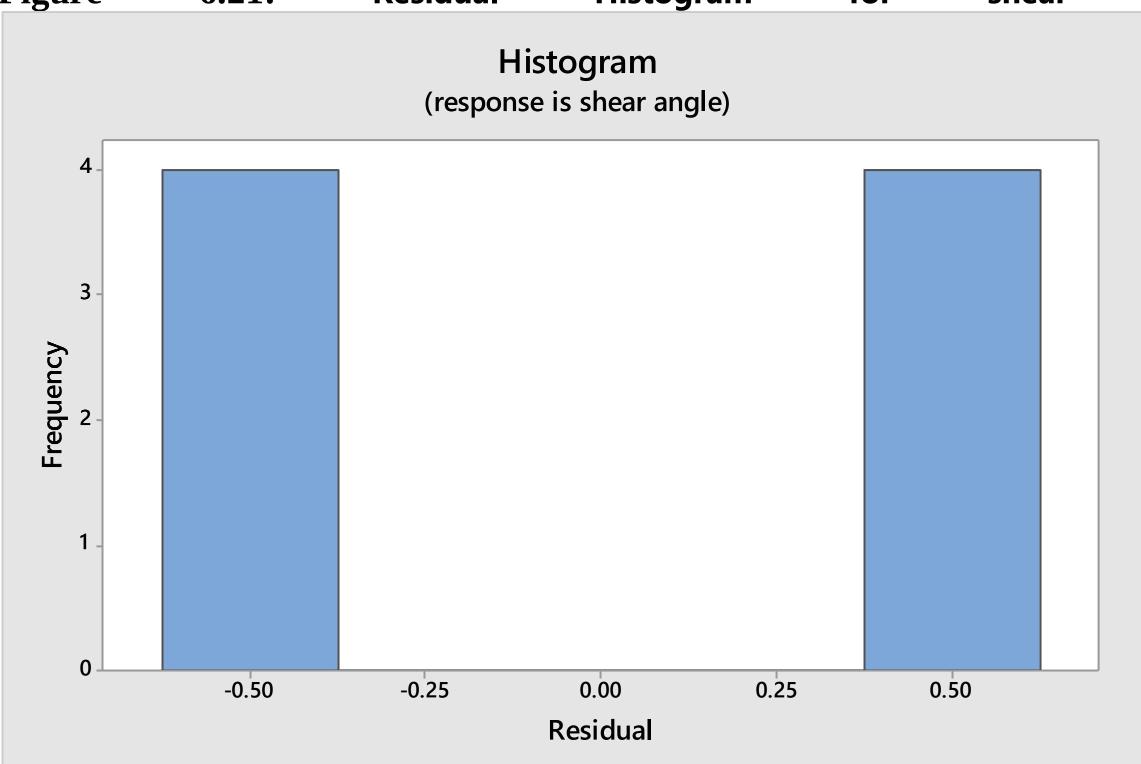


Figure 6.22: Contour Plot of shear angle vs. feed(mm), Speed(rpm)

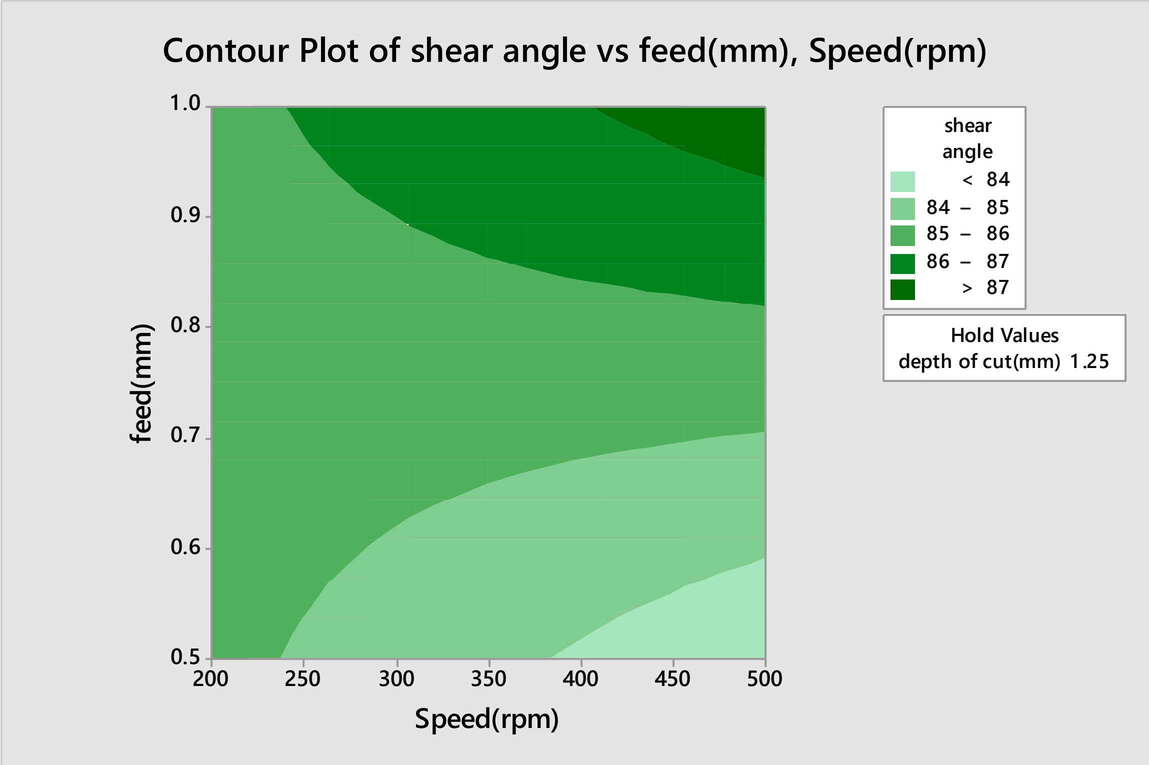


Figure 6.23: Contour Plot of shear angle vs. feed(mm), depth of cut(mm)

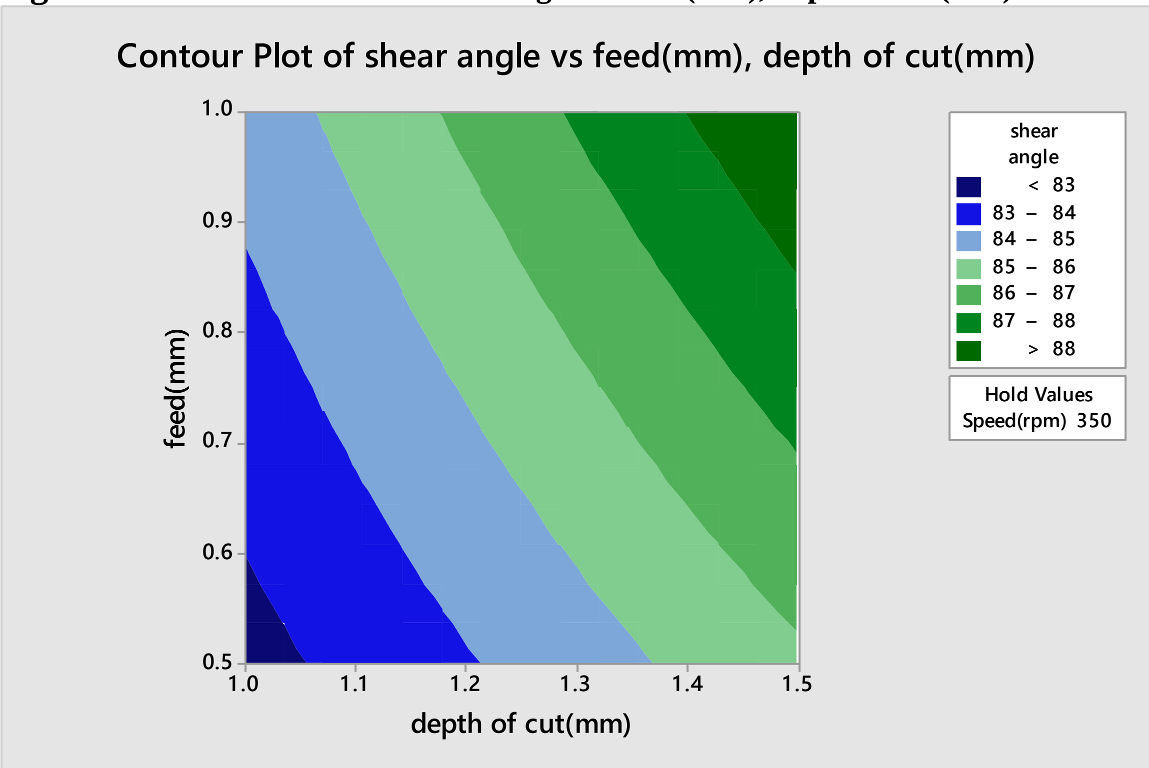


Figure 6.24: Contour Plot of shear angle vs. Speed(rpm), depth of cut(mm)

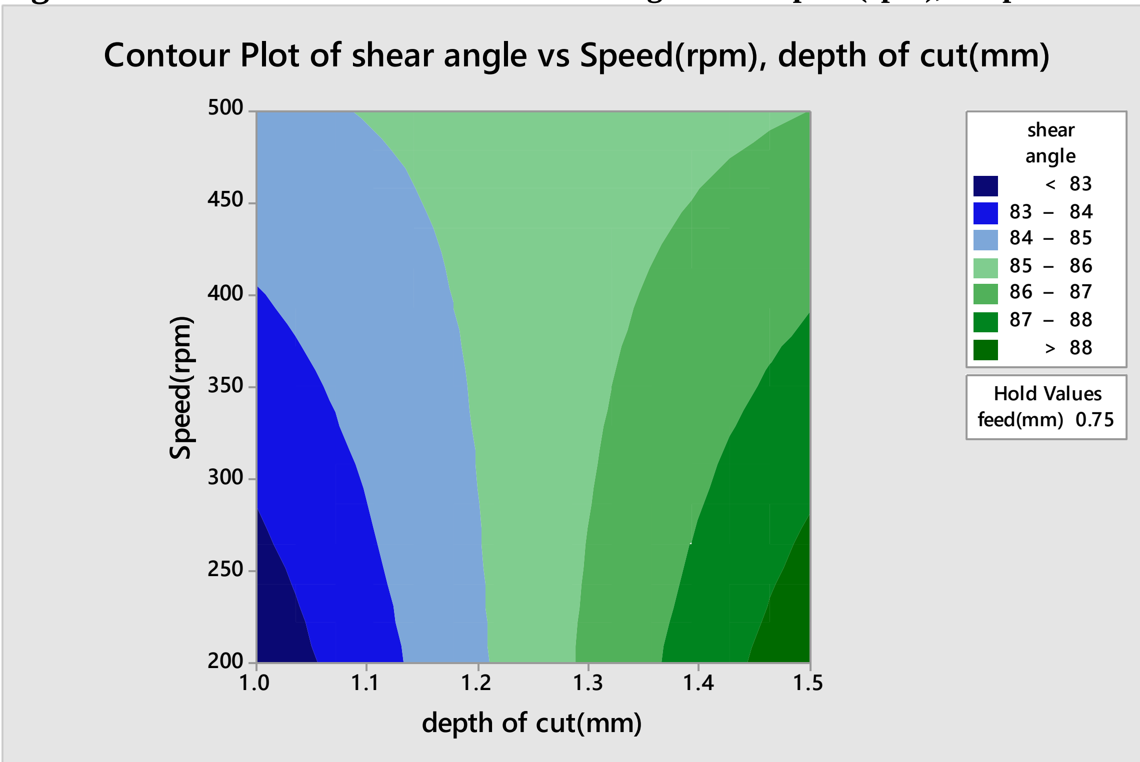


Figure 6.25: Suface Plot of shear angle vs. feed(mm), Speed(rpm)

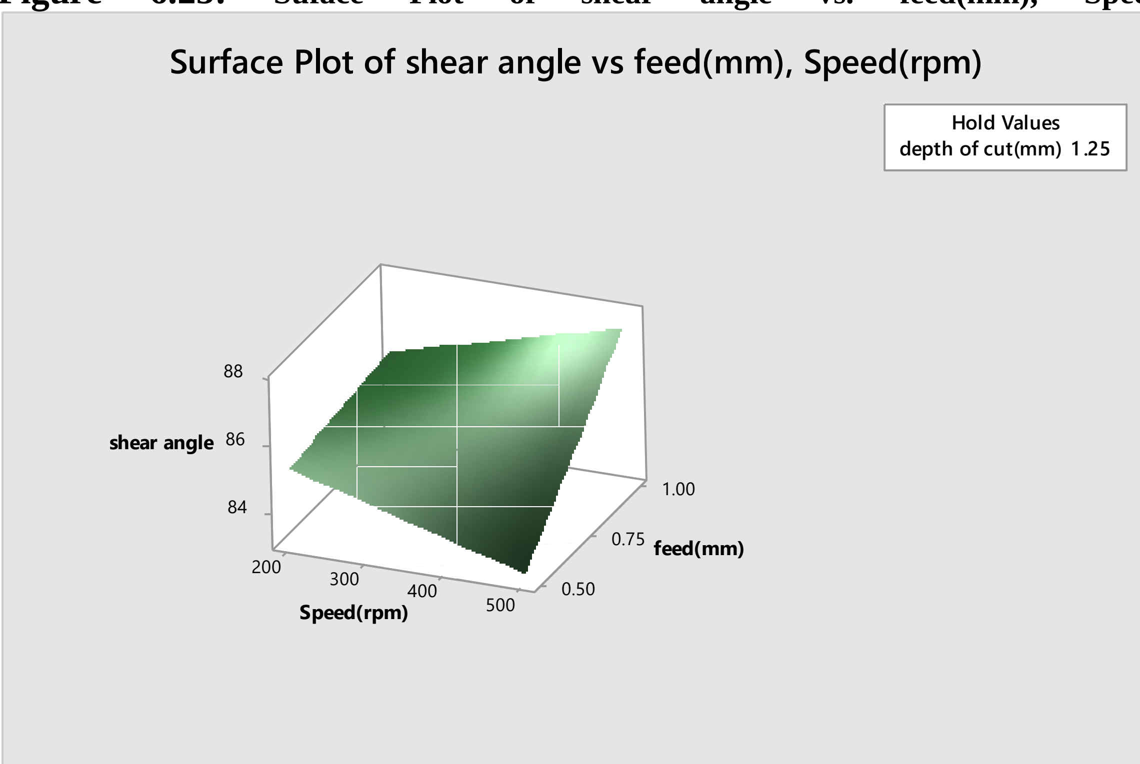


Figure 6.26: Surface Plot of shear angle vs depth of cut(mm), Speed(rpm)

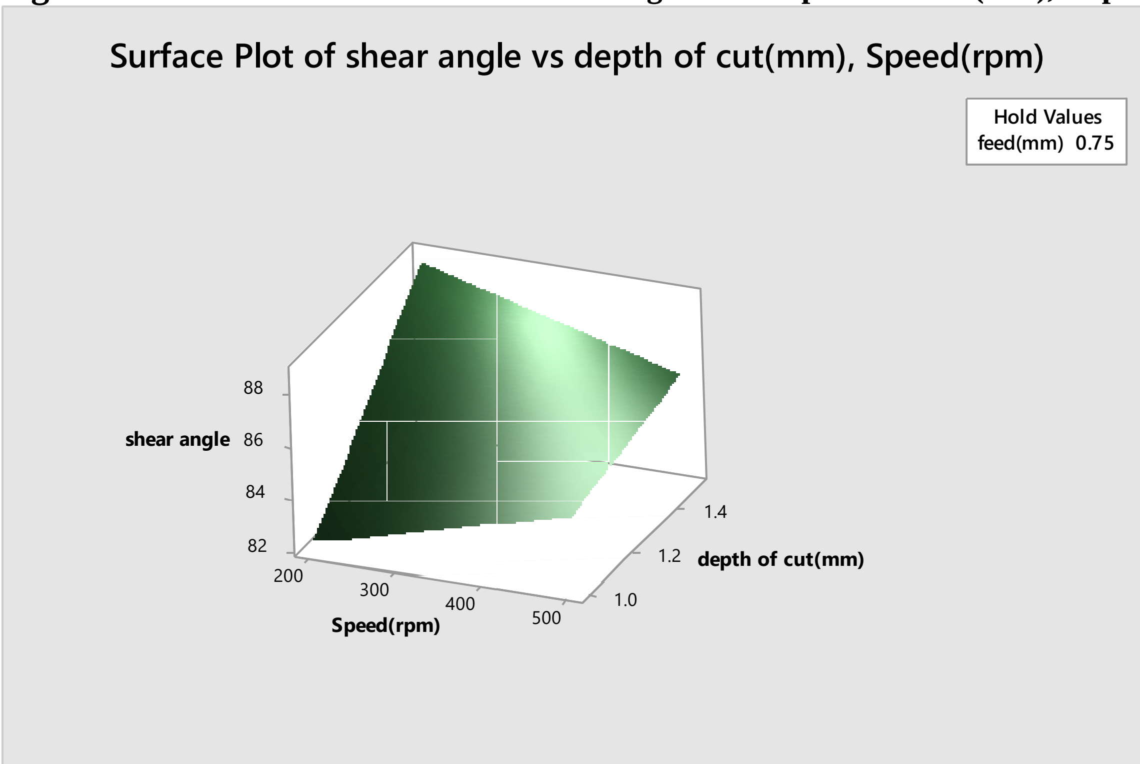
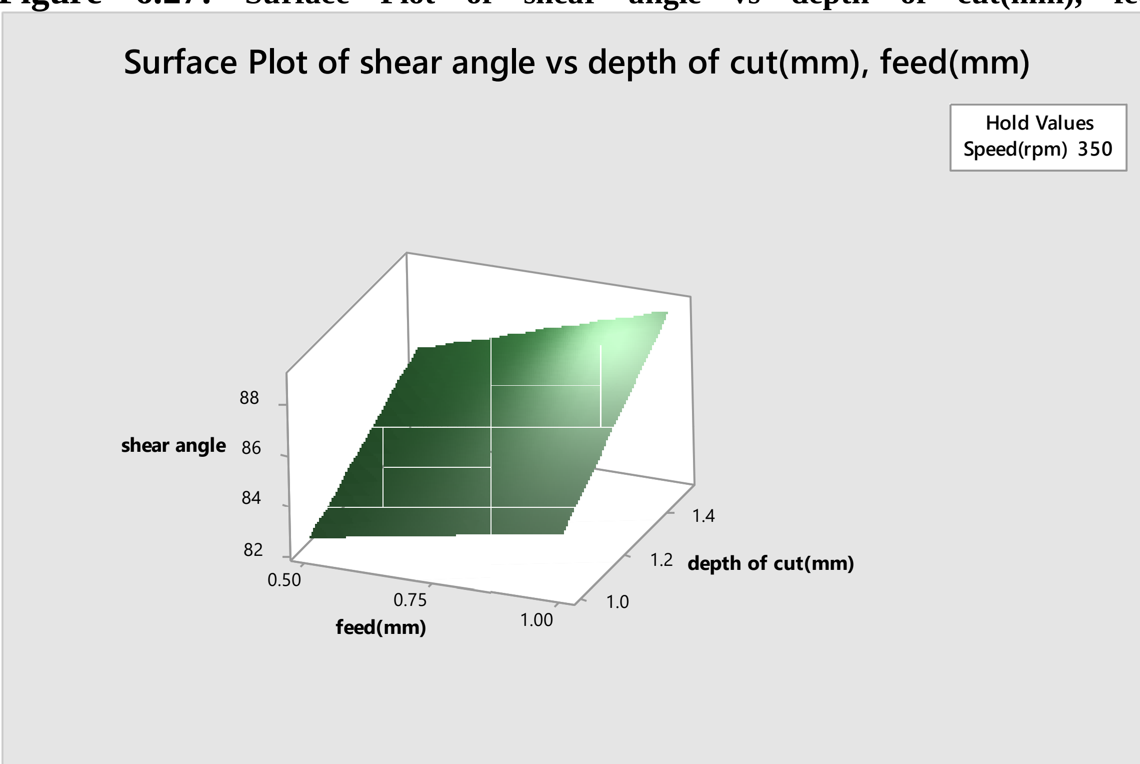


Figure 6.27: Surface Plot of shear angle vs depth of cut(mm), feed(mm)



Response Optimization: shear angle, chip thickness ratio, temperature (°C)

Parameters

Response	Goal	Lower	Target	Upper	Weight	Importance
shear angle	Maximum	81.7600	89.1000		1	1
chip thickness ratio	Maximum	0.0072	0.0866		1	1
temperature (°C)	Minimum		54.0000	217	1	1

Solution

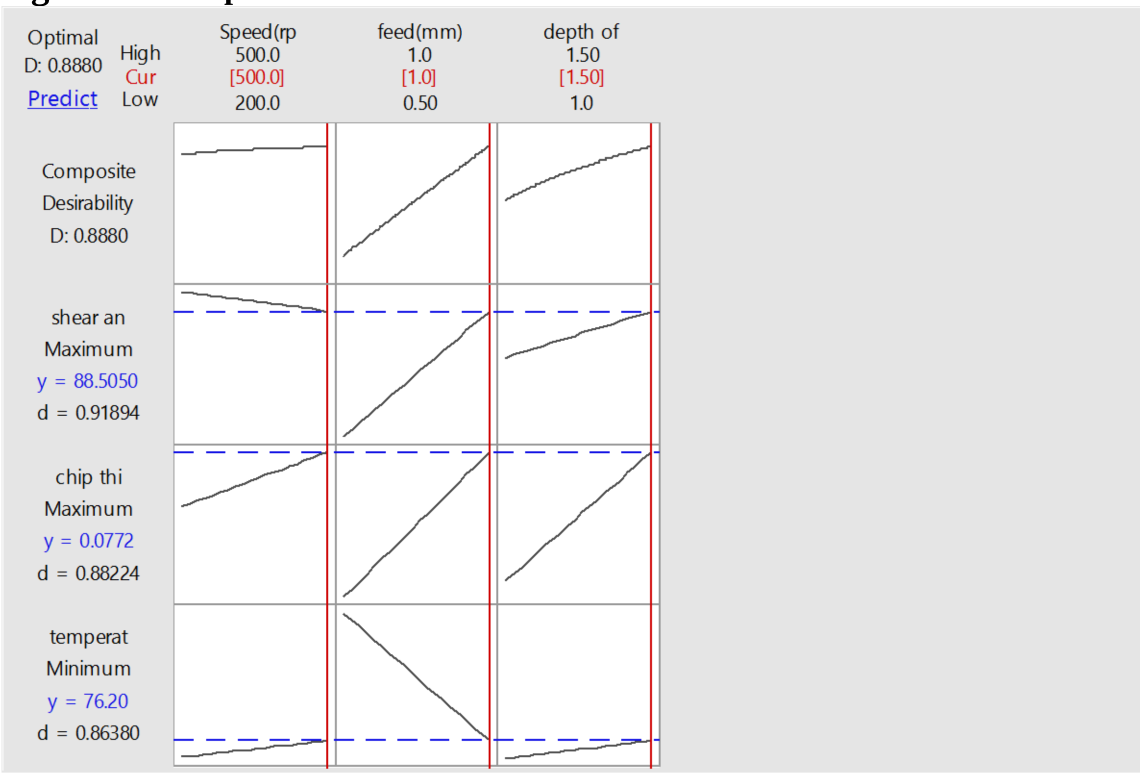
Solution	Speed(rpm)	feed(mm)	depth of cut(mm)	shear angle Fit	chip thickness ratio Fit	temperature (°C) Fit	Composite Desirability
1	500	1	1.5	88.505	0.077245	76.2	0.888033

Multiple Response Prediction

Variable	Setting
Speed(rpm)	500
feed(mm)	1
depth of cut(mm)	1.5

Response	Fit	SE Fit	95% CI	95% PI
shear angle	88.50	1.57	(68.50, 108.51)	(59.22, 117.79)
chip thickness ratio	0.0772	0.0248	(-0.2372, 0.3917)	(-0.3831, 0.5376)
temperature (°C)	76.2	34.9	(-367.6, 520.0)	(-573.4, 725.8)

Figure 6.28: Optimization Plot



6.6.OBSERVATION TABLE FOR EN19 WET CONDITION:

S.no	Speed	Feed	D.O.C	Temperature	Chip thickness ratio	Shear angle	Chip formation
1	200	0.5	1	40.3	0.004	75.2	Continuous
2	200	0.5	1.5	42.8	0.053	79.09	Discontinuous
3	200	1	1	43	0.016	56.4	Discontinuous
4	200	1	1.5	41	0.045	77.16	Continuous
5	500	0.5	1	66	0.0053	78.906	Discontinuous
6	500	0.5	1.5	87	0.0031	71.56	Continuous with built-up edge
7	500	1	1	57	0.011	46.6	Continuous
8	500	1	1.5	57	0.072	81.904	Discontinuous

6.7.RESULTS FOR EN19 WET CONDITIONS

Response Surface Regression: temperature (°C) versus Speed(rpm), feed(mm), depth of cut(mm)

The following terms cannot be estimated and were removed:
Speed(rpm)*Speed(rpm), feed(mm)*feed(mm), depth of cut(mm)*depth of cut(mm)

Analysis of Variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Model	6	1819.55	98.16%	1819.55	303.26	8.91	0.251
Linear	3	1486.73	80.21%	1486.73	495.58	14.56	0.190
Speed(rpm)	1	1247.50	67.30%	1247.50	1247.50	36.66	0.104
feed(mm)	1	181.45	9.79%	181.45	181.45	5.33	0.260
depth of cut(mm)	1	57.78	3.12%	57.78	57.78	1.70	0.417
2-Way Interaction	3	332.81	17.96%	332.81	110.94	3.26	0.382
Speed(rpm)*feed(mm)	1	199.00	10.74%	199.00	199.00	5.85	0.250
Speed(rpm)*depth of cut(mm)	1	52.53	2.83%	52.53	52.53	1.54	0.431
feed(mm)*depth of cut(mm)	1	81.28	4.39%	81.28	81.28	2.39	0.366
Error	1	34.03	1.84%	34.03	34.03		
Total	7	1853.58	100.00%				

Model Summary

S	R-sq	R-sq(adj)	PRESS	R-sq(pred)
5.83363	98.16%	87.15%	2178	0.00%

Coded Coefficients

Term	Effect	Coef	SE Coef	95% CI	T-Value	P-Value	VIF
Constant		54.26	2.06	(28.06, 80.47)	26.31	0.024	
Speed(rpm)	24.98	12.49	2.06	(-13.72, 38.69)	6.05	0.104	1.00
feed(mm)	-9.53	-4.76	2.06	(-30.97, 21.44)	-2.31	0.260	1.00
depth of cut(mm)	5.37	2.69	2.06	(-23.52, 28.89)	1.30	0.417	1.00
Speed(rpm)*feed(mm)	-9.98	-4.99	2.06	(-31.19, 21.22)	-2.42	0.250	1.00
Speed(rpm)*depth of cut(mm)	5.13	2.56	2.06	(-23.64, 28.77)	1.24	0.431	1.00

```
feed(mm)*depth of cut(mm)      -6.38   -3.19      2.06   (-29.39, 23.02)    -1.55    0.366
1.00


Regression Equation in Uncoded Units

temperature (°C) = -26.9 + 0.0976 Speed(rpm) + 91.3 feed(mm) + 25.1 depth of cut(mm)
                   - 0.1330 Speed(rpm)*feed(mm) + 0.0683 Speed(rpm)*depth of cut(mm)
                   - 51.0 feed(mm)*depth of cut(mm)
```

Figure 6.29: Normplot of Residuals for temperature (°C)

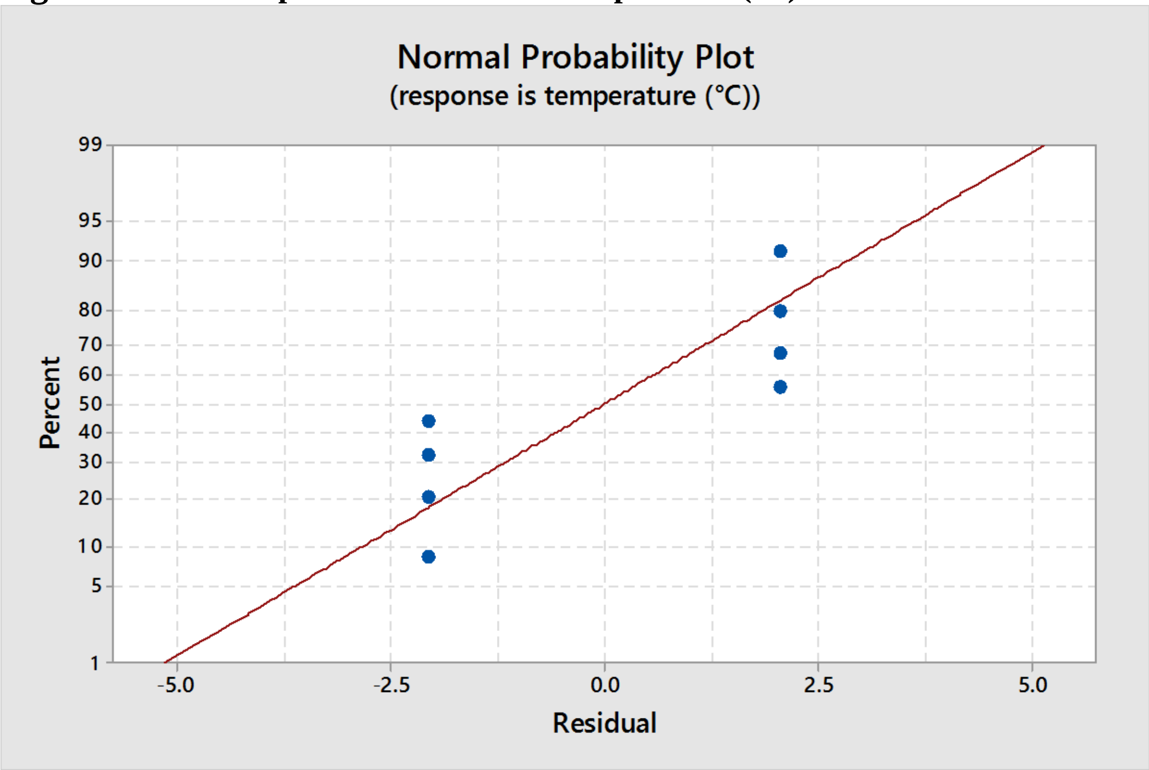


Figure 6.30: Residuals vs. Fits for temperature (°C)

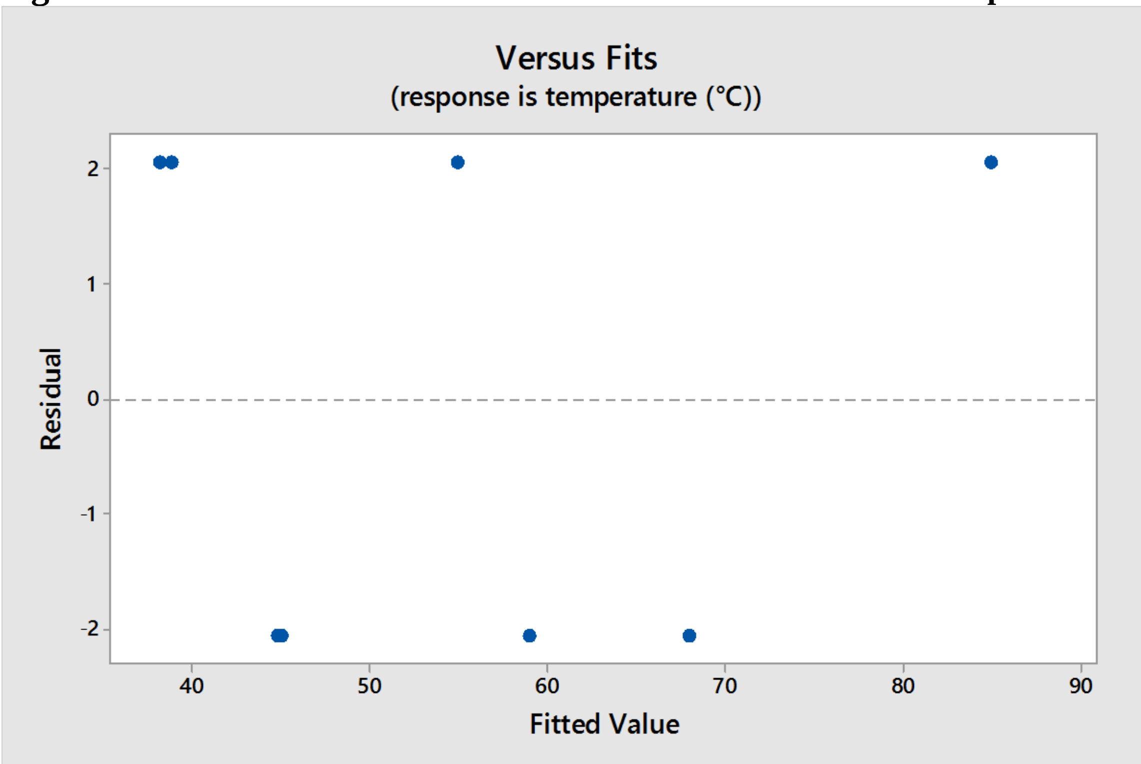


Figure 6.31: Residual Histogram for temperature (°C)

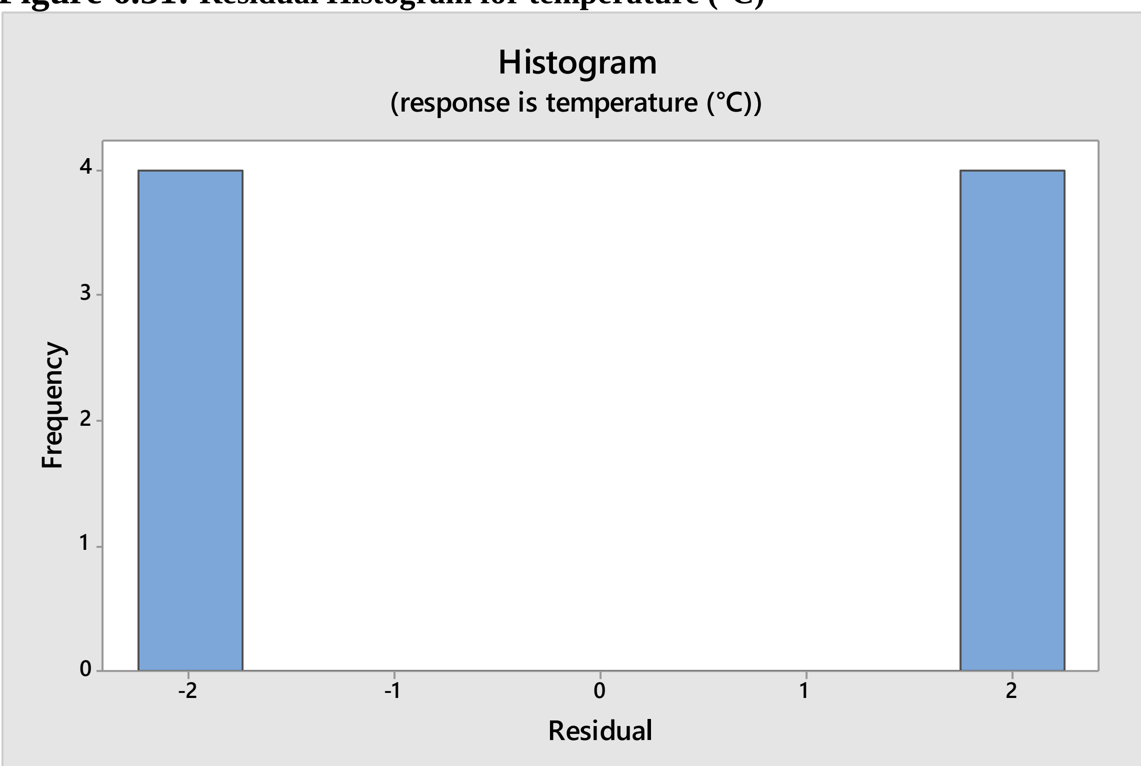


Figure 6.32: **Contour Plot of temperature (°C) vs feed(mm), Speed(rpm)**

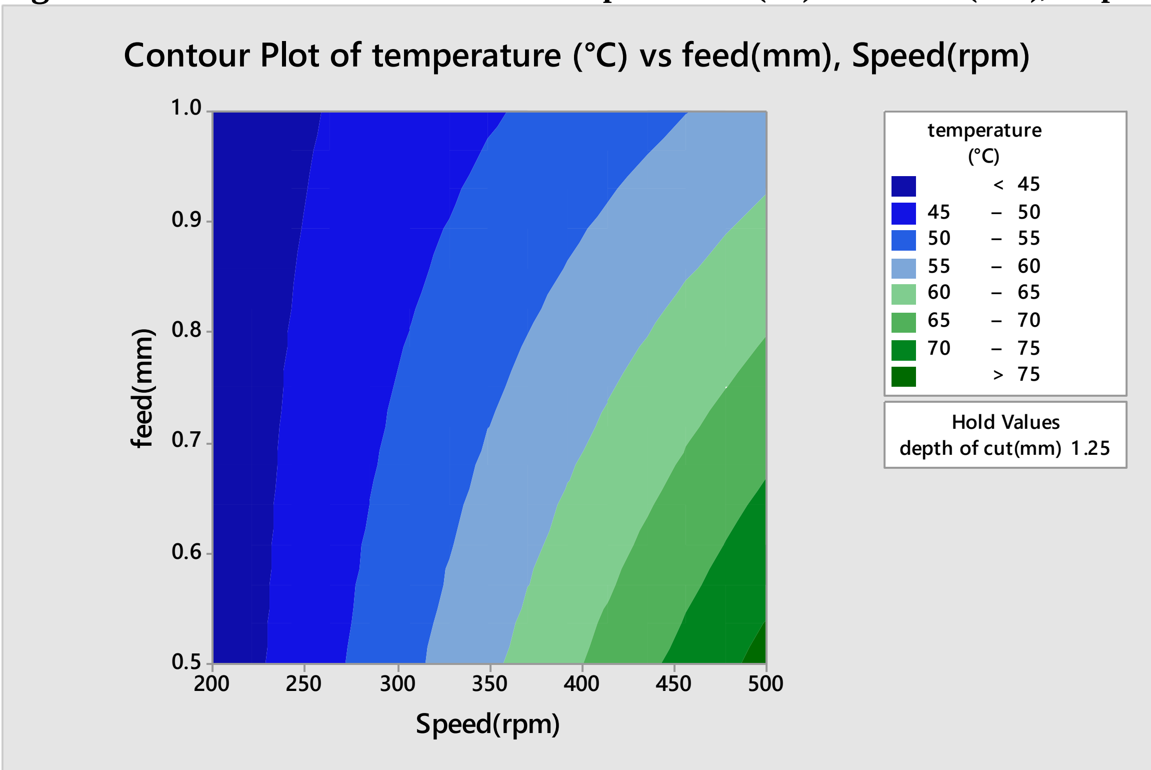


Figure 6.33: **Contour Plot of temperature (°C) vs feed(mm), Speed(rpm)**

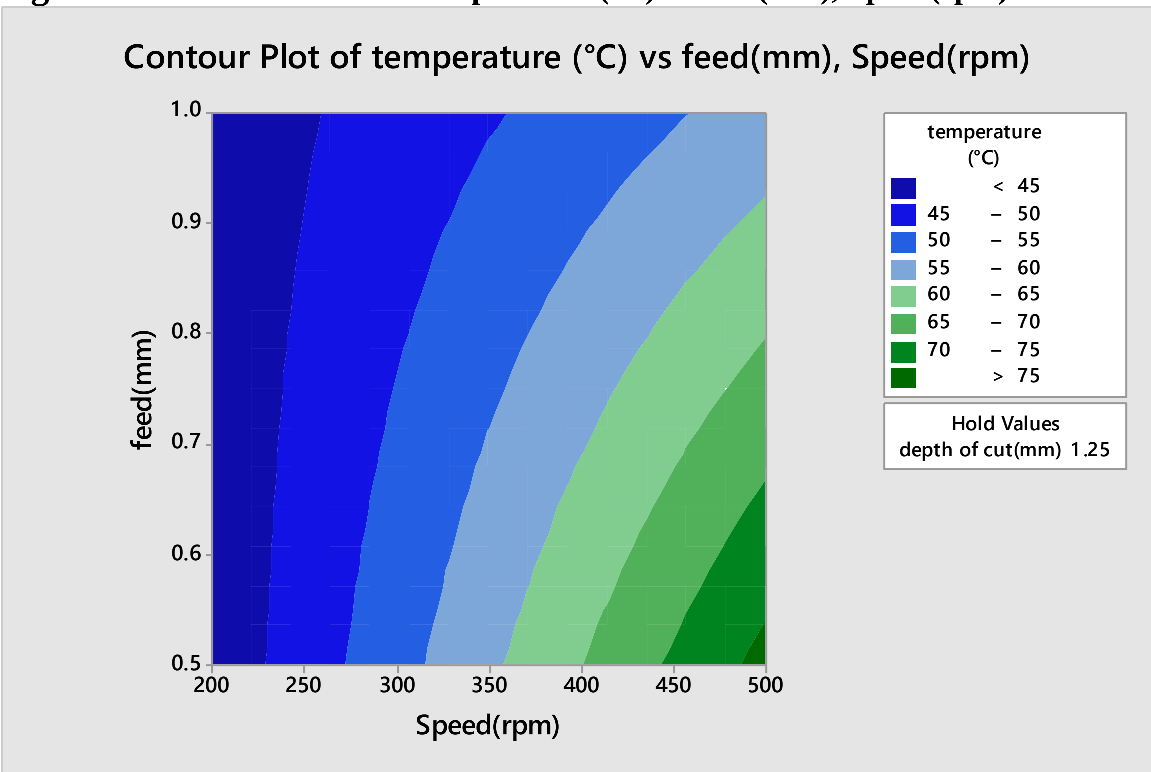


Figure 6.34: Contour Plot of temperature (°C) vs. depth of cut(mm), Speed(rpm)

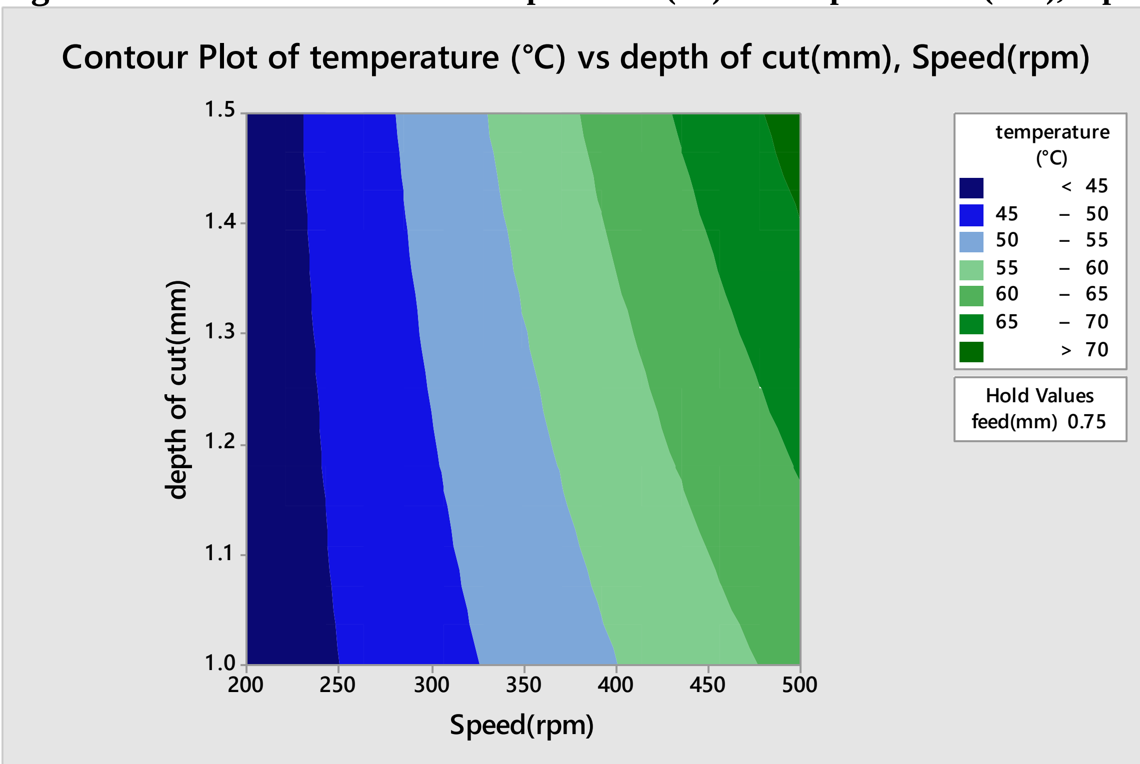


Figure 6.35: Contour Plot of temperature (°C) vs. depth of cut(mm), feed(mm)

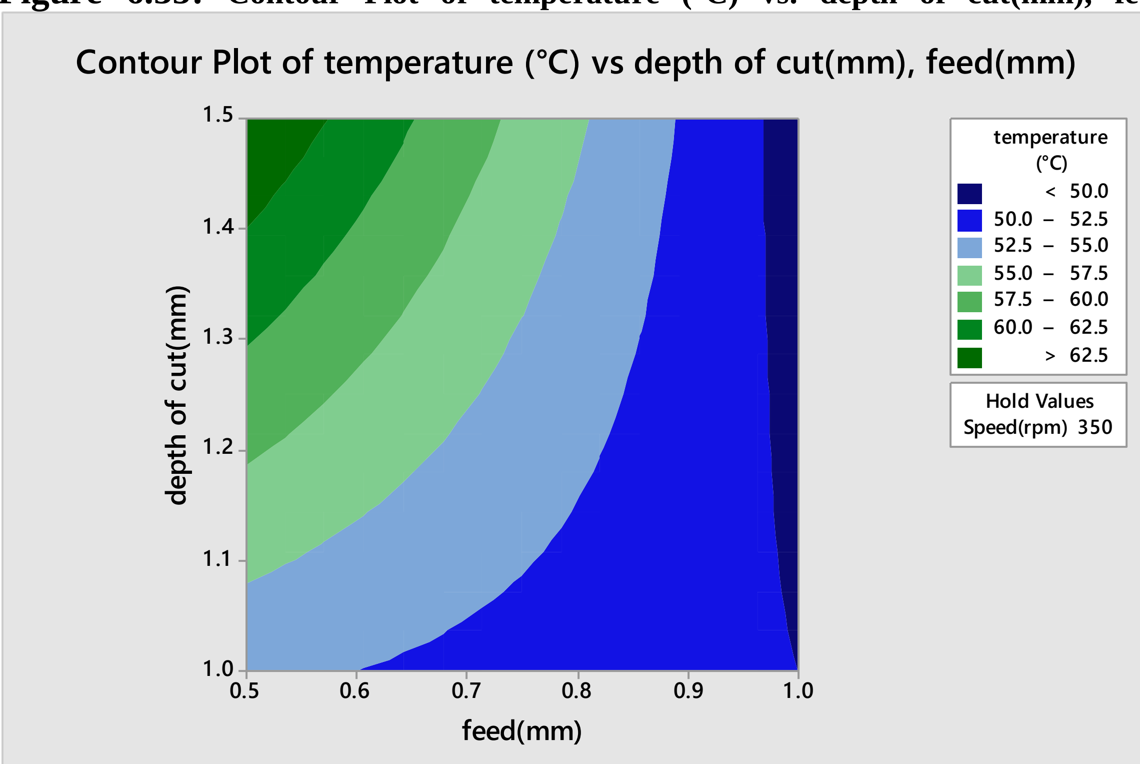


Figure 6.36: Surface Plot of temperature (°C) vs. feed(mm), Speed(rpm)

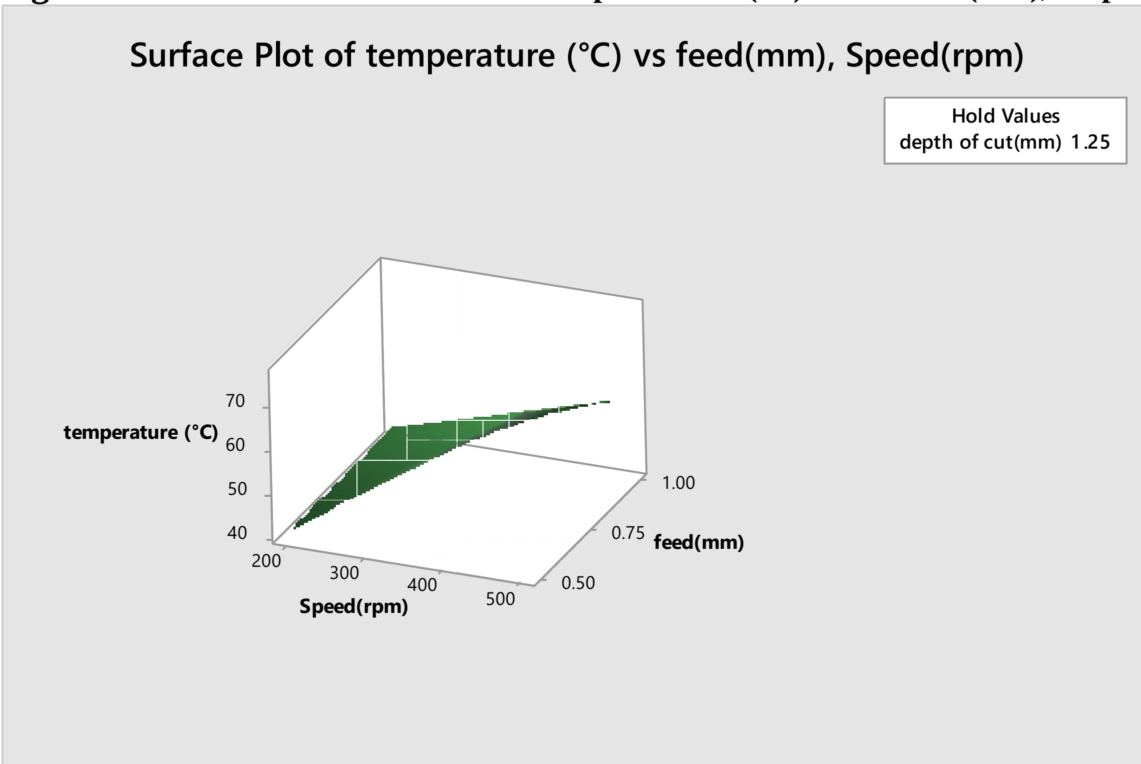


Figure 6.37: Surface Plot of temperature (°C) vs. depth of cut(mm), Speed(rpm)

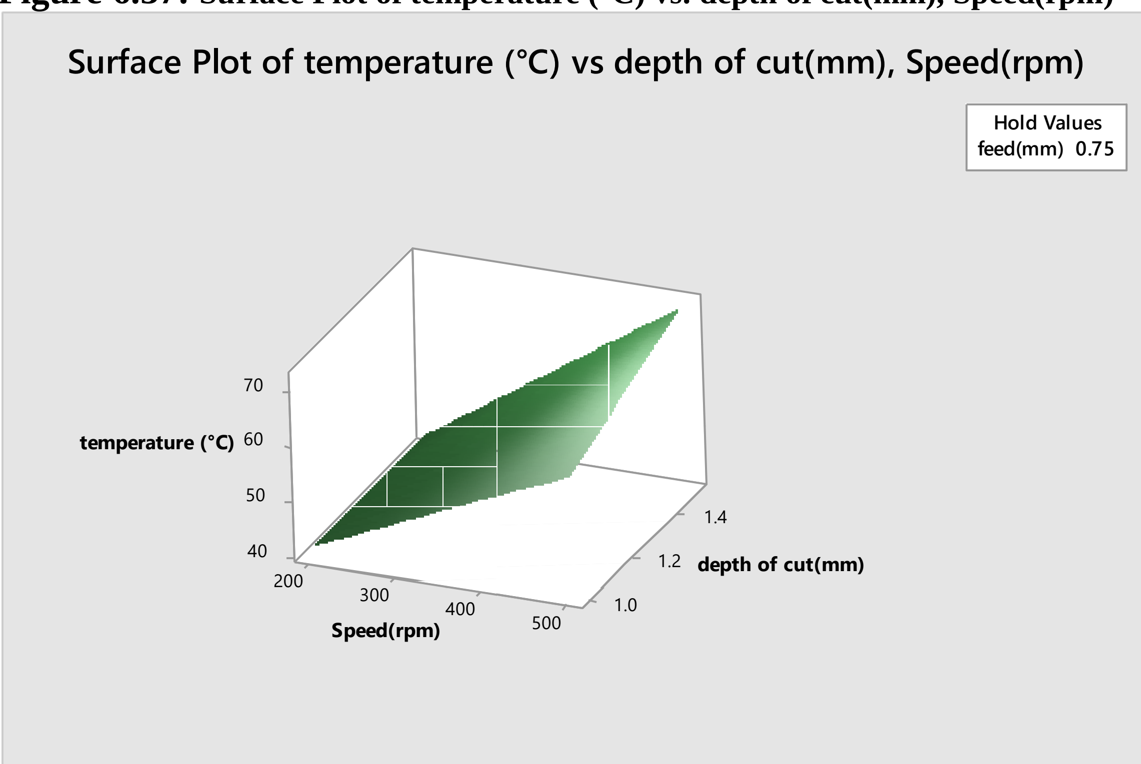
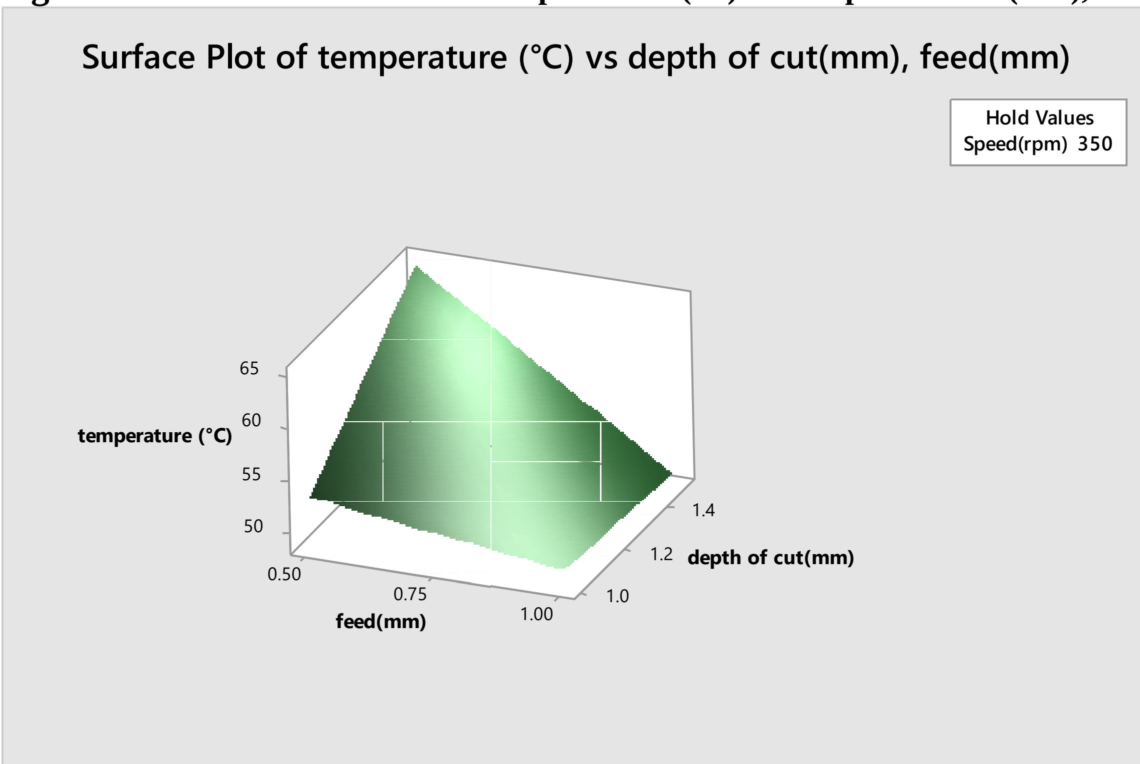


Figure 6.38: Surface Plot of temperature (°C) vs depth of cut(mm), feed(mm)



Response Surface Regression: chip thickness r versus Speed(rpm), feed(mm), depth of cut(mm)

```
The following terms cannot be estimated and were removed:
   Speed(rpm)*Speed(rpm), feed(mm)*feed(mm), depth of cut(mm)*depth of cut(mm)
```

Analysis of Variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value
Model	6	0.004102	82.58%	0.004102	0.000684	0.79
Linear	3	0.003200	64.42%	0.003200	0.001067	1.23
Speed(rpm)	1	0.000088	1.78%	0.000088	0.000088	0.10
feed(mm)	1	0.000772	15.55%	0.000772	0.000772	0.89
depth of cut(mm)	1	0.002339	47.09%	0.002339	0.002339	2.70
2-Way Interaction	3	0.000902	18.17%	0.000902	0.000301	0.35
Speed(rpm)*feed(mm)	1	0.000623	12.54%	0.000623	0.000623	0.72
Speed(rpm)*depth of cut(mm)	1	0.000046	0.93%	0.000046	0.000046	0.05
feed(mm)*depth of cut(mm)	1	0.000233	4.70%	0.000233	0.000233	0.27
Error	1	0.000865	17.42%	0.000865	0.000865	

Total	7	0.004968	100.00%

Source	P-Value
Model	0.696
Linear	0.566
Speed(rpm)	0.803
feed(mm)	0.518
depth of cut(mm)	0.348
2-Way Interaction	0.812
Speed(rpm)*feed(mm)	0.552
Speed(rpm)*depth of cut(mm)	0.856
feed(mm)*depth of cut(mm)	0.695
Error	
Total	

Model Summary

S	R-sq	R-sq(adj)	PRESS	R-sq(pred)
0.0294156	82.58%	0.00%	0.0553779	0.00%

Coded Coefficients

Term	Effect	Coef	SE Coef	95% CI	T-Value	P-Value
Constant		0.0262	0.0104	(-0.1060, 0.1583)	2.52	0.241
Speed(rpm)	-0.0067	-0.0033	0.0104	(-0.1355, 0.1288)	-0.32	0.803
feed(mm)	0.0197	0.0098	0.0104	(-0.1223, 0.1420)	0.94	0.518
depth of cut(mm)	0.0342	0.0171	0.0104	(-0.1150, 0.1492)	1.64	0.348
Speed(rpm)*feed(mm)	0.0177	0.0088	0.0104	(-0.1233, 0.1410)	0.85	0.552
Speed(rpm)*depth of cut(mm)	-0.0048	-0.0024	0.0104	(-0.1345, 0.1297)	-0.23	0.856
feed(mm)*depth of cut(mm)	0.0108	0.0054	0.0104	(-0.1267, 0.1375)	0.52	0.695

Term	VIF
Constant	
Speed(rpm)	1.00
feed(mm)	1.00
depth of cut(mm)	1.00
Speed(rpm)*feed(mm)	1.00
Speed(rpm)*depth of cut(mm)	1.00
feed(mm)*depth of cut(mm)	1.00

Regression Equation in Uncoded Units

chip thickness ratio = 0.034 - 0.000119 Speed(rpm) - 0.151 feed(mm) + 0.026 depth of cut(mm)
+ 0.000235 Speed(rpm)*feed(mm) - 0.000064 Speed(rpm)*depth of cut(mm)
+ 0.086 feed(mm)*depth of cut(mm)

Figure 6.39: Normplot of Residuals for chip thickness ratio

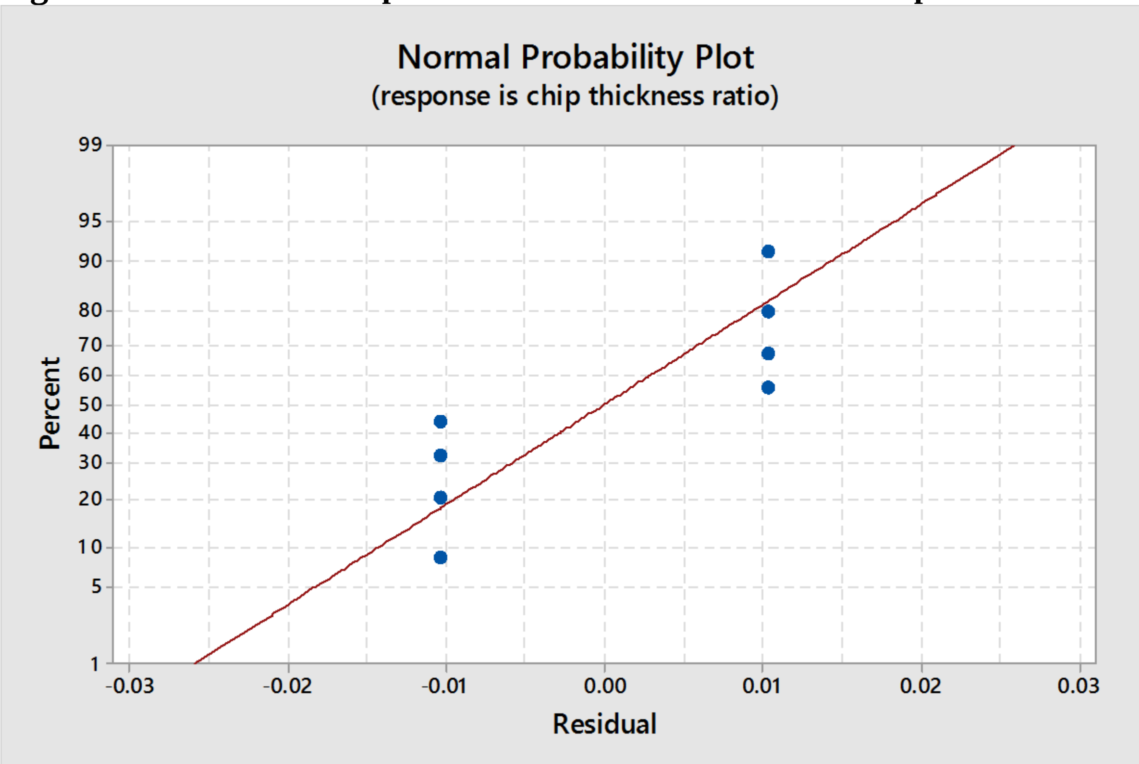


Figure 6.40: Residuals vs. Fits for chip thickness ratio

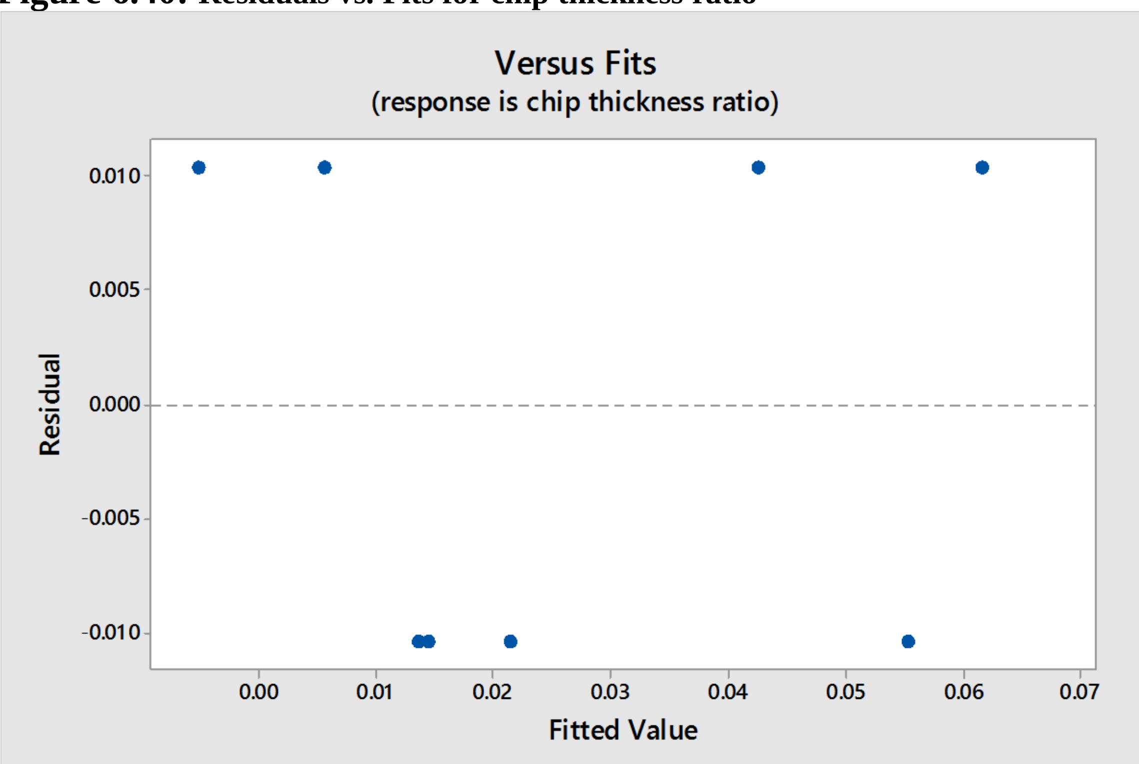


Figure 6.41: Residual Histogram for chip thickness ratio

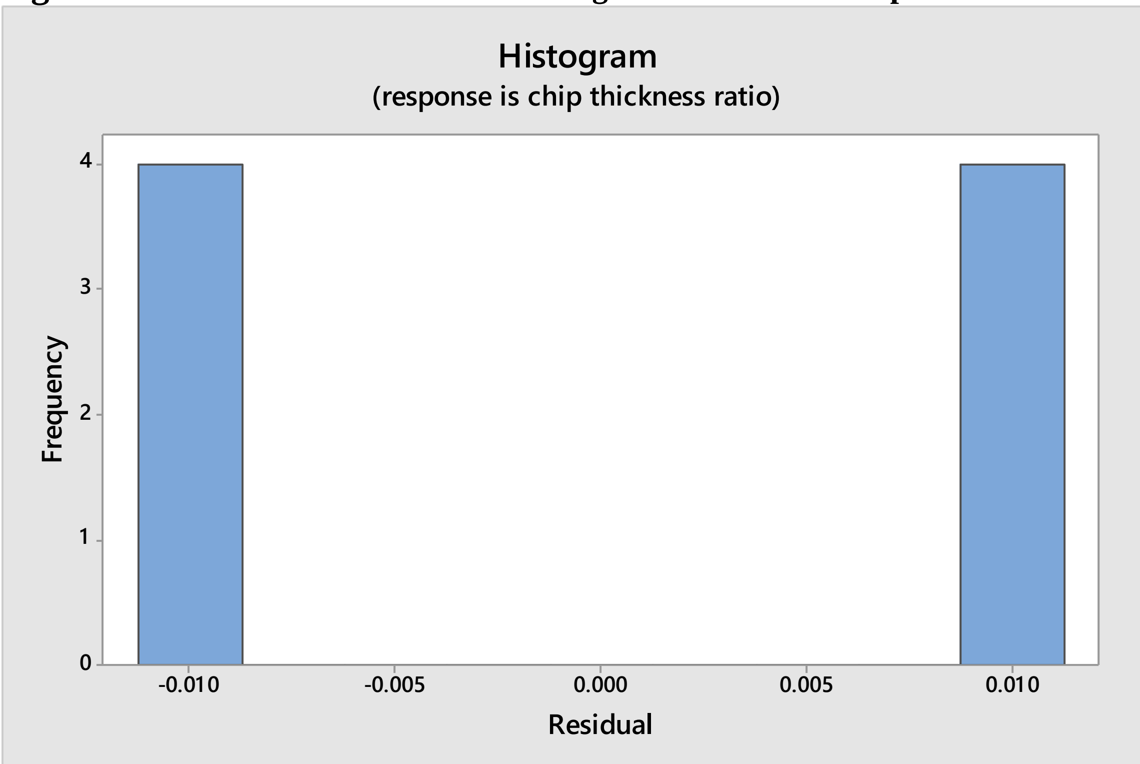


Figure 6.42: Contour Plot of chip thickness ratio vs. feed(mm), Speed(rpm)

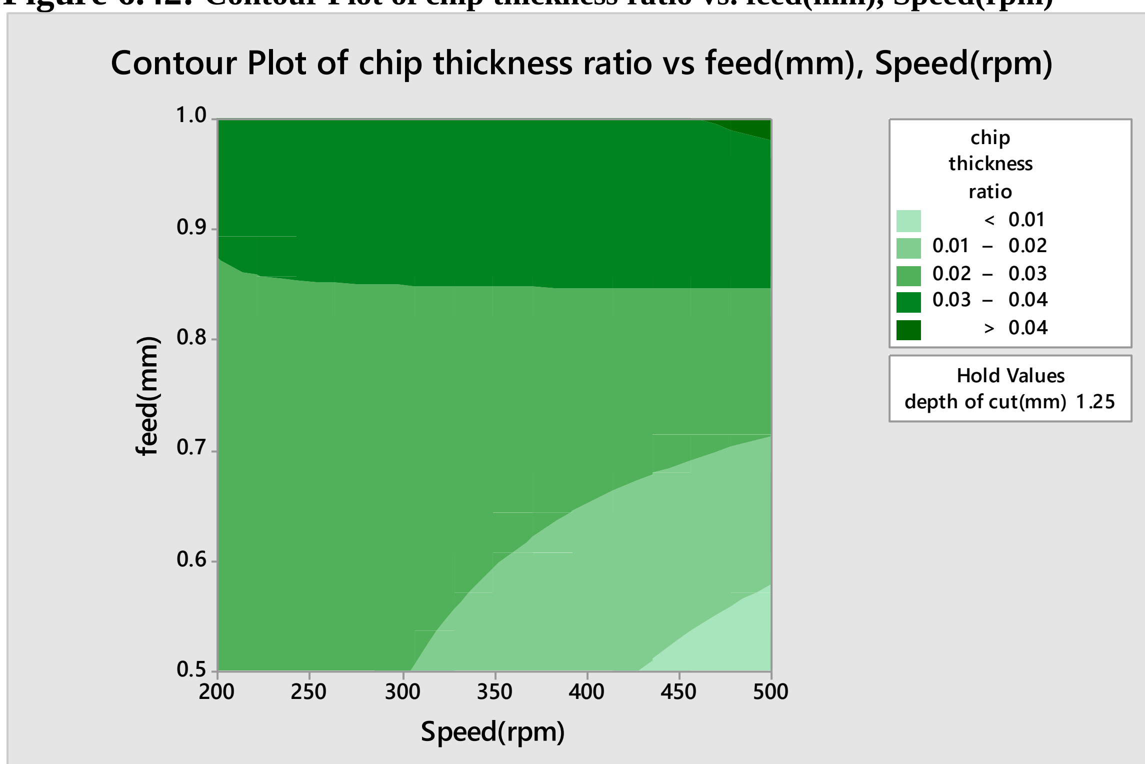


Figure 6.43: **Contour Plot of chip thickness ratio vs. depth of cut(mm), Speed(rpm)**

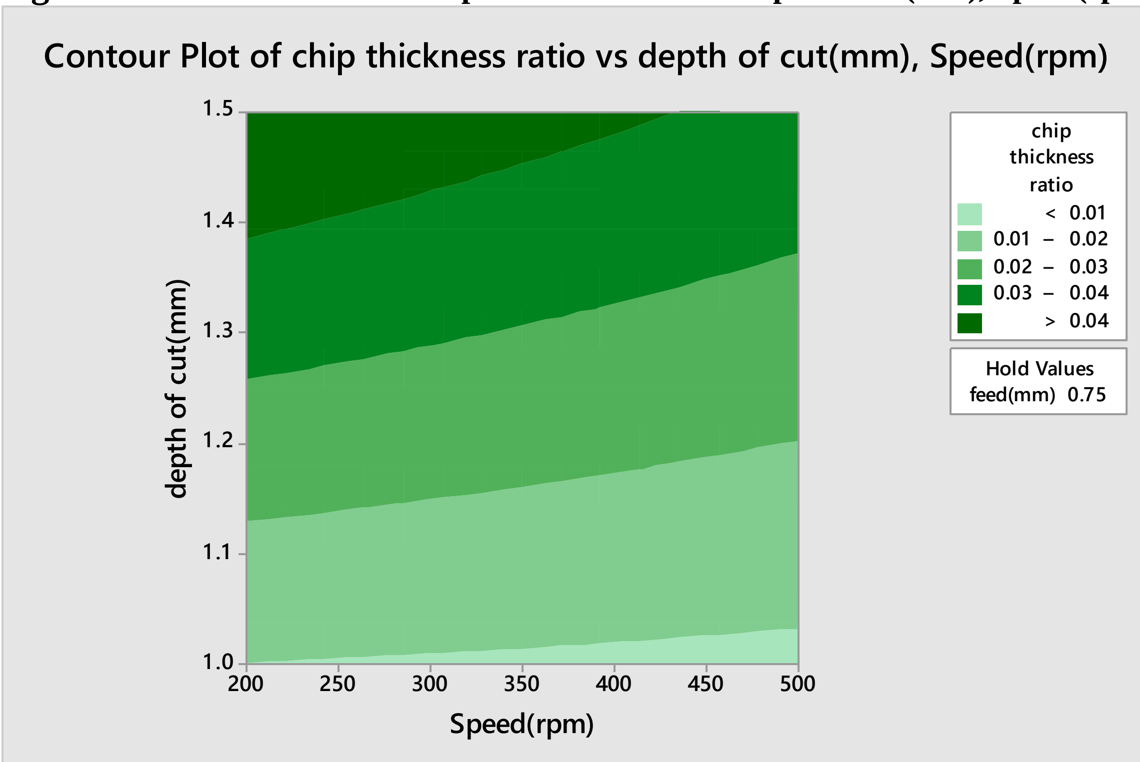


Figure 6.44: **Contour Plot of chip thickness ratio vs. depth of cut(mm), feed(mm)**

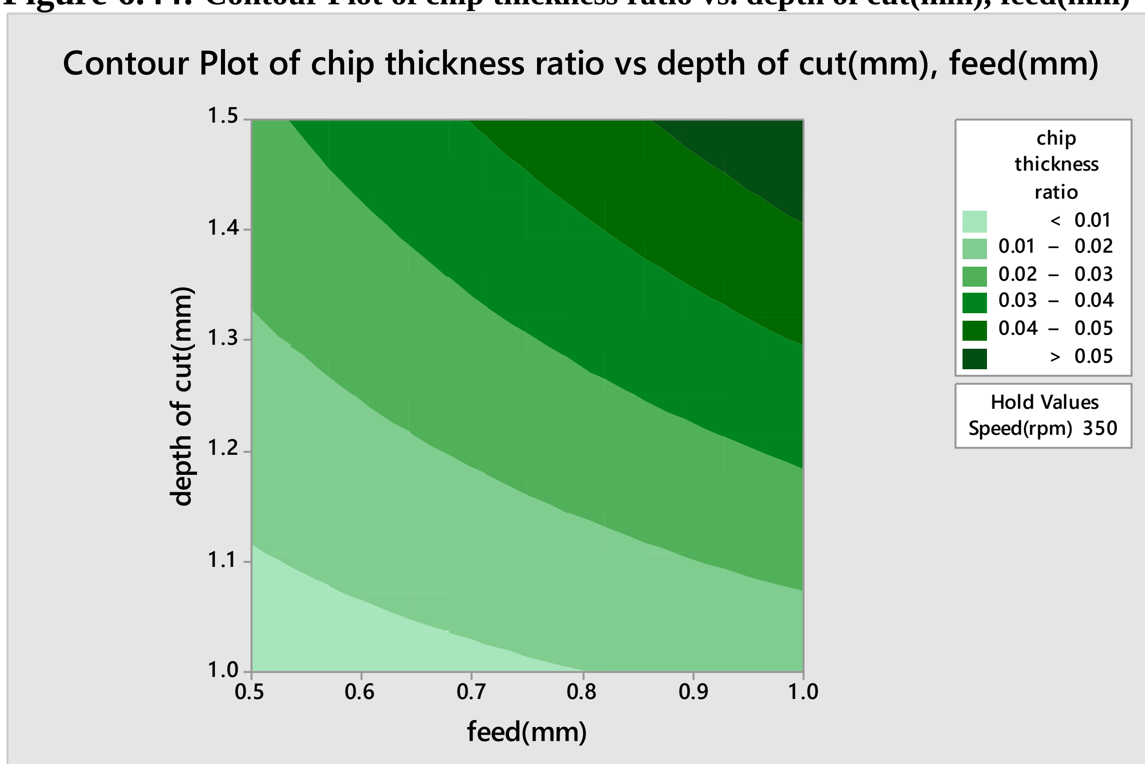


Figure 6.45: Surface Plot of chip thickness ratio vs feed(mm), Speed(rpm)

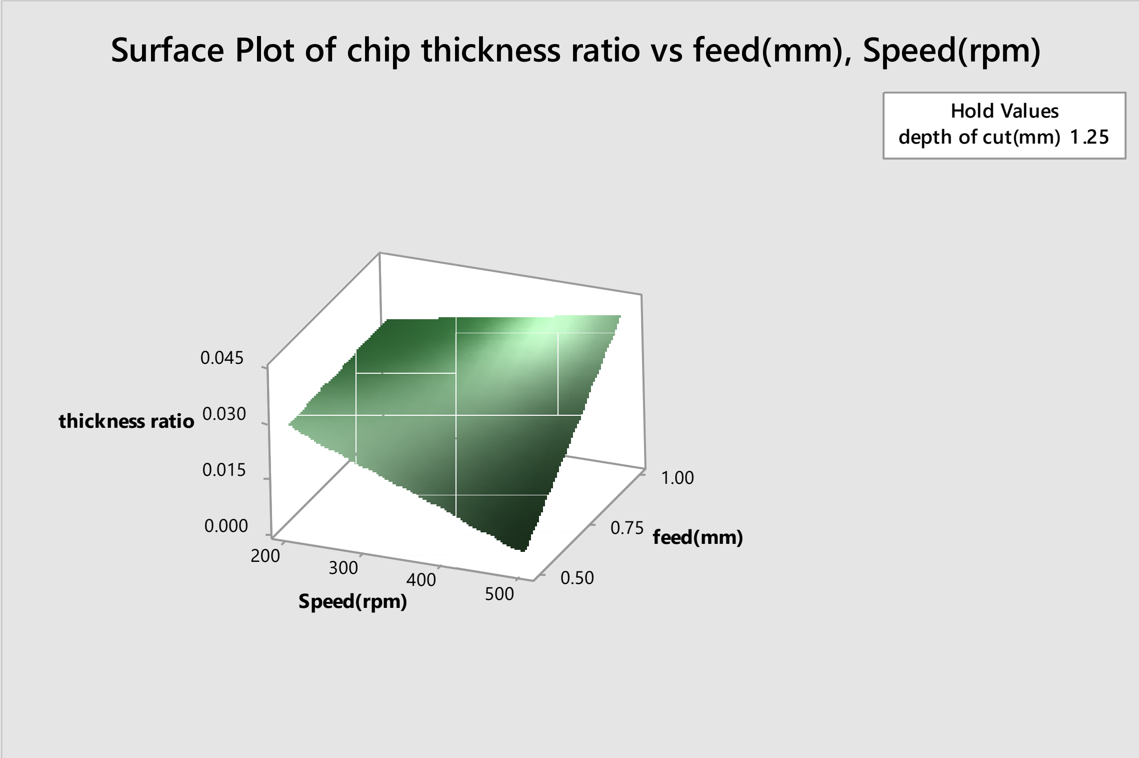


Figure 6.46: Surface Plot of chip thickness ratio vs depth of cut(mm), Speed(rpm)

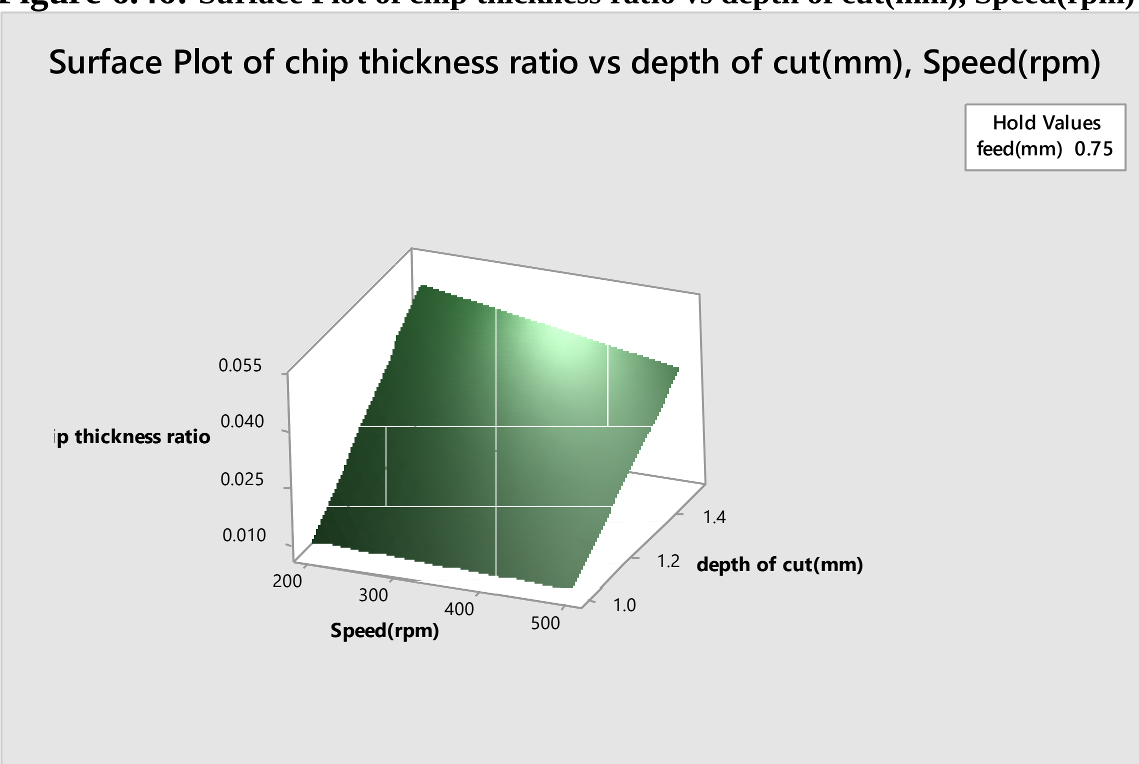
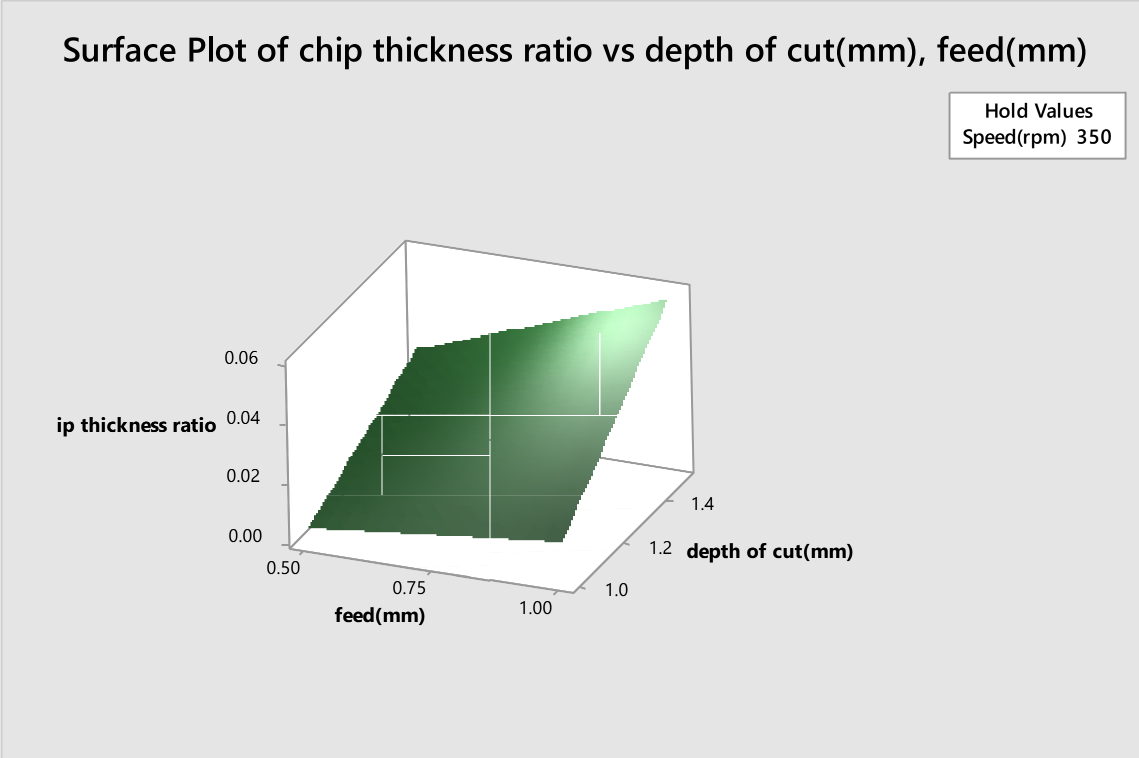


Figure 6.47: Surface Plot of chip thickness ratio vs. depth of cut(mm), feed(mm)



Response Surface Regression: shear angle versus Speed(rpm), feed(mm), depth of cut(mm)

```
The following terms cannot be estimated and were removed:
   Speed(rpm)*Speed(rpm), feed(mm)*feed(mm), depth of cut(mm)*depth of cut(mm)
```

Analysis of Variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value
Model	6	1028.02	92.52%	1028.02	171.337	2.06
Linear	3	583.63	52.53%	583.63	194.544	2.34
Speed(rpm)	1	9.86	0.89%	9.86	9.857	0.12
feed(mm)	1	227.83	20.50%	227.83	227.826	2.74
depth of cut(mm)	1	345.95	31.14%	345.95	345.950	4.16
2-Way Interaction	3	444.39	40.00%	444.39	148.129	1.78
Speed(rpm)*feed(mm)	1	0.19	0.02%	0.19	0.190	0.00
Speed(rpm)*depth of cut(mm)	1	1.37	0.12%	1.37	1.368	0.02
feed(mm)*depth of cut(mm)	1	442.83	39.86%	442.83	442.829	5.33
Error	1	83.08	7.48%	83.08	83.076	
Total	7	1111.10	100.00%			

Source	P-Value
Model	0.488
Linear	0.440
Speed(rpm)	0.789
feed(mm)	0.346
depth of cut(mm)	0.290
2-Way Interaction	0.492
Speed(rpm)*feed(mm)	0.970
Speed(rpm)*depth of cut(mm)	0.919

```
    feed(mm)*depth of cut(mm)      0.260
Error
Total


Model Summary

      S    R-sq  R-sq(adj)    PRESS  R-sq(pred)
9.11461  92.52%     47.66%  5316.87       0.00%


Coded Coefficients

Term                           Effect   Coef  SE Coef       95% CI        T-Value  P-Value  VIF
Constant                                70.85      3.22   ( 29.91, 111.80)     21.99  0.029
Speed(rpm)                      -2.22  -1.11      3.22   (-42.06,  39.84)     -0.34  0.789  1.00
feed(mm)                       -10.67  -5.34      3.22   (-46.28,  35.61)     -1.66  0.346  1.00
depth of cut(mm)                13.15   6.58      3.22   (-34.37,  47.52)      2.04  0.290  1.00
Speed(rpm)*feed(mm)             -0.31  -0.15      3.22   (-41.10,  40.79)     -0.05  0.970  1.00
Speed(rpm)*depth of cut(mm)      0.83   0.41      3.22   (-40.53,  41.36)      0.13  0.919  1.00
feed(mm)*depth of cut(mm)       14.88   7.44      3.22   (-33.51,  48.39)      2.31  0.260  1.00


Regression Equation in Uncoded Units

shear angle = 171.9 - 0.018 Speed(rpm) - 168.7 feed(mm) - 66.8 depth of cut(mm)
              - 0.0041 Speed(rpm)*feed(mm) + 0.0110 Speed(rpm)*depth of cut(mm)
              + 119.0 feed(mm)*depth of cut(mm)
```

Figure 6.48: Normplot of Residuals for shear angle

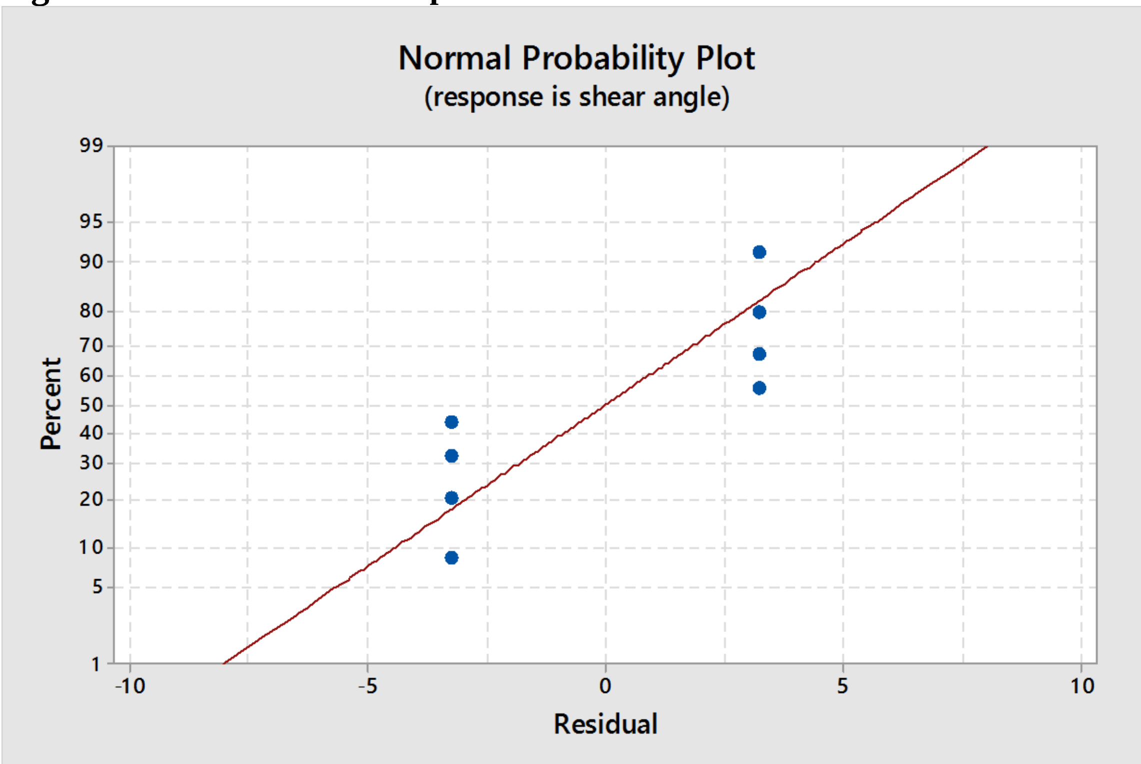


Figure 6.49: Residuals vs Fits for shear angle

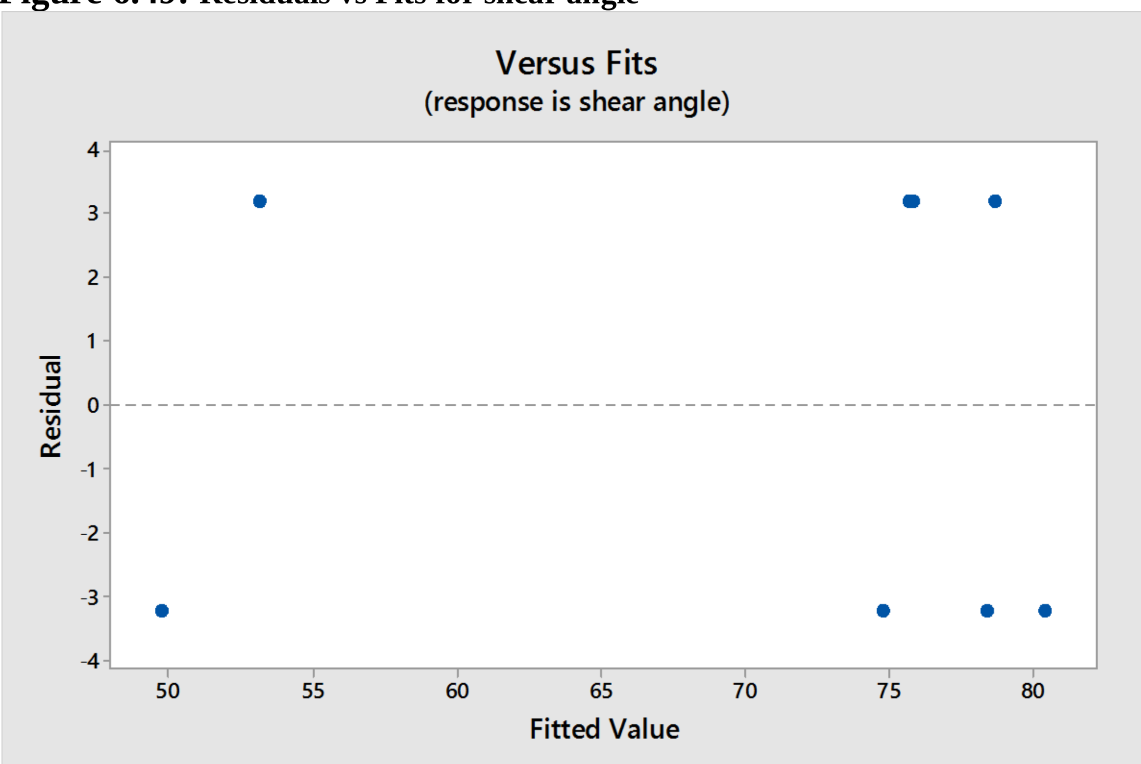


Figure 6.50: Residual Histogram for shear angle

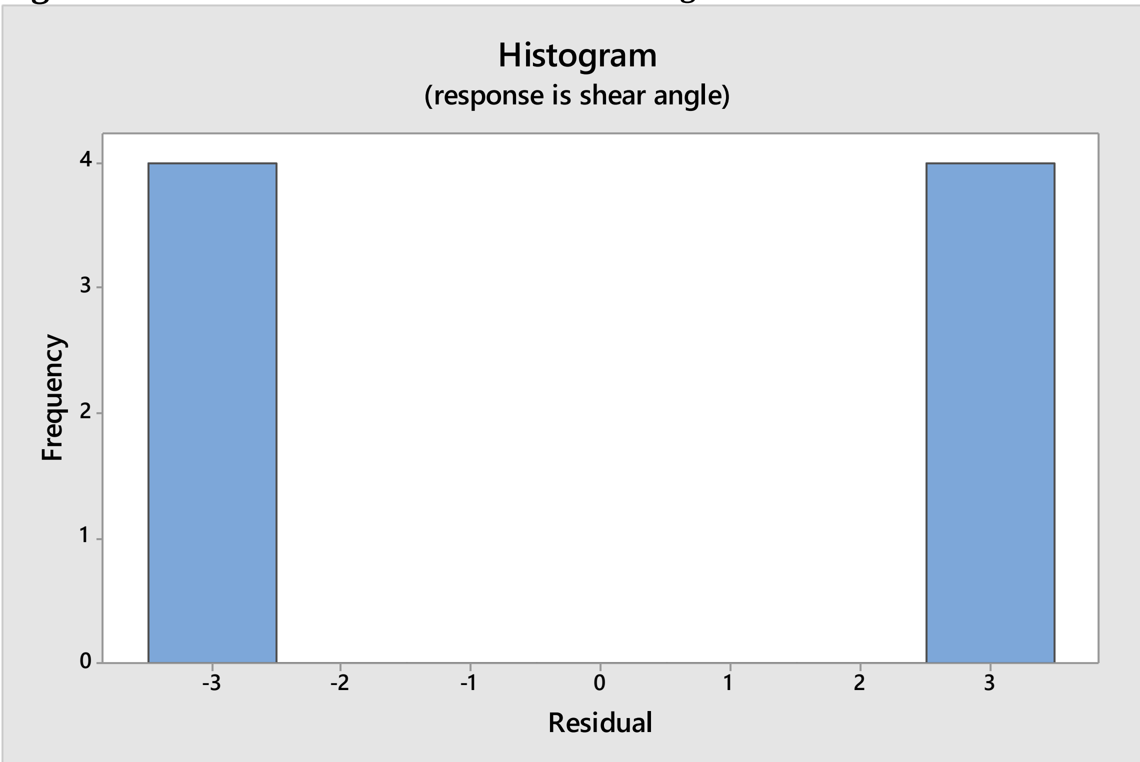


Figure 6.51: Contour Plot of shear angle vs. feed(mm), Speed(rpm)

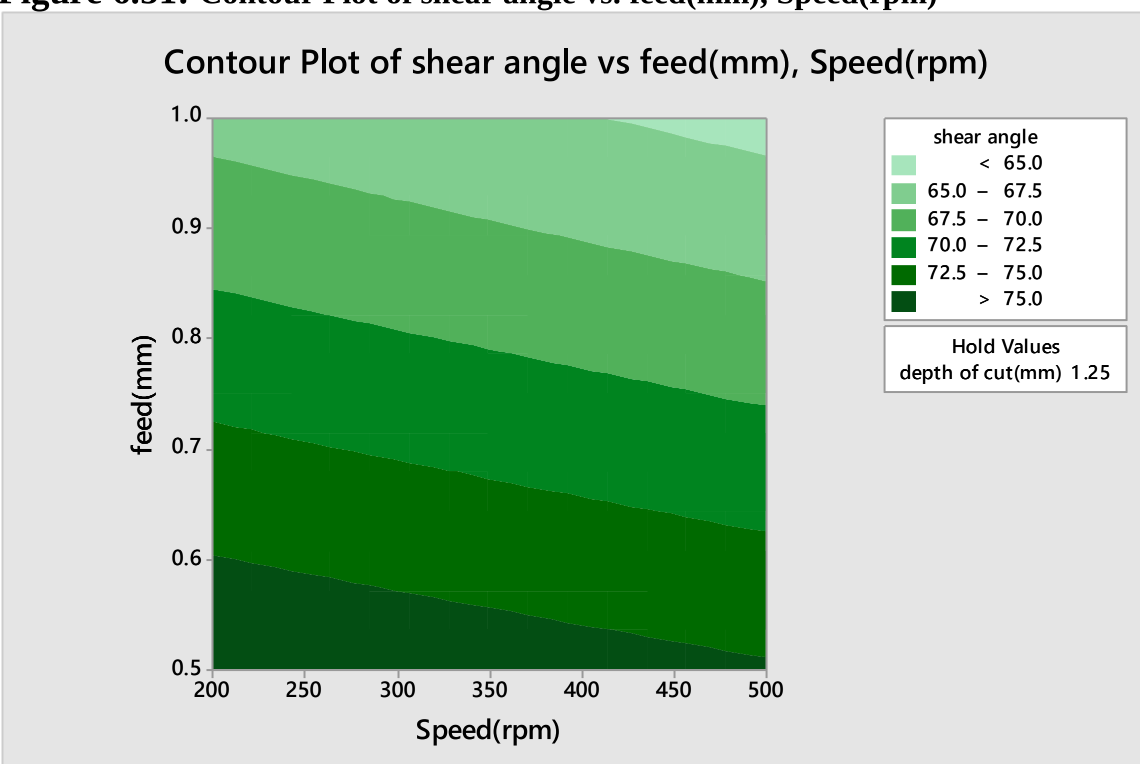


Figure 6.52: Contour Plot of shear angle vs. depth of cut(mm), Speed(rpm)

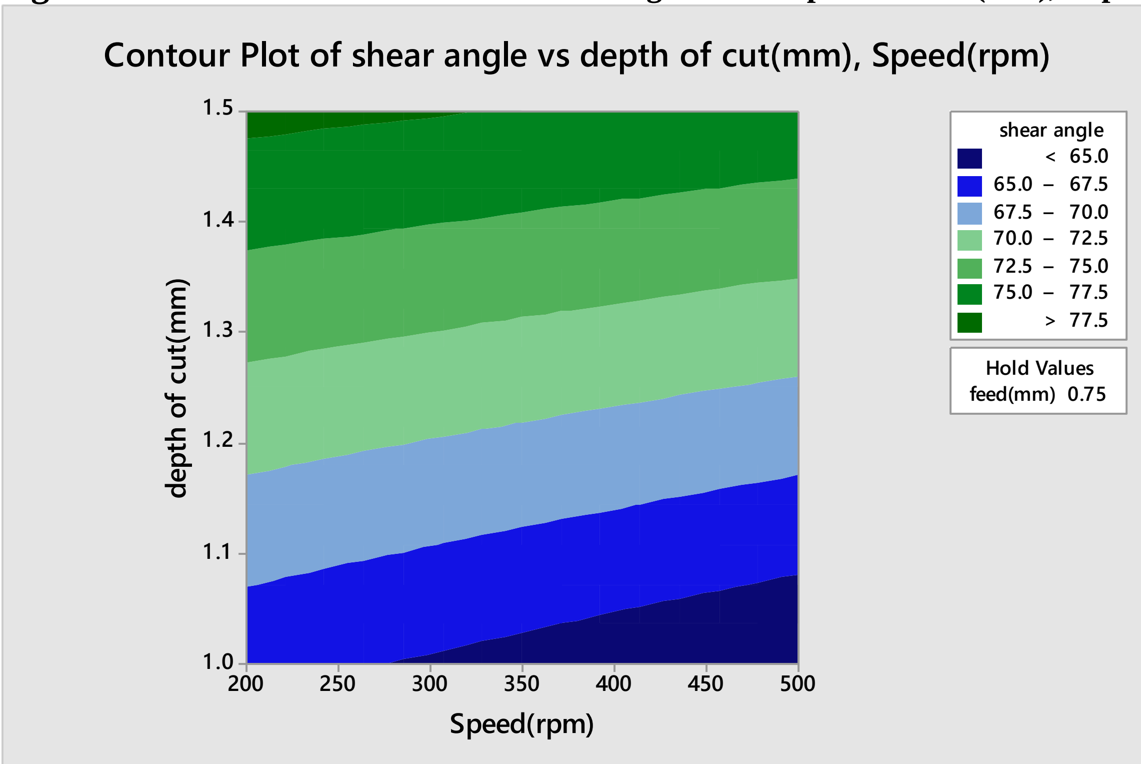


Figure 6.53: Contour Plot of shear angle vs. depth of cut(mm), feed(mm)

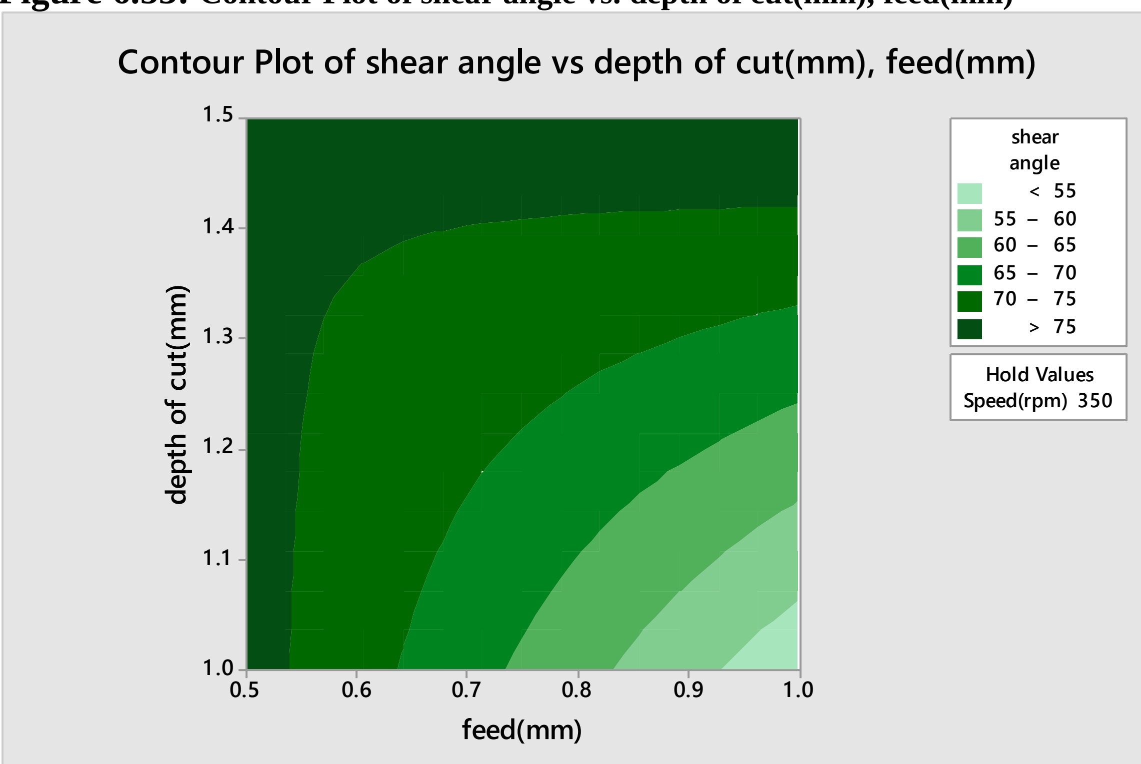


Figure 6.54: Surface Plot of shear angle vs. feed(mm), Speed(rpm)

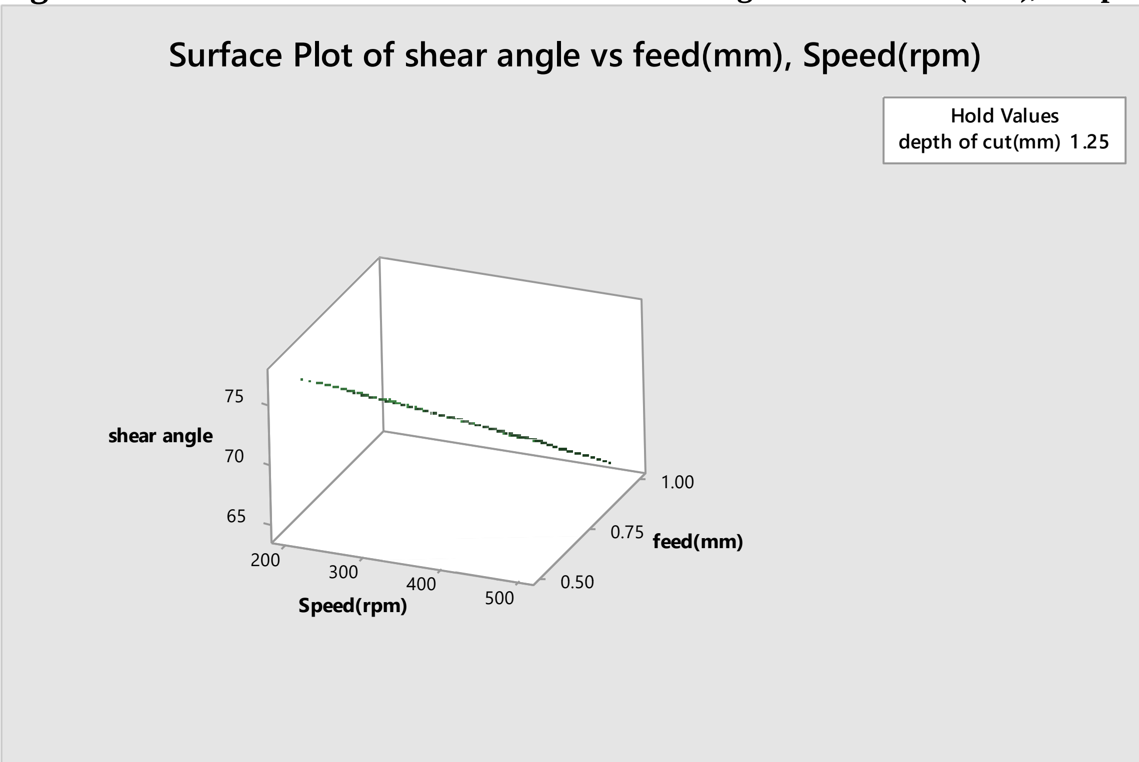


Figure 6.55: Surface Plot of shear angle vs. feed(mm), depth of cut(mm)

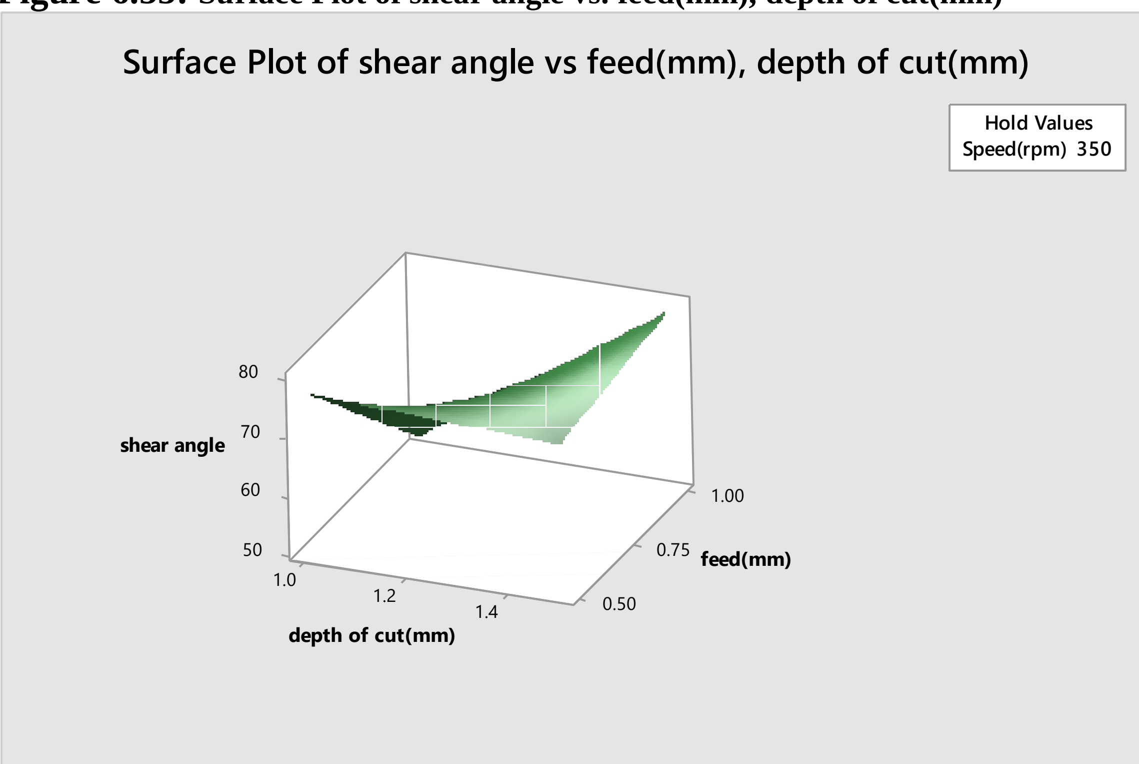
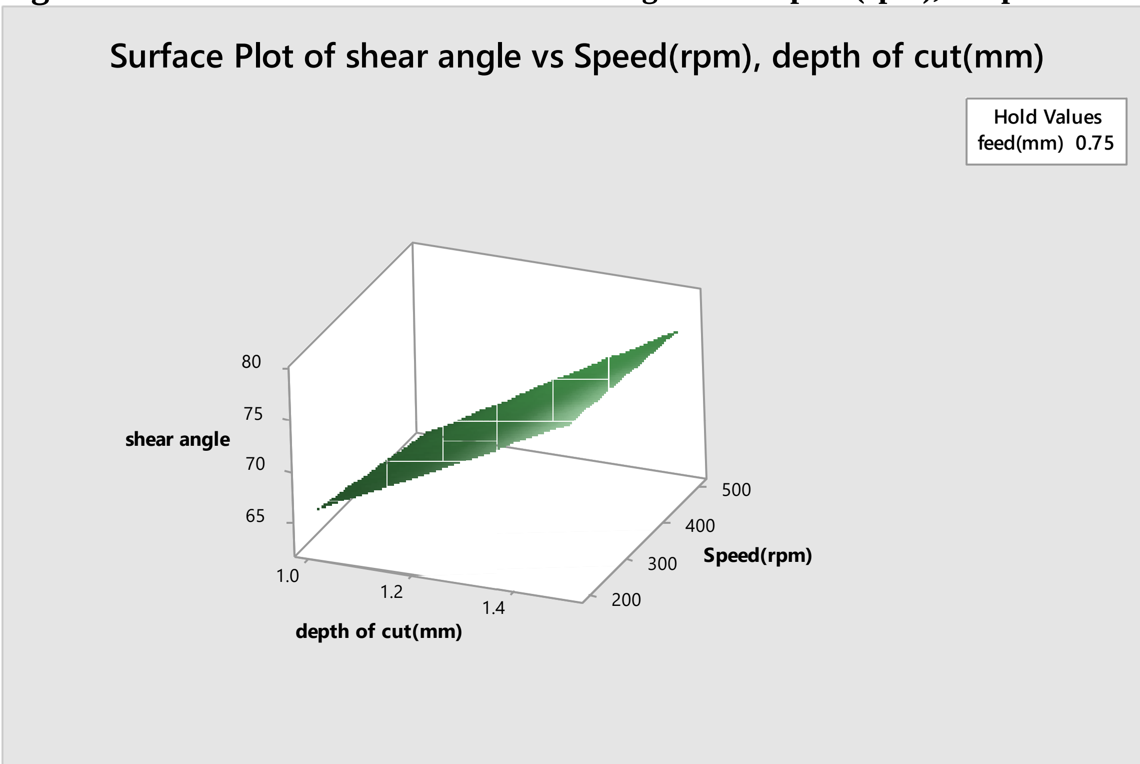


Figure 6.56: Surface Plot of shear angle vs. Speed(rpm), depth of cut(mm)



Response Optimization: shear angle, chip thickness ratio, temperature (°C)

Parameters

Response	Goal	Lower	Target	Upper	Weight	Importance
shear angle	Maximum	46.6000	81.904		1	1
chip thickness ratio	Maximum	0.0031	0.072		1	1
temperature (°C)	Minimum		40.300	87	1	1

Solution

Solution	Speed(rpm)	feed(mm)	depth of cut(mm)	shear angle Fit	Chip thickness ratio Fit	temperature (°C) Fit	Composite Desirability
1	218.182	1	1.5	80.2794	0.0557758	40.1572	0.900141

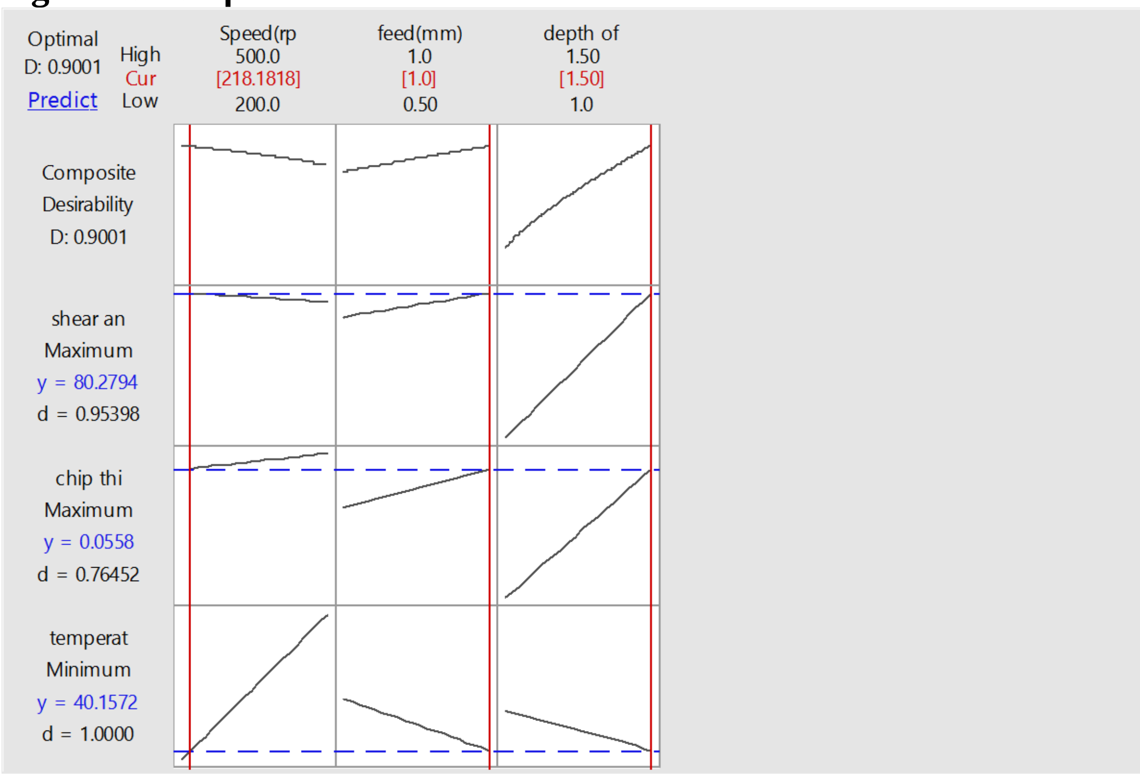
Multiple Response Prediction

Variable	Setting
Speed(rpm)	218.182
feed(mm)	1
depth of cut(mm)	1.5

Response	Fit	SE Fit	95% CI	95% PI
shear angle	80.28	8.10	(-22.63, 183.19)	(-74.65, 235.21)

```
chip thickness ratio  0.0558  0.0261  (-0.2763, 0.3879)  (-0.4442, 0.5558)
temperature (°C)       40.16    5.18  ( -25.71, 106.02)  ( -59.00, 139.32)
```

Figure 6.57: Optimization Plot



CHAPTER 7.CONCLUSION

- From the optimization plot, it is clear that EN19 material should be machined under wet conditions.
- Mini Tab produces a direct equation with the combination of controlled parameters, which can be used in industries to know the Values of cutting temperature, chip thickness ratio, and shear angle.
- Hence the optimal solution for shear angle is 88.5050(°c), chip thickness ratio is 0.0772, cutting temperature 76.20(ºC)will be obtained when the EN19 workpiece is machined at speed 500rpm, feed 1.0(mm/rev), and depth of cut 1.50(mm) under dry condition using carbide tool for turning.
- Hence the optimal solution for shear angle is 80.2794(°c), chip thickness ratio is 0.0558, cutting temperature 40.1572(ºC)will be obtained when the EN19 workpiece is machined at speed 218.1818rpm, feed 1.0(mm/rev) and depth of cut 1.50(mm) under wet condition using carbide tool for turning.

CHAPTER 8.FUTURE SCOPE OF WORK

- By using Carbide Tool with the workpiece of EN19 ,cutting forces can also be measured.
- Material Removal Rate can also be measured
- The tool life can also be predicted under wet and dry conditions by using carbide tool with machining of EN19 workpiece.
- The tool wear can also be measured with continuously machined under wet and dry conditions.

CHAPTER 9.REFERENCES

1. SAGE Journals. 2021. Tool wear prediction in hard turning of EN8 steel using cutting force and surface roughness with artificial neural network - Thangarasu SK, S Shankar, Mohanraj T, Devendran K, 2020. [online] Available at: <https://journals.sagepub.com/doi/10.1177/0954406219873932> [Accessed 4 June 2021].

2. Ijsr.net. 2021. Optimization of Surface Roughness of EN8 Steel by Changing Cutting Parameters and Insert Geometry in Turning Process. [online] Available at: <https://ijsr.net/archive/v3i11/T0NUMTQxMjM1.pdf> [Accessed 4 June 2021].

3. Zulfiqar Ahmad Khan, Matthew Grover, and Mian Hammad Nazir et al The Implications ofWet and Dry Turning on the Surface Quality of EN8 Steel.

4. N. Satheesh Kumara, Ajay Shettyb, Ashay Shettyb, Ananth Kb, Harsha Shettyba et al, Effect of spindle speed and feed rate on surface roughness of Carbon Steels in CNC turning.

5. Ijser.org. 2021. Analysis of effect of cutting parameters on responses Surface Roughness and Material Removal Rate for En 19 work-pieces material with and without heat treatment. [online] Available at: <https://www.ijser.org/researchpaper/Analysis-of-effect-of-cutting-parameters-on-responses-Surface-Roughness.pdf> [Accessed 4 June 2021].

6. Ijirst.org. 2021. An Investigation of Temperature, Surface Roughness And Material Removal Rate During Hard Turning of EN19 Material - A Review. <http://www.ijirst.org/articles/IJIRSTV1I8010.pdf> [Accessed 4 June 2021].

7. academia.edu. 2021. multiresponse optimization of surface grinding operation of en19 alloy steel using grey relational analysis (gra). [online] available at: <https://www.academia.edu/13092150/multiresponse_optimization_of_surface_grinding_operation_of_en19_alloy_steel_using_grey_relational_analysis_gra_> [accessed 4 june 2021].

8. Dhiraj Kumar and Sharifuddin Mondal et al, Multi-Objective Optimization of ECM Process Parameters of EN-19 Tool Steel using Taguchi based TOPSIS.

9. Abhishek S Shetty1, Akshar K S1, Prashanth B Y1, Gajanan M Naik2 et al, Optimization of Machining Parameters on MRR for EN19 & EN31 Steel using Taguchi Method, International Journal of Emerging Research in Management &Technology ISSN: 2278-9359 (Volume-6, Issue-5).

10. T.rajaprabu1, dr.k.chandrasekaran2 , p.dheenathayalan3, v.thirumalairaj4& r.sivakumar5 et al, optimium condition for turning en19 steel using design of experiments, international journal of applied engineering research issn 0973-4562 volume 10, number 15 (2015).

11. N. Baskar, R. Prabhu, R. Vaiysnavan, R. Prakash, T. Naveen Kumar et al, Optimization of Machining Parameters on EN8 Material Using Genetic Algorithm.