COMPARISON OF CUTTING PARAMETERS ON ALLOY WORK PIECES BY USING RESPONSE SURFACE METHODOLOGY ON DRILLING MACHINE DURING WET CONDITION.

A project report submitted in partial fulfillment of the requirements for

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ABSTRACT

The main objective of this work deals with the effect of cutting parameters on different alloys (Brass, Bronze) in drilling operation to optimize the minimum cutting forces, minimum temperature and maximum material removal rate using surface response analysis. Now a days Brass and Bronze alloys are used in many engineering applications such as manufacturing of shafts, gears, stressed pins, studs, bolts, keys etc., due to good tensile strength.

In the present work full factorial design is considered with process parameters such as speed, feed, and diameter of the drill bit. By using mathematical model the main and interaction effect of various parameters on MRR, temperature, cutting forces are studied. The developed model helps in achieving desired material removal rate and minimum cutting forces in wet conditions (using cutting fluids).

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NOMENCLATURE

1. DOE - design of experiment
2. MRR - material removal rate
3. DIA - diameter
4. Sur Rgn - surface roughness
5. TEMP - temperature
6. BPCL OIL - Bharat petroleum corporation limited

CHAPTER 1

INTRODUCTION

1.1 Drilling Operation

Drilling is a cutting process that uses a drill bit to cut a hole of circular cross-section in solid materials as shown in fig 1.1. The drill bit is usually a rotary cutting tool, often multipoint. The bit is pressed against the work piece and rotated at rates from hundreds to thousands of revolutions per minute. This forces the cutting edge against the work piece, cutting off chips from the hole as it is drilled. The machine used for drilling is called drilling machine.

The drilling operation can also be accomplished in lathe, in which the drill is held in tailstock and the work is held by the chuck.

The most common drill used is the twist drill.

Fig 1.1 : Drilling operation

1.2 Adjustable Cutting parameters in Drilling

The three primary factors in any basic drilling operation are speed, feed and depth of cut other factors such as kind of material and type of tool have a large 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 important 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. It is simply. the product of the rotating speed times the circumference of the work piece before the out 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

$$v = \pi DN/1000 \text{ (mm/min)}$$

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 machines, 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.

$$Fm = f^{*}N \text{ (mm/min)}$$

Here, Fm 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. It is the thickness of the layer being over (in a single pass) from the work piece or the distance from the uncut surface of work to the cut surface, 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.

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

D-Depth of cut in mm

Di-Initial diameter of the work piece

Dr-Final diameter of the work piece.

1.3 Drill Bit

Drill bits are cutting tools used to remove material to create holes, almost always of circular cross-section. Drill bits come in many sizes and shape and can create different kinds of holes in many different materials. In order to create holes drill bits are attached to a drill, which powers them to cut through the workpiece typically by rotation. The drill will grasp the upper end of a bit called the shank in the chuck.

Drill bits come in dard sizes, described in the drill bit sizes article. A comprehensive drill bit and tap size chart lists metric and imperial sized drill bits alongside the required screw tap sizes. There are also certain specialized drill bits that can create holes with a non-circular cross-section. To drill a satisfactory hole in any material, the correct type of drill bit must be used: it must be used correctly and be sharpened as appropriate. Many jobs around the house require a hole of some kind to be drilled- whether it is putting up a shelf, building a cabinet or hanging a light fitting for basic requirements, a set of high-speed steel twist drills and some masonry bits will probably be sufficient for the average handyman. But for more sophisticated jobs/material, others bits will be required - perhaps larger, or designed for a specific material/purpose. Good quality drill bits can be expensive, so take care of them, keep them in a case or box if possible, rather than allowing them to roll around loose in a toolbox where the cutting edges may be damaged. Learning how to sharpen drill bits is cost effective, it better to keep a bit sharp by occasional sharpening rather than waiting until it becomes really blunt. A sharp bit cuts better with less effort whether used in a power or hand drill. A sharp bit will also give a cleaner hole.

1.3.1 Twist bits:

Usually referred to as twist drills, twist bits are probably the most common drilling tools used by the handyman with either a hand or electric drill The front edges cut the material and the spirals along the length remove the debris from the hole and tend to keep the bit straight as shown in fig 1.2. They can be used on timber, metal,plastics and similar materials. Most twist bits are made from following High speed steel (HSS) these are suitable for drilling most types of material,when drilling metal the HSS stands up to the high temperatures. High Speed Steel is a high carbon tool steel, containing a large dose of tungsten. A typical HSS composition is: 18%tungsten, 4% Chromium, 1% vanadium, 0.7% carbon and the rest, Iron. HSS tools have a hamess of 62-64 Rc. The addition of 5 to 8% cobalt to HSS imparts higher strength and wear resistance carbon steel: these bits are specially ground for drilling wood and should not be used for drilling metals, they tend to be more brittle, less flexible than HSS bits.

Low Carbon Steel-Composition of 0.05%-0.25% carbon and up to 0.4% manganese. Also known as mild steel, it is a low-cost material that is easy to shape. While not as hard as higher-carbon steels, carburizing can increase its surface hardness.

Medium Carbon Steel-Composition of 0.29%-0.54% carbon, with 0.60%-1.65% manganese. Medium carbon steel is ductile and strong, with long-wearing properties.

High Carbon Steel-Composition of 0.55%-0.95% carbon, with 0.30%-0.90% manganese. It is very strong and holds shape memory well, making it ideal for springs and wire.Very High Carbon Steel-Composition of 0.96%-2.1% carbon. Its high carbon content makes it an extremely strong material. Due to its brittleness, this grade requires special handling.

Twist bits are also available coated with Titanium nitride (TiN), these are easily identified by the gold like colour. This coating increases the hardness of the bit and adds a self-lubricating property. The coating is only really effective when metal is being drilled, it has little effect when working with other materials. Twist drills are usually available in sizes 0.8-12 mm plus. They are designed for drilling relatively small holes, they sometimes tend to clog quickly especially when the wood is 'green' so when drilling deep holes (especially in hardwood) the bits should be withdrawn regularly to remove the waste. Special care is required when using the smallest sizes since these bits are thin and brittle. Always hold the drill square to the work and apply only light pressure when drilling.

sharpening - use a drill sharpener, a grindstone jig or an oilstone. Titanium nitride bits cannot be sharpened without destroying the coating (although if the drill needs sharpening, the coating will probably have already been destroyed). Forming the correct angle at the tip is important for efficient cutting.

FIG 1.2 : Twist Drill bit

1.3.2 Screwdriver bit:

Drills designed to fit in rechargeable screwdriver these bits have a hexagonal shank. They are ideal for drilling pilot holes but are limited by the low power of these type of screwdrivers and the limited size of small bits available. Sharpening: same as for twist drills.

1.3.3 Masonry bit

As the name suggests, these are designed for drilling into brick, block, stone,tiles or concrete. The cutting tip is often made from tungsten carbide bonded to quarry a spiraled steel shaft. Some masonry drills are described as 'durum tipped', this term refers to a highly durable silicon bronze alloy used instead of tungsten as the cutting point as shown in fig 1.3. Masonry drills are usually used in a power drill; although they can be used with a lot of effort in a hand brace. Most masonry bits can be used with a hammer action power drill, but always check as the action is quite punishing on the bit and cheaper bits have been known to shatter when subjected to the pounding. Always use a slow rotational speed for drilling into harder materials to avoid overheating the tip, and frequently withdraw the bit to remove dust. Long Masonry bits (300 to 400mm) are available for drilling through masonry walls.

Bit sizes range from 4 to 16mm: use a drill sharpener or grindstone to sharpen the tungsten carbide tip.

Fig 1.3 : Masonry Drill Bit

1.3.4 Spur point bit:

Also known as a wood or dowel bit they have a central point and two raised spurs that help keep the bit drilling straight as shown in fig 1.4. The bit cuts timber very fast when used in a power drill and leaves a clean sided hole. They are ideal for drilling holes for dowels as the sides of the holes are clean and parallel. Sizes range from 3 to 10mm. Spur point bits should only be used for drilling wood or some plastics.

Fig 1.4 : spur point bit

Sharpening : a bit fiddly as it has to be done by hand. Sharpen the point and spurs with a fine file or edge of a fine grindstone; the angle between the point and spurs should be 90°.

1.3.5 Bullet pilot point:

With their central point and two spurs, Bullet drills resemble spur point bits,but can be used in metal, wood and plastics. Unlike normal twist drill, the twisted flutes are ground away; making a truer, more accurate bit than normal twist bits as shown in fig 1.5. They cut a clean hole and cause little damage when they break through the back of the workpiece. Bit sizes range from 1.5 to 13 mm.Sharpening-cannot be carried out satisfactorily.

Fig 1.5 : Bullet Point Drill Bit

1.3.6 Countersink:

Although not a true 'drill', it is used in a power or hand drill to form the conical recess for the heads of countersunk screws as shown in fig 1.6. These bits tend to be designed for use on soft materials such as timber and plastics, not metals. When used with a power drill to counter sink an existing hole, the bit tends top 'chatter, leaving a rough surface. Better results be will obtained if the countersink bit is used before the hole is drilled, then take care to ensure that the hole is in the centre of the countersunk depression. Countersinks are available with fitted handles so that they can be used by hand twisting, often easier than changing the bit in the drill when only a relatively few holes need countersinking.

Sharpening: difficult, but can be done with a fine triangular file

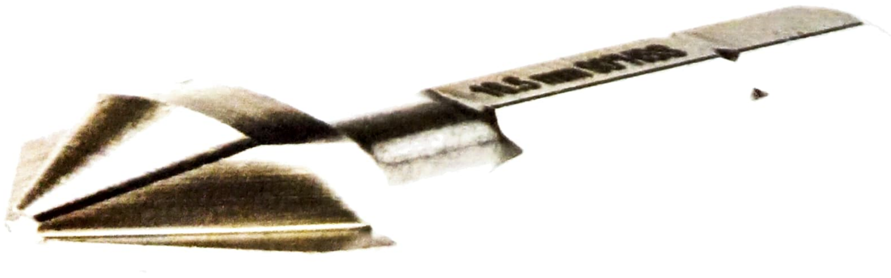


Fig 1.6 : counter sink drill bit

1.3.7 Countersink with clearance drill:

These combination bits are quite clever , they drill the clearance hole and countersinks it all in one stroke. Can be used in a power drill or some routers. Different bits are required for different size of clearance holes and they are probably not cost effective unless a large number of a given hole size need to be drilled and countersunk.Sharpening: difficult, due to shape of spur points.

1.3.8 Tile bit:

A bit for drilling ceramic tiles and glass, it has a ground tungsten carbide tip as shown in fig 1.7. They can be used with a hand drill, but are best used in a variable speed power drill on a slow speed. When drilling glass, some form of lubricant (i.e.turpentine or white spirit) should be used to keep the tip cool. Ceramic tiles can also be drilled using a masonry bit if it is used at slow speed and without hammer action.

With care and patience, a blunt edge can be made good using an oilstone.1.3.9

fig 1.7: Tile Bit

1.3.9 Flat wood bit:

Intended for power drill use only, the Centre point locates the bit and the flat steel on either side cuts away the timber as shown in fig 1.8. These bits are u drill fairly large holes and they give a flat bottomed hole (with a central point) so are ideal where the head of a screw/bolt needs to be recessed into the timber- always use this bit before drilling the clearance hole for the bolt.

The larger bits require a fairly powerful drill to bore deep holes. The bits cause a lot of splintering as they break out the back of the workpiece using a sacrificial backing board will reduce this. Flat wood bits are not really suitable for enlarging an existing hole.Sizes range between 8 and 32mm.Sharpening use a fine file, oilstone or grindstone.

Fig 1.8 : Flat Bit

1.3.10 Hole saw:

Used for cutting large, fixed, diameter holes in wood or plastic. They will usually cut up t a depth of 18mm - deeper versions are available. Best used in a power drill at low speed as the blade saws it's way through the material. Sharpening - could be done with a fine triangular file as for an ordinary saw. Combination hole saw Li the Hole Saw above, these combination saws can cut large holes but they consist of a number of different sized round saw blades, usually ranging from about 25 to 62 mm in diameter. Normally the blade are secures by a radial screw in the head, all blades other than the desired sized being removed before the screw is inserted to secure the required diameter blade. Best used in a power drill at low speed as the blade saws it's way through the material.

Sharpening-could be done with a fine triangular file and 'setter' as for an ordinary saw.

1.3.11 Forstner bit:

Used to form holes with a flat bottom, such as for kitchen cupboard hinges.Best used in a power drill held in a drill stand as there's little in the way of a centralpoint. If used freehand, the positioning is difficult to control as there is no central pilot bit. The bit is shown in fig 1.9

Sharpening-on an oilstone or with a fine file.

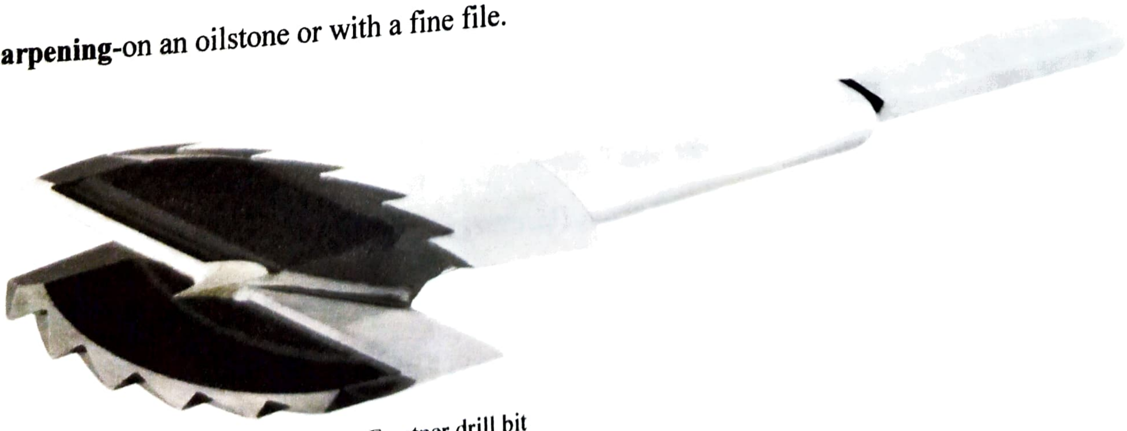


fig 1.9 : Forstner drill bit

1.3.12 Wood auger bit:

This is ideal when drilling large-diameter, deep holes in wood or thick man made boards as shown in fig 1.10. Generally an Auger should be used in hand brace.The bit will cut a clean and deep, flat bottomed holes. The single spur cuts and defines the edge of the hole while the chisel-ike cutting edge removes the waste within the previously cut circle. The threaded Centre bites into the wood and pulls the bit into the timber. This' pulling action means that the bit is really unsuitable for use in a power drill.

Fig 1.10 : wood auger drill bit

Sharpening- use a fine file or oilstone to keep the spur and main cutting edges sharp.

1.4 Classification of Drilling Machines:

In a lot of manufacturing processes, one of the most indispensable machining tools is the drilling machine. The drilling machine is commonly called a drill press and is responsible for drilling various sizes of holes in any surface area and to precise depths. Aside from the fact the drilling machine is used primarily in drilling holes, there are a few other functions that the drilling machine is capable of performing.

These functions include tapping, spot facing, reaming, countersinking, and counter boring to name a few.

1.4.1 Table top sensitive drilling machine:

General purpose drilling machines of common use Table top small sensitive drilling machine These small capacity (=0.5 kW) upright (vertical) single spindle drilling machines are mounted (bolted) on rigid table and manually operated using usually small size (f=10 mm) drills. Fig 1.11 typically shows one such machine.

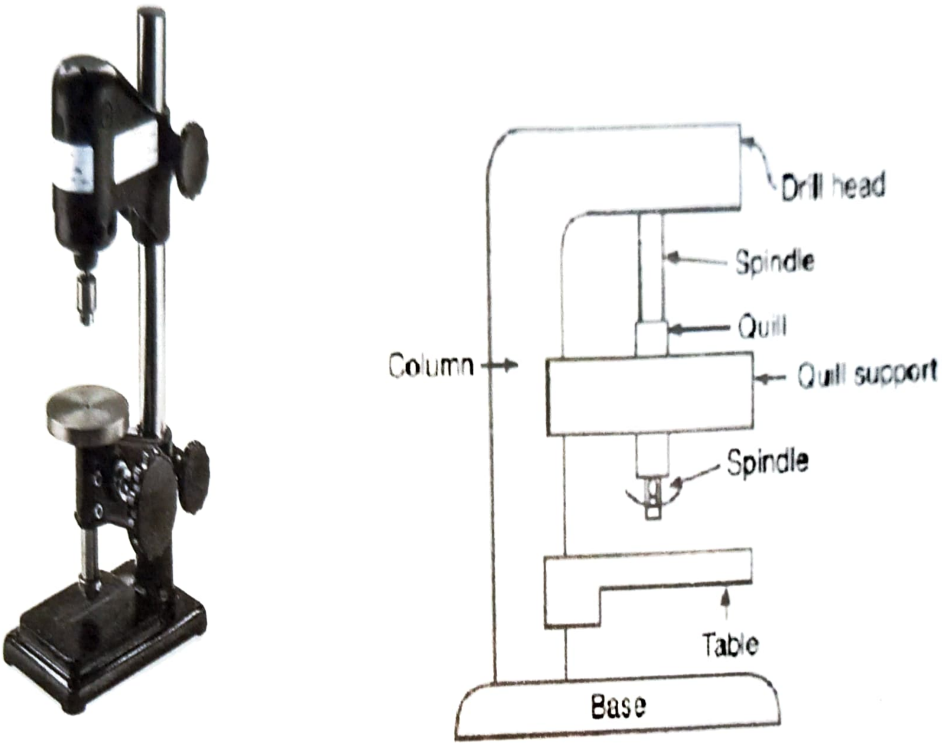


Fig 1.11 : table top sensitive drilling machine

1.4.2 Pillar drilling machine:

These drilling machines, usually called pillar drills, are quite similar to the table top drilling machines but of little larger size and higher capacity (0.55 1.1 kW) and are grouted on the floor (foundation). Here also, the drill-feed and the work table movement are done manually. Fig 1.12 typically shows a pillar drill. These low cost drilling machines have tall tubular columns and are generally used for small jobs and light drilling.

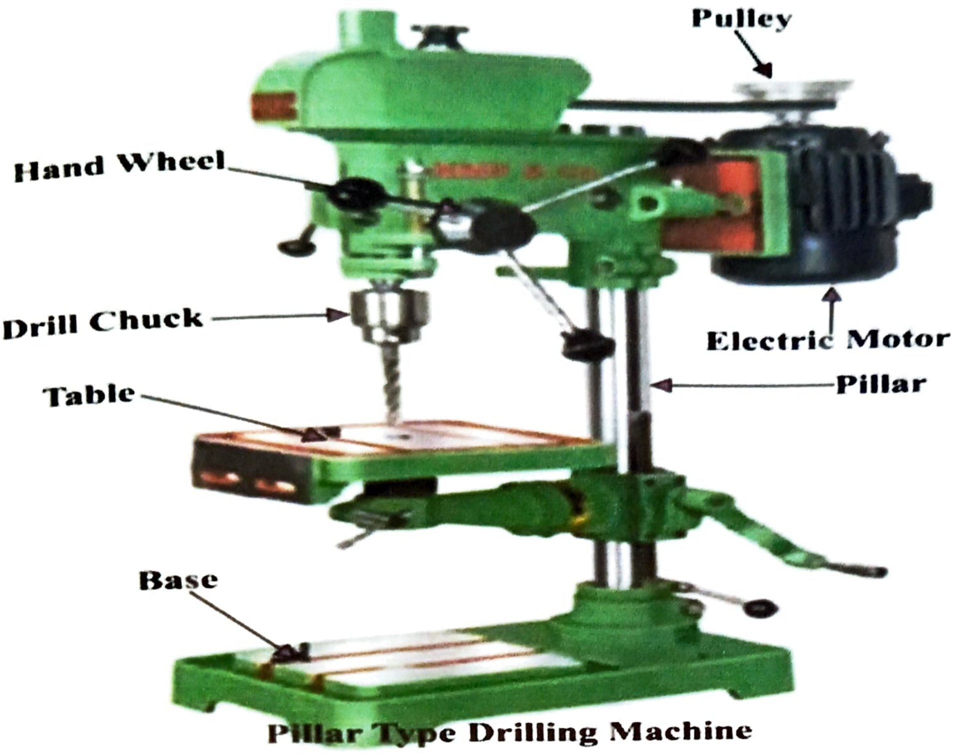


Fig 1.12 : pillar drilling machine

1.4.3 Column drilling machine:

These box shaped column type drilling machines as shown in fig 1.13 is much more strong, rigid and powerful than the pillar drills. In column drills the feed gear box enables automatic and power feed of the rotating drill at different feed rates as desired. Blanks of various size and shape are rigidly clamped on the bed or table or in the vice fitted on that. Such drilling machines are most widely used and over wide range (light to heavy) work.

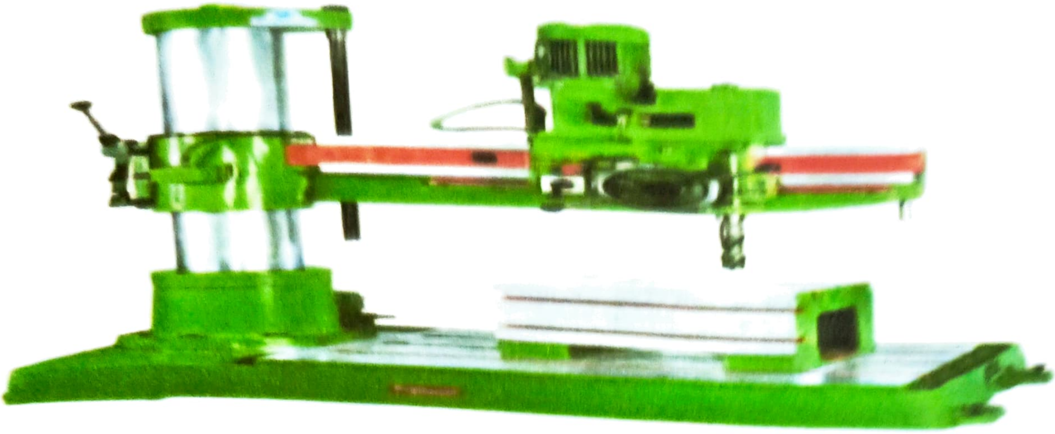


Fig 1.13 : column drilling machine

1.4.4 Radial drilling machine:

This usually large drilling machine possesses a radial arm which along with the drilling head can swing and move vertically up and down as can be seen in fig 1.14. The radial, vertical and swing movement of the drilling head enables locating the drill spindle at any point within a very large space required by large and odd shaped jobs. There are some more versatile radial drilling machines where the spindle can be additionally swiveled and/ or tilted.

Fig 1.14 : radial drilling machine

1.4.5 CNC Column drilling machine:

In these versatile and flexibly automatic drilling machine having box- column type rigid structure the work table movements and spindle rotation are programmed and accomplished by Computer Numerical Control (CNC) as shown in fig 1.15

These modern sophisticated drilling machines are suitable for piece or batch production of precision jobs.

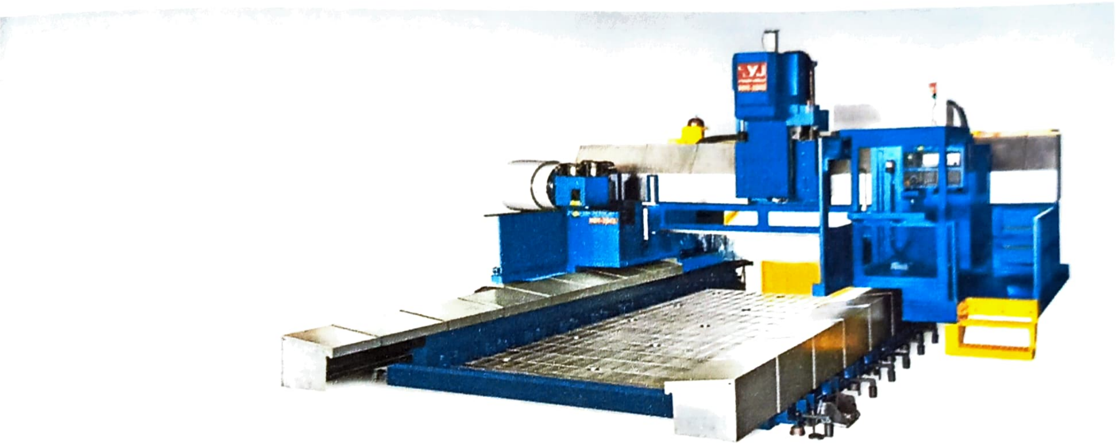


Fig 1.15 : cnc column drilling machine

1.4.6 Hand drills:

Unlike the grouted stationary drilling machines, the hand drill is a portable drilling device which is mostly held in hand and used at the locations where holes have to be drilled.. The small and reasonably light hand drills are run by a high speed electric motor. In fire hazardous areas the drill is often rotated by compressed air. Hand drill in operation.

1.4.7 Gang drilling machine:

In this almost single purpose and more productive machine a number (2to 6) of spindles with drills (of same or different size) in a row are made to produce number of holes progressively or simultaneously through the jig. Fig 1.16 schematically shows a typical gang drilling machine.

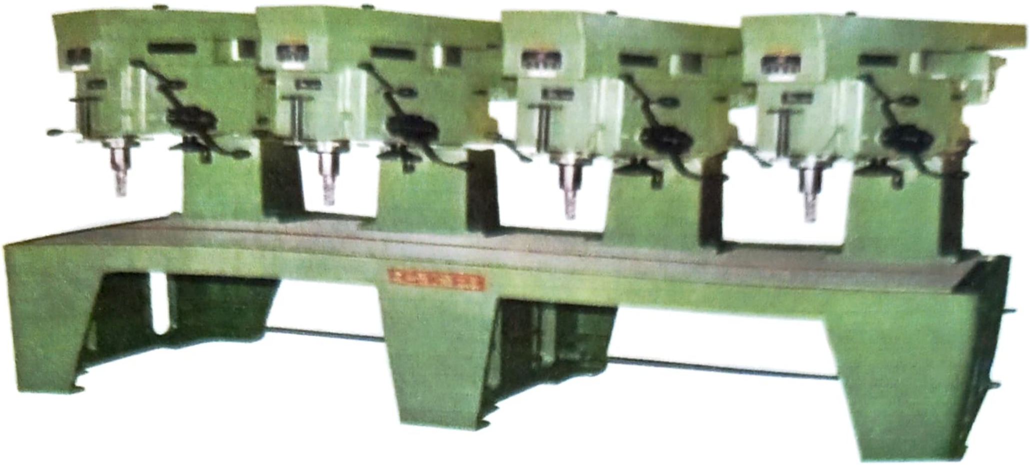


Fig 1.16 : Gang drilling machine.

1.4.8 Turret (type) drilling machine:

Turret drilling machines are structurally rigid column type but are more productive like gang drill by having a pentagon or hexagon turret as shown in fig. the turret bearing a number of drills and similar tools is indexed and moved up and down to perform quickly the desired series of operations progressively . These drilling machines are available with varying degree of automation both fixed and flexible type . schematic view of turret type drilling machine is shown in fig 1.17

Fig 1.17 : turret (type) drilling machine

1.4.9 Multispindle drilling machine:

In these high production machine tools a large number of drills work simultaneously on blank through a jig specially made for the particular job, the entire drilling head works repeatedly using the same jig for batch or lot production of a particular job. Fig 1.18 shows a typical multispindle drilling machine. The rotation of planetary gears in mesh with the central gear and the corresponding flexible shafts. The position of those parallel shafts holding the drill area adjusted depending upon the location of the holes to be made on the job. Each shaft possesses a telescopic part and two universal joints at its ends to allow its change in length and orientation respectively for adjustment of location of the drills of varying size and length. In some heavy duty multi spindle drilling machines, the work table is raised to give feed motion instead of moving the heavy drilling head.

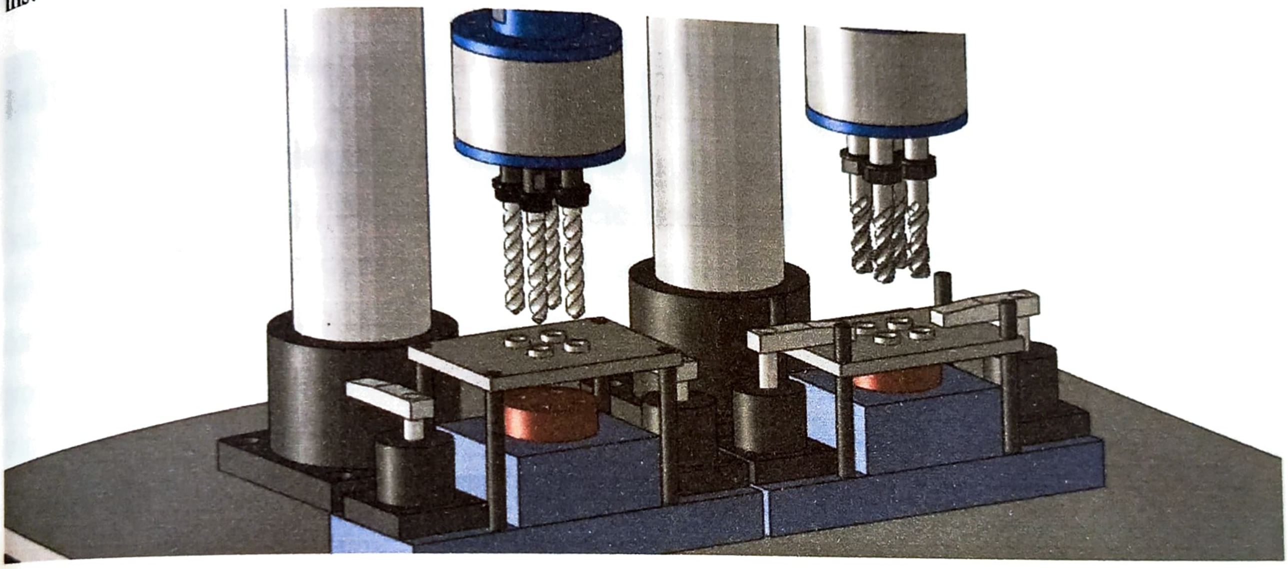


fig 1.18 : a typical multi nspindle drilling machine

1.4.10 Micro(or mini) drilling machine :

The type of tony drilling machine of height within around 200 mm is placed or clamped on a table, as shown in fig 1.19 and operated manually for drilling small holes of around 1 to 3 mm diameter in small work pieces.

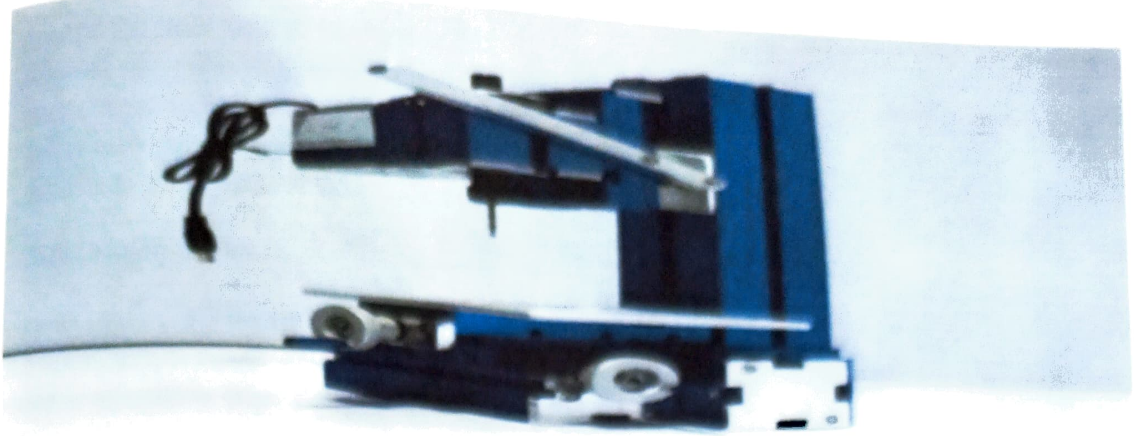


fig 1.19 : photo graphic view of a micro drilling machine

1.4.11 Deep hole drilling machine:

Very deep holes of L/D ratio 6 to even 30, required for rifle barrels, long spindles , oil holes in shafts , bearing , connecting rods etc. are very difficult to make for slenderness of the drills and difficulties in cutting fluid application and chip removal . Such drilling cannot be done in ordinary drilling machine such as gun drilling machines with horizontal axis which are provided with high spindle speed high rigidity tool guide pressurized cutting oil for effective cooling, chip removal and lubrication at the drill tip as shown in fig 1.20. Deep hole drilling machines are available with both hard automation and CNC system.

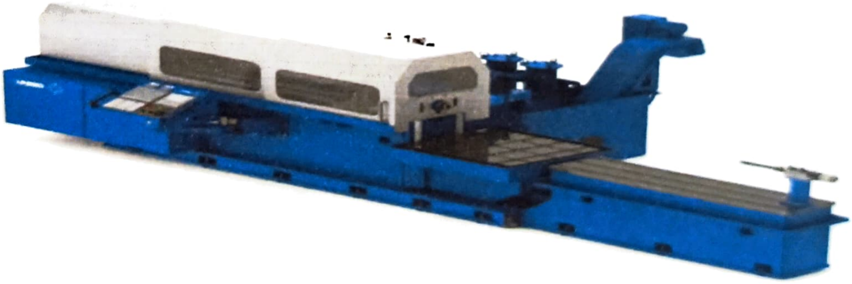


Fig 1.20: deep hole drilling machine

1.5 Kinematic system of general purpose drilling machine and their principle of working:

Kinematic system in any machine tool is comprised of chains(s) of several mechanisms to enable transform and transmit motions (s) from the power sources(s) from the cutting tool and the work piece for the desired machining action. The kinematic structure varies from machine tool to machine tool requiring different type and number of tool work motions .

even for the same type of machine tool , say column drilling machine , the designer may take different kinematic structure depending upon productivity, process capability , durability, compactness, overall cost etc,Targeted. Schematically shows a typical kinematic a system of a very general purpose drilling machine like, a column drilling machine having 12 spindle speeds and 6 feeds .the kinematic system enable the drilling machine the following essential works .

1.5.1 Cutting motion:

The cutting motion in drilling machines is attained by rotating the drill at different speeds (rpm). Like center lathes, milling machines etc., drilling machines also need to have a reasonably large number of spindle speeds to cover the useful ranges of work material, tool material, drill diameter, machining and machine tool conditions, it is shown in fig 545646 that drill gets its rotary motion from the motor through the speed gear box(SGB) and a pair of bevel gears. For the same motor speed, the drill speed can be changed to any of the 12 speeds by shifting the cluster gears in the SGB, the direction of rotation of the drill can be changed, if needed, by operating the clutch in the speed reversal mechanisms.

1.5.2 Feed motion:

In drilling machines, generally both the cutting motion and feed motion are imparted to the drill. Like cutting velocity or speed, the feed (rate) also needs varying (with in a range) depending upon the tool work materials and other conditions and requirements. Fig visualizes that the drill receives its feed motion from the output shaft of the SGB through the feed gear box (FGA), and the clutch. The feed rate can be changed to any of the 6 rates by shifting the gears in the FGB and the automatic feed direction can be reversed, when required, by operating the speed reversal mechanism. The slow rotation of the pinion causes the axial motion of the drill by moving the rack provided on the quill. The upper position of the spindle is reduced in diameter and splined to allow its passing through the gear without hampering transmission of its rotation.

1.5.3 Application of drilling machines:

Drilling machines of different capacity and configuration are basically used for originating cylindrical holes and occasionally for enlarging the existing holes to full or partial depth .but different types of drills are suitably used for various applications depending upon work material, tool material, depth and diameter of the holes.

1.6 Tool geometry:

For the present machine process twist drill had been used. Twist drills are the most common cutting tools used with the drilling machines. Twist drills are designed to make round holes quickly and accurately in all materials. They are called twist drills mainly because of the helical flutes or grooves that wind around the body from the point to the neck of the drill and appear to be twisted. Twist drills are simply constructed but designed very trough to withstand the high torque of turning the downward pressure on the drill, and the high heat generated by friction following are the different nomenclature of twist drill

1.6.1 Axis:

Axis is an imaginary straight line that forms the center line of the drill as shown in fig 1.21.

Fig 1.21: axis

1.6.2 Back taper: It is a straight decrease in diameter from point towards shank, in the body of the drill as shown in fig 1.22.

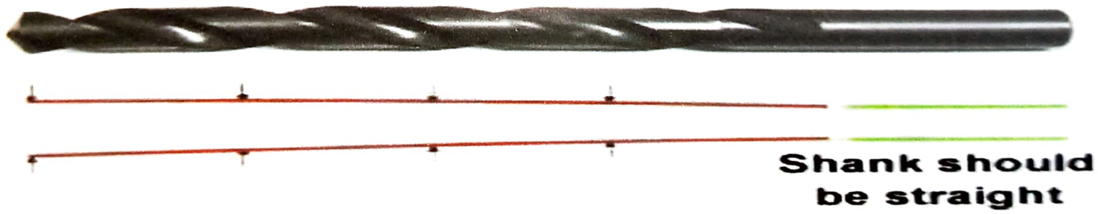


Fig 1.22 : back taper

1.6.3 Body diameter clearance: The portion of the land that has been cut away so it will not bind against yhe walls of the hole as shown in fig 1.23

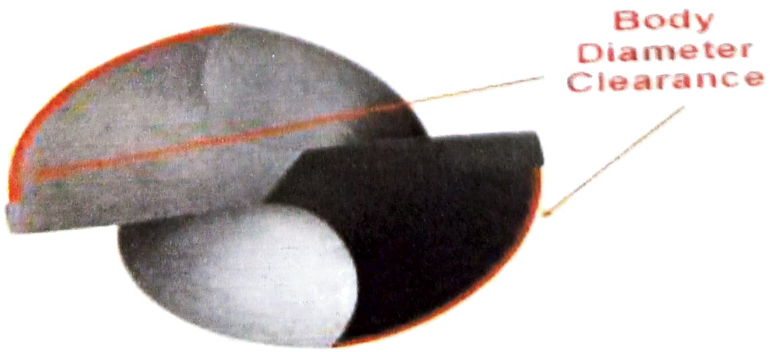


Fig 1.23 : body diametric clearance

1.6.4 Body:

Portion of the drill extending from the end of the flutes to the outer corner of the cutting edges as shown in fig 1.24

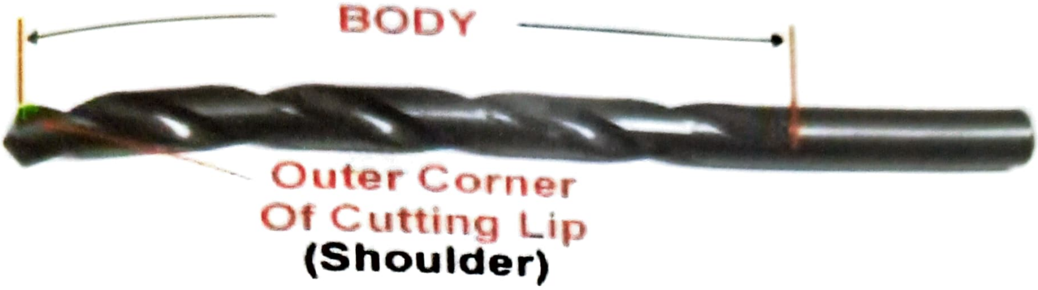


Fig 1.24 : body of drill bit

1.6.5 Chisel edge:

The edge at the end of the web that connects the cutting lips as shown in fig 1.25

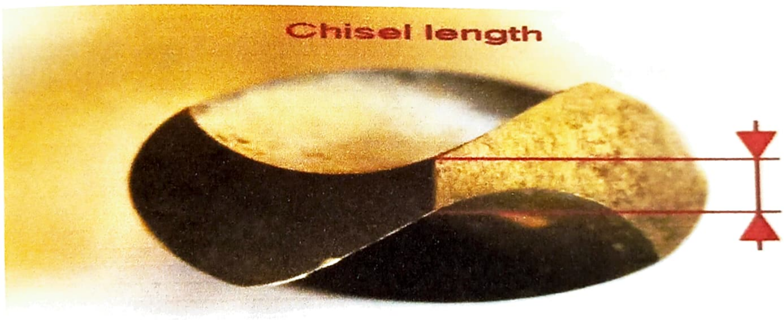


Fig 1.25 : chisel edge

1.6.6 Chisel edge angle:

The angle between the chisel edge and the cutting lips (edges) as shown in fig 1.26

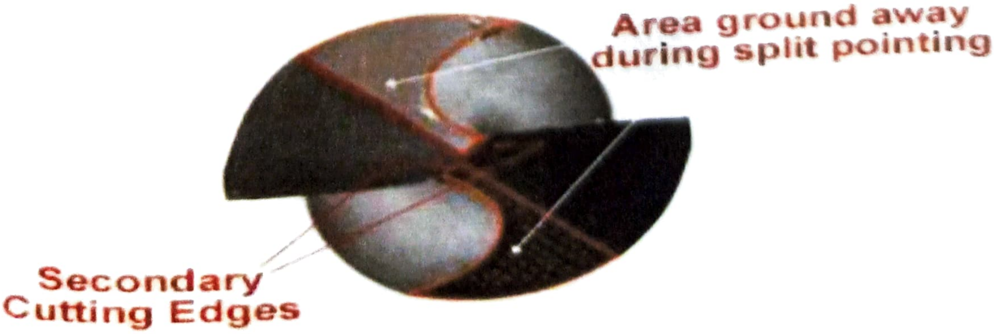


Fig 1.26 : drill diameter

1.6.7 Drill diameter:

The diameter over the margins of the drill measures at the point as shown in fig 1.27 .

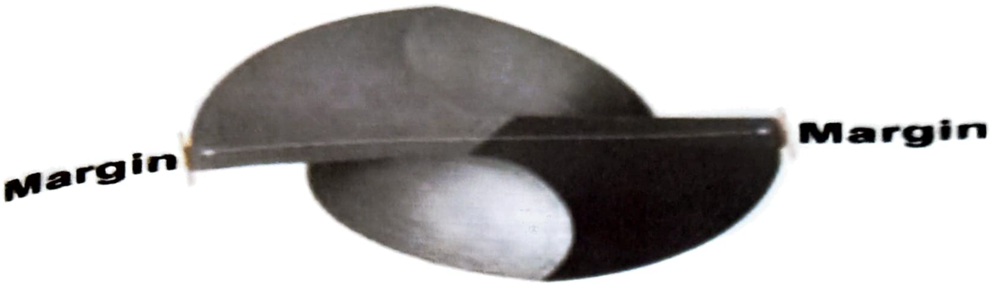


fig 1.27 : drill diameter

1.6.8 Flutes:

Grooves formed in the body of the drill to provide cutting edges, to permit removal of chips, and to allow cutting fluid to reach the cutting area as shown in fig 1.28 .

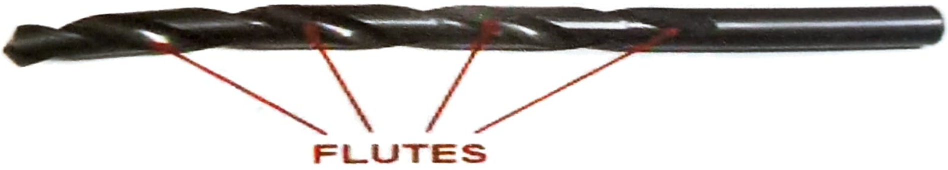


Fig 1.28 : lip relief angle

1.6.9 Lip relief angle:

The relief angle at the outer corner of the lip as shown in fig 1.29

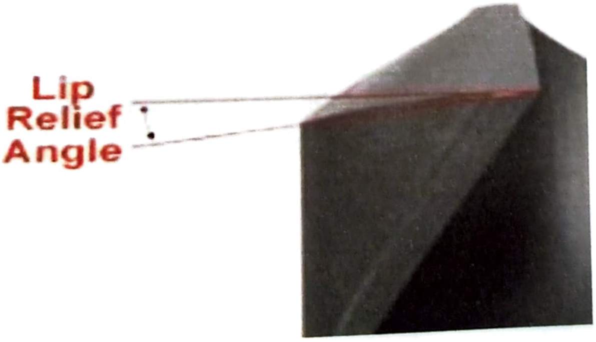


Fig 1.29 : margin of drll bit

1.6.10 Margin:

The narrow portion of the land which is not cut away to provide clearance, it stabilizes the drill in the holes as shown in fig 1.30.

Fig 1.30 : margin of drill bit

1.6.11 Margin width:

The width of the portion of the drill lands not cut away foe clearance as shown in fig 1.30 .

1.6.12 Web tapered:

The web thickness increases in thickness from point to the shank to enhance the rigidity of the drill as shown in fig 1.31 .

fig 1.31 : web tapered

1.6.13 Web:

The central portion of the body that joins the lands. The extreme end of the web forms the chisel edge on a two flute drill as shown in fig 1.32.

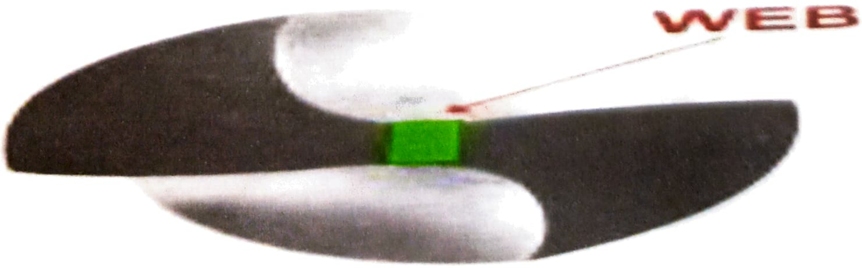


Fig 1.32 : web

1.7 Drilling operations:

Operations that can be performed in a drilling machine are

- Drilling
- reaming
- Boring
- Counter boring
- Counter sinking
- Tapping

1.7.1 Drilling:

It is an operation by which holes are produced in solid metal by means of revolving tool called 'drill'. Fig 1.33 shows the various operations on drilling machine.

1.7.2 Reaming:

Reaming is an accurate way of sizing and finishing the pre existing hole. Multi tooth cutting tool. Accuracy of 0.005 mm can be achieved.

1.7.3 Boring:

Boring is a process of enlarging an existing hole by single point cutting tool. Boring operation is often preferred because we can correct hole size, or alignment can produce smooth finish. Boring tool is held in the boring bar which has the shank. Accuracy of 0.005mm can be achieved.

1.7.4 Counter bore:

This operation uses pilot to guide the cutting action to accommodate the heads of the bolts. Fig1.33 illustrates the counter boring, countersinking and spot facing process.

1.7.5 Counter sink:

Special angle cone shaped enlargement at the end of the hole to accommodate the screws. Cone angles of 60, 82, 90, 100, 110, 120.

1.7.6 Tapping

Tapping is a process by which internal threads are formed. it is performed either by hand or machine . Minor diameter of the thread is drilled and then tapping is done. Fig1.33 shows the tapping process.

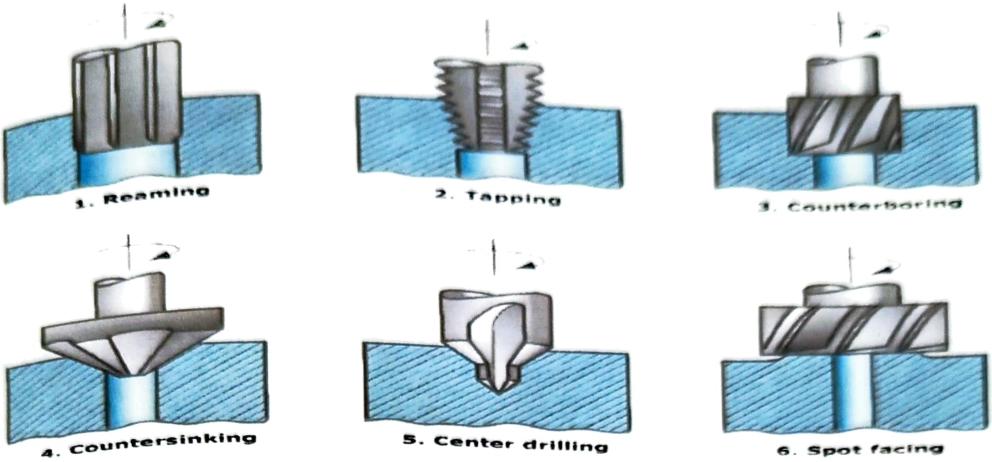


Fig 1.33 : various operations performed on drilling machine

1.8 Work holding devices:

1.8.1 Machine table vice:

The machine vice is equipped with jaws with clamps the work piece. The vice can be bolted to the drilling table or the tail can be swung around fig shows the standard and swivel vice. The swivel vice is machine wise that can be swivel through 360 on horizontal plane.

Fig 1.34 : machine table vice

1.8.2 Step blocks:

These are built to allow height adjustments for mounting the drilling jobs and are used to strap clamps and long T slot bolts.

1.8.3 Clamps:

They are small, portable vises, which bear against the work piece and holding devices .common type of clamps are c-clamps, parallel clamp, machine strap clamp, u-clamp, etc. shows the correct and incorrect methods of mounting the work piece.

1.8.4 V blocks:

They are designed to hold round work pieces.

1.8.5 Angles:

Angle plates are made in 90 angle with slot and bolt holes for securing work to the table.

1.8.6 Jigs:

The jigs guide the drill through a bushing to locate and drill holes accurately.

1.8.7 T-slot bolts:

They are special bolts which as at shaped head, which slides into T slots of drilling machine work table.

1.9 Introduction to Mini tab:

Mini tab is a statistical package. It was developed at the Pennsylvania state university by researchers Barbara F.ryan, Thomas a ryan jr., and brain l. joiner in 1972. Minitab begins with a lighter version of OMINITAB, statistical analysis research. Statistical analysis computer application has the advantages of being accurate, reliable and general faster than computing statistics and drawing graphs by hand. Mini tab is relatively easy to use once you know a few fundamentals.

Minitab is disturbed by Minitab Inc., a privately owned company head quartered in a state college, Pennsylvania with subsidiaries inventory, England (mini tab limited), Paris, France (Minitab sarl) and Sydney, Australia (Minitab pty).

Today mini tab is often used in conjunction with implementation of six sigma, CMMI and others statically base process improvements methods. Minitab 17 latest version of the software is available in 7 languages: English, France, German, Japanese, Korean, simplified Chinese and Spanish.

Minitab is statistical analysis software. It can be used for learning about statics and statistical research. Statistical analysis computer applications have the advantage of being accurate, reliable, and generally faster than computing statistics and drawing graphs by hand. Mini tab is a relatively easy to use once you know a few fundamentals.

Minitab Inc. produces two other complement mini tab17: Quality trainer, a learning package that reaches statistical tools and concepts in the context of quality improvement that integrates with mini tab 17 to simultaneously develop the users statistical knowledge and ability to use the mini tab software and quality companion, an integrated tools for managing six sigma and lean manufacturing project that allows mini tab data to be combined with management and governance tools and documents.

Mini tab has two main types of files, projects and work sheets. Worksheets are files that are made up of data think of a spread sheet containing variables of data. Projects are made up of the commands, graphs, and work sheets. Every time you save a minicab project you will be saving graphs, worksheets and commands. However each one of the elements can be saved individually for use in the commands. Likewise you can print projects and its elements.

1.9.1 Mini tab project and work sheets:

Mini tab has two main types of files, projects and work sheets. Worksheets are files that are made up of data: think of a spread sheet containing variables of data. Projects are made up of commands graphs, and work sheets. Every time you save a minicab project you will be saving graphs, worksheets and commands. However each one of the elements can be saved individually for use in the commands. Likewise you can print projects and its elements.

The menu bar you can open menus and choose commands. Here you can find the built in routines.

The tool bar: short cut to Minitab commands.

1.9.2 Two windows in mini tab:

- **Session window :**

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

- **Worksheet window**: a grid of rows and columns used to enter and manipulate the data.

NOTE:

The area looks like a spread sheet 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 17 has the report manger that helps you to recognize your results in a report.
- **Other windows:** history and project manager are two windows. see Minitab help for more information on these if needed.

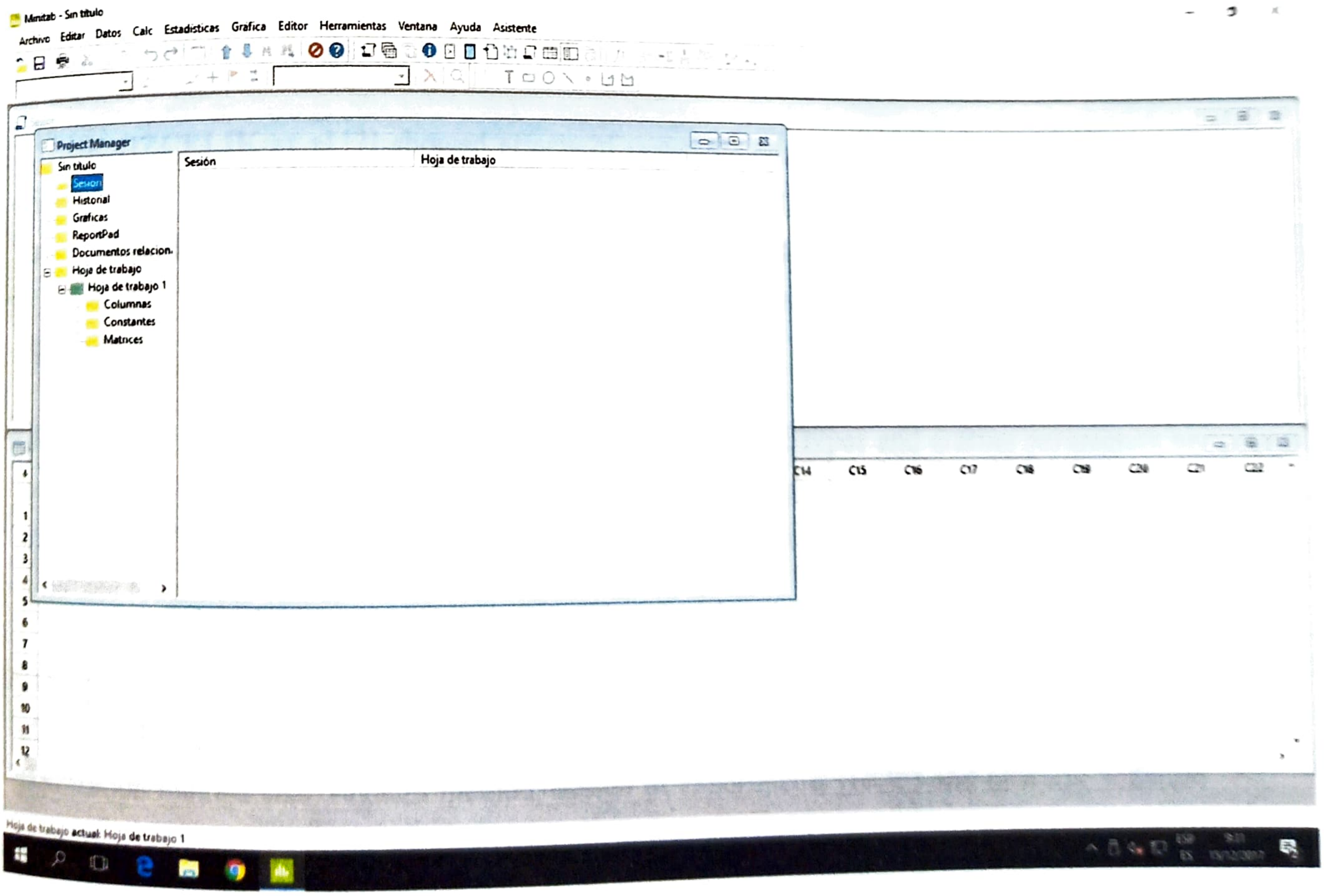


Fig 1.36 : environment in mini tab

CHAPTER 2

LITERATURE REVIEW

Before starting the project, we had a brief study on various papers related to the cutting parameters on drilling and materials to be selected for the study. Several authors portrayed different ideas related to their works on drilling. Their views are listed below:

B.P.PATEL et al,[1] studied experimentally the cutting parameters required to optimize the geometric dimensions and tolerance (GD&T) requirements such as perpendicularity. This paper reports an experimental investigation of a full factorial design performed on EN8 and EN31 materials using HSS drill with point angle 118° and helix angle 30° by varying the drilling parameters such as spindle speeds, feed and coolant ratio to determine the optimum cutting conditions. The work piece geometric dimensions and tolerance (GD&T) requirements analysed by perpendicularity. Analysis of variance (ANOVA) was carried out for perpendicularity on EN8 and EN31 materials and their contribution rates was determined. Design of experiments (DOE) methodology by full factorial design was used in the multiple objective optimizations (using mini tab 16, software) to find the optimum cutting conditions for least perpendicularity defect.

BABUR OZCELIK et al,[2] showed effects of vegetable based cutting fluids on the wear in drilling. They worked on semi-synthetic commercial cutting fluid, sun-flower and canola oils. Their experimental results shows that canola based cutting fluid gives the better performance due to its higher lubricant properties with respect to other cutting fluids at constant cutting conditions.

E.KURAM et al,[3] they investigate the effect of cutting fluid types and cutting parameters on surface roughness and thrust force and concluded that an increase in spindle speed, decreased the thrust force value and surface roughness value and increase in feed rate, increased the force value on surface roughness value.

Asst.Prof. J.PATEL et al,[4] investigated on effect of cutting parameters on drilling operations for perpendicularity and based on research paper they concluded that by using proper optimization method like Taguchi method, design of experiments (DOE) and efficient software like (Mini tab16, Analysis of Variance (ANOVA)), we can obtain optimum response parameters such as surface roughness, perpendicularity, cylindricity and circularity.

S. SATHIYARAJ et al,[5] they investigated on optimization of machining parameters for EN8 steel through Taguchi method and conclude that cutting speed has most dominant effect on the Observed surface roughness, followed by feed and depth of cut whose influences on surface roughness are smaller.

GULTEKAN UZUN et al,[6] in this study, the effect of different foaming duration on pure structure of aluminium foam material are examined and the foaming duration for homogenous pore distribution was determined. The obtained samples were drilled ith drills of different diameters at different feed rates and cutting speeds. Feed forces increased with increase in cutting speed. Feed force exhibit in increases in the interval 200-500% with increase in feed amount. Foamed structure effected the chip breakings causing an increase in chip adhesions proportionally with the cutting speed.

Mr. T BHARADWAJ et al,[7] they showed optimization of process parameters in drilling EN8 steel using Taguchi technique and gave conclusion hat surface toughness increases with increase in feed, increase in depth of hole while with spindle speed, surface roughness initially decreases as the spindle speed increases from 360 RPM to 490 RPM and surface roughness increases with increase in spindle speed from 490 RPM to 680 RPM and all the three independent parameters (speed, feed and depth of hole) seem to be influential drilling parameters and that affect the surface roughness.

P. VENKATARAMAIAH et al,[8] focussed on development of neural network model to predict the multi-responses and to study the influence of drilling parameters-cutting speeds, feed rates, type of drill tools, cutting fluids on output parameters-torque, cutting force, surface roughness, material removal rate and power for determining the optimum input parameters combinations using Taguchi method. It was found that, surface finish and torque are mostly effected by types of drill tools. Cutting force is mostly effected by cutting environment, material removal rate is mostly affected by feed rate, with increase in feed rate there is decrease in MRR and power is mostly effected by cutting speed.

S. JAYABAL et al,[9] showed the influence of cutting parameters on thrust force and torque in drilling of E-glass/polyster composites and conclusion that thrust force depends on drill point angle, speed and feed rate and increases with increase of point angle and feed rate.

SUMESH A S et al,[10] studied on optimization of drilling parameters for minimum surface roughness using Taguchi method and concluded that the drilling parameters are optimised with respect to multiple performances in order to achieve a good quality of holes in drilling of cast iron. Optimization of the parameters was carried out using Taguchi method.

RAMAZAN CAKIROG. Et al,[11] had performed the experiment to optimise the cutting parameters on drill bit temperature in drilling. The work piece material is AL7075 and drill tool is the uncoated and coated carbide drills in the experiment. The optimisation of the cutting parameters was carried out by Taguchi method with L18 orthogonal array. The cutting speed, feed rate and cutting tool are selected as control factors. Taguchi design method exhibit a good performance in the optimization of cutting parameters on drill bit temperature measurements. In addition, the empirical equations of drill bit temperatures were derived by using regression analysis. From ANOVA they founded that the most significant factor in affecting the drill bit temperature was the feed rate having a percentage contribution of 56.15%. Taguchi design method, Regression analysis was able to provide the minimum cost and time in the manufacturing engineering applications.

J. K. SAKHIYA et al,[12] investigated that drilling operation may affected by several parameters like cutting speed, feed rate, tool geometry, tool angle, application of different lubrication , coating on tool and this all parameters affect the tool wear or tool life, surface roughness of drilled hole, productivity and accuracy of hole and there is a scope to work on drilling operation with pneumatic feed drive automatic application and can perform the parametric study on it. Pressure of pneumatic drive can be taken as control parameter to find out effect of on MRR, tool wear rate, production time etc.

T. KARTHIKEYA SHARMA[13] conducted a study of drilling parameters of Al2014 in radial drilling machine under dry conditions and optimizes the drilling parameters based on Taguchi method of design of experiments. They identified that a spindle speed of 200 rpm, point angle and helix angle of 90°/15° and a feed rate of 0.36 mm/rev is the optimal combination of drilling parameters that produced a high value of S/N ratios of hole diameter.

ERROR KILICKAP[14] they influence of machining parameters-cutting speed, feed rate, and cutting environment on surface roughness obtained in drilling of AISI 1045 was studied and he was concluded that minimum surface roughness is obtained at lower cutting speeds, while it deteriorates as a feed rate is increased. Surface roughness was much better for the MQL conditions than for the compressed air and dry drilling, also it increase under dry drilling.

J. PATEL et al,[15] have studied the effect of drilling parameters such as spindle speed, feed rate, coolant ratio for obtaining the optimum perpendiculairty for materials EN8, EN24and EN31 as work piece materials using cobalt alloy steel drill with point angle 135° and helix angle 30°. This study shows that how significant drilling parameter are for obtaining optimum perpendicularity. Analysis of variance (ANOVA) was carried out for perpendicularity and their contribution rates determined optimum cutting conditions for least perpendicularity defect obtained by using design of experiments (DOE) methodology for achieving optimization using Mini tab 16 software.

Mr. NALAWDE P.S. et al,[16] effort had been taken to optimise surface finish and hole accuracy in drilling operation. They performed experiment on EN31 material. Speed, type of tool, feed and depth of cut was selected as a input parameter. The effect of drilling parameters on surface finish and hole accuracy were investigated in drilling of EN31 material with different HSS twist drill. In this work drilling operation performed using 10 mm diameter HSS TiN coated drills, HSS TiAlN coted drills, HSS twist uncoated drills. Smaller is better was selected as optimization of setting of parameter for achieving higher surface finish. Experimental trails shown the result based on L9 orthogonal array. Several input parameters had been taken depending upon orthogonal arrays. This study investigates the effects of input parameters by the application of Taguchi method on surface finish and hole accuracy in dry drilling of EN31 material. For surface finish optimum value of cutting speed was 30m/min, feed(0.2mm/min) and type of tool was HSS uncoated twisted drill. For a hole accuracy optimum value is obtained from analysis was cutting speed (30m/min), feed0.2mm/min and type of tool was (HSS+ TiN) coated drill.

E. KURAM et al,[17] in this study different cutting fluids are used to determine the surface roughness and thrust force during drilling of AISI304 austenitic stainless steel with HSSE tool and the results obtained from vegetable cutting fluids were compared with commercial cutting fluids and the given conclusion was the least surface roughness was achieved at spindle speed of 720rpm using CVCF. SCF-Ⅰ was the most effective in reducing surface roughness as spindle speed increased. SCF-Ⅱ had smllest surface roughness at feed rates lower than 0.12mm/rev,the least surface roughness was achieved at feed rate of 0.08mm/rev using SCF-Ⅱ. An increase in the spindle speed decrease the thrust force value. An increase in spindle speed decrease the surface roughness value. An increase in feed rate increases the thrust force value. An increase in feed rate increased the surface roughness value. Tool wears were not observed with all cutting fluids.

From the above literature survey, the authors have identified some of the gaps in the areas pf drilling. Hence the authors have embarked to study the influence of various cutting parameters. In this work, the effect of cutting parameters in drilling of alloy materials(Brass, Bronze) by using surface response methodology in wet conditions is carried out by the following experimental procedure.

CHAPTER 3

DESIGN OF EXPERIMENTS

3.1 Design of experiments(DOE)Overview:

Industry, designed experiments can be used to 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 manfacturability,reliability,quality,and field performance. As the resources are limited, it is very important 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 effects that are important. If there is an interaction between two input variables .

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

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 inavoiding 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. Hence 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 informatiopn.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 gain through observation or previous experimentation. Make sure the process and measurement systems are in control. Ideally, both the process and the measurements should be instatistical control as measure by a functioning statistical functioning control (SPC) system. Minitab provides numerous tools to evaluate process control and analyze 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 effect product quality. This reduction allows focusing process improvement efforts on the really important variables. Screening suggest 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 useful in some screening experimentation and robustness testing.
- General full factorial designs (designs with more than two levels) may also be useful for small screening experiments.

3.1.3 Optimization: after identifying the vital variables by screening, there is 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 mini tab 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 methods for designing and analyzing simplex, centroid, simplex lattice and extreme vertices designs. Mixture designs are a special class of response surface designs where the proportions of the componernts (factors),rather than their magnitude,are important .
- 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 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 operated 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 important parameters to obtain the best responses.DOE also can provides us with the most optimal setting of parametric values to find the best possible output characteristics. Besides from that, the mathematical model generated can be used as a prediction model which can 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 function in such manner 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 error occurring. Some of them might be predictable while some errors are just out of control. DOE allows us to handle these errors while still continuing with the analysis. DOE is excellent when it comes to prediction linear behavior.

However, when it comes to non linear 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 performing an experiment, varying the levels of the factors simultaneously rather than one at a time is efficient in terms of time and cost, and also allows for the study of interactions between the factors. Interactions are the driving force in many processes. Without the use of factorial experiments, important interactions may remain undetected.

3.3(b) Screening designs

In many process development and manufacturing applications, the number of potential input variables (factors) is large. Screening (process characterization) is used to reduce 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 really important 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 Placket-Burman designs are often used to "screen" for the really important 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 full 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 off runs is the "design".

3.3.1(a) Two level full factorial designs:

In a two-level full factorial design, each experimental factor has only two levels. The experimental runs include all combinations of these factor levels. Although two-level factorial designs are unable to explore fully a wide region in the factor space, there provide a useful information for relatively few runs for factor. Because two-level factorial can indicate major trends which are used to provide directions for further experimentation.

3.3.1(b) General full factorial designs:

In a general full 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, factor C may have five levels. The experimental runs include all combination of these factor levels. General full factorial designs may be used with small screening experiments or 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.

Two 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 designs for up to 15 factors.

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

3.3.3 Plackett-Burman designs:

Plackett-Burman designs are a class of resolution iii, two-level fractional factorial designs that are often used to study the main effects. In a resolution iii design, 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 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 performing the experiment, 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 factorial designs, Plackett-Burman designs, and full factorials for designs with more than two levels. While choosing a design there is 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:

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 **Number of factors**, choose a number from 2 to 15.

4 Click **Designs.**

5 Click in **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 back to the main dialog box.

7 Click **options** or **factors** and use any of the 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: Shows the number of factors that are chosen for the design. Thos 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.

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

Will be placed in 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.

Dialog Box Items

Factor: Shows the number of factors is chosen for 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: 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 Factor:

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 the factor row to assign values and enter any numeric or text values. 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.

Create Desgin Options:

Stat>DOE>Factorial>Create Factorial Design>choose General full factorial design>**Options** Allow to randomize the design, and store the desgin (and desgin object) in the worksheet. **Dialog Box Items**

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

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.

3.6 Desgin Of Experiments In Coded Form

The coded form in design of experiments was done by giving the values of input parameters to the **MINITAB** software. The coded form is given as"+1" for the maximum input and"-1" for minimum output, the are shown in **Table 3.1**

Table 3.1; Desgin Of Experiments In Coded Form

speed	feed	drill bit diia
-1	1	-1
1	-1	0
1	1	-1
-1	0	1
1	0	1
0	0	1
0	-1	0
0	0	0
0	1	1
1	-1	-1
1	0	0
1	-1	1
-1	1	1
-1	-1	0
-1	-1	-1
0	-1	-1
0	-1	1
-1	1	0
0	1	0
-1	0	0
-1	-1	1
0	0	-1
0	1	-1
1	0	-1
1	1	0
1	1	1
-1	0	-1

3.6 Desgin Of Experiments In Uncoded Units

The uncoded units are obtained by decoding the values in coded from and the values are shown in Table 3.2

Table 3.2 DOE In Minitab

SPEED (rpm)	FEED (mm/rev)	DIAMETER (mm)	TEMP (°c)	MRR (mm³/sec)	thrust (kgm)	torque (kgf)	eccentricity (cm)	WEIGHT (kg)
180	0.13	8	27.4	24.32	15	12	1.7	0.72
180	0.13	10	25.2	30.4	26	14	3	0.87
180	0.13	12	27.2	31.92	21	14	3.1	1.042
180	0.21	8	29.2	29.46	19	16	1.7	0.708
180	0.21	10	25	51.56	35	13	3	0.851
180	0.21	12	28.2	51.56	36	20	3.1	1.01
180	0.33	8	29.8	54.02	21	20	1.9	0.694
180	0.33	10	27.6	69.45	32	17	3	0.833
180	0.33	12	30.1	57.88	46	29	3.1	0.985
280	0.13	8	28.3	28.37	15	15	1.8	0.682
280	0.13	10	26.8	47.29	23	11	3	0.813
280	0.13	12	28.4	64.92	24	10	3	0.95
280	0.21	8	31.4	45.83	17	17	1.8	0.67
280	0.21	10	28.2	68.78	28	18	3	0.795
280	0.21	12	33.8	102.05	30	11	3	0.933
280	0.33	8	29.6	60.03	21	20	2	0.66
280	0.33	10	29.6	72.03	33	20	2.8	0.783
280	0.33	12	33	92.09	35	20	3.1	0.901
450	0.13	8	29.8	41.8	17	15	1.7	0.649
450	0.13	10	30	72.2	22	11	1.8	0.764
450	0.13	12	37	64.6	35	23	3.1	0.916
450	0.21	8	29.8	61.39	20	10	0.5	0.639
450	0.21	10	31.2	98.23	26	15	1.8	0.748
450	0.21	12	38	92.09	26	18	3.1	0.901
450	0.33	8	34.9	67.52	35	13	0.5	0.632
450	0.33	10	33.4	115.7	30	18	1.6	0.736
450	0.33	12	44	106.11	35	21	3.1	0.89

CHAPTER 4

EXPERIMENTAL SETUP AND MACHINING

The experimental setup of the project work was done by taking work piece as alloy materials(brass,bronze) and using cutting fluids as BPCL OIL as shown in fig 4.1.

The project was done in 3 stages.

- Design of experiments was done using full factorial method .
- Observation and calculation of cutting forces ,temperature ,material removal rate by machining the work pieces on Radial drilling machine in wet condition.
- Analysis of results was done using MINITAB 18.

Fig 4.1: experimental set up of drilling

4.1 Selection of Process Variables

- A total of three process variables and 3 levels are selected for the experimental procedure.
- The deciding process variables are
    - Speed
    - Feed
    - Diameter of drill bit

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
- Diameter of drill bit is the diameter of the hole to the drilled on the work piece

Selection of levels:

- Since it is a three level design by observing the parameters taken in various projects the levels of factors are designed as follows as shown in table 4.1.

FACTORS	LEVEL1	LEVEL2	LEVEL3
SPEED(RPM)	180	280	450
FEED(MM/REV)	0.13	0.21	0.33
DIAMETER OF DRILL BIT(MM)	8	10	12

Table 4.1: Selection of process variables

4.2. Design of Experiments

- Design of Experiments was done using full factorial method.

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

4.3 Machining of the Work piece

The machining of the work piece on RADIAL DRILLING MACHINE is done by using the following procedure

- Selection of material

- Clamping of the Work piece

- Clamping of the work piece

- Drilling of the work piece

4.3.1 Selection of material:

By studying various projects material selected for machining operation because of its high tensile strength.The composition of

Brass:

copper-55% to 95%

zinc-5% to 40%

Bronze:

copper- 88%

tin- 12%

4.3.2 Clamping of the work piece:

The work piece is clamped to the machine by using plain vice.

Mechanism involved in work piece clamping / declamping to the vice

The work piece is clamped to the plain vice by the means of a threaded screw which has a lever at its end to tighten or let loose the work piece between the clamps of the vice as shown in fig 4.3.

Fig 4.2: clamping of work piece

4.3.3 Clamping of cutting tool:

The clamping of a cutting tool is done by the tool holding devices. Here the cutting tool is of 3 diameters namely 12 mm,10 mm,8 mm. The cutting tool is fitted to the drilling machine either directly fitting it to the spindle tool or by fitting it in drill sleeve and socket in fig 4.3.

4.3.4 Drilling of the work piece:

The work piece after fixing in the plain vice is subjected to drilling or machining operation. The tool is also fitted in the sleeve and the machine is turned on and the process variables are set like speed,feed and diameter of the tool. Then the holes are drilled on the work piece using different inputs using the process variables. This process of drilling is done in wet condition (use of cutting fluids BCPL OIL) as shown in fig4.4.

Fig 4.3 : drilling of work piece

4.4 Measurement of cutting forces

During the drilling operation of the machine the cutting forces can be known namely torque and thrust. The cutting force can be calculated by the means of the dynamometer as shown in fig 4.5. The dynamometer can be connected to the drilling machine and simultaneously the values are noted while the holes are being drilled.

Fig 4.4 electrical dynamometer

4.5 Temperature Indicator

The temperature reading at the point of removal of the process of drilling can be known by means of a temperature indicator. The temperature indicator used in this process is laser gun which is shown in fig4.6. The laser is concentrated at the tip of the tool and work piece and the temperature can be known.

Fig 4.5 : laser gun temperature indicator

4.6 Material Removal Rate

The material removal rate of the work piece is calculated by the formula given by

MRR=(Change in weight)/ (density * time) mm3/sec

CHAPTER5

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 a vast array of other fields for data analysis. Despite its widespread use, some practitioners fail to recognize the need to check the validity of several key assumptions before applying an ANOVA to their data. It is the hope that this article may provide certain useful guidelines for performing basic 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 useful 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 largely 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 in the analysis of 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 as well as 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, along with 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 to 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

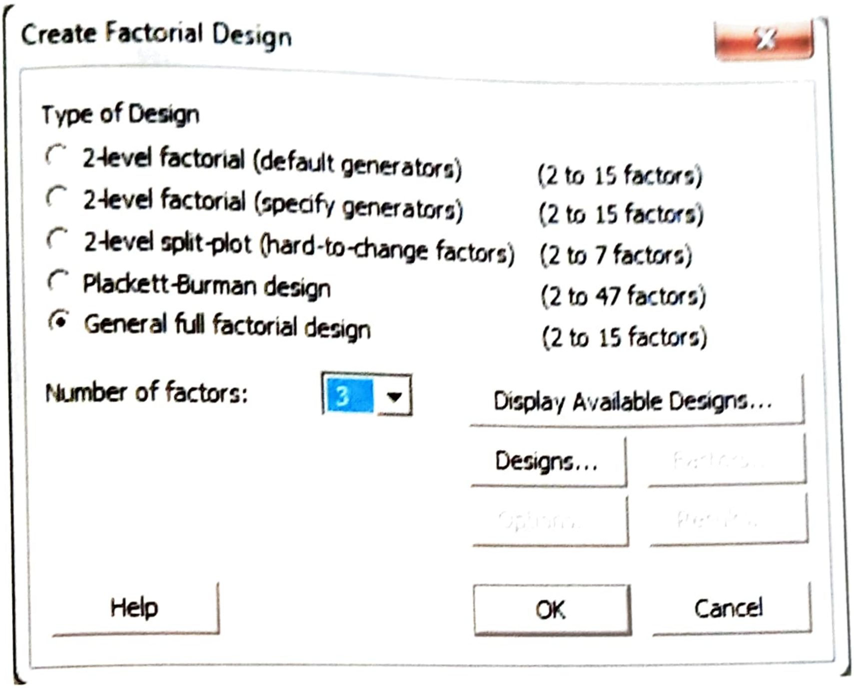
The purpose of this handout is to assist the burgeoning statistician in analyzing and interpreting the meaning of a statistically significant interaction in the context of factorial analysis of variance (ANOVA). We shall assume that the reader is already familiar with the results obtained when factorial 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 of the 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
2. statistical comparison of cell means

Steps involved in Factorial method

Step 1: Create design using General factorial method

Stat – DOE – Factorial – Create Factorial design



Type of Design

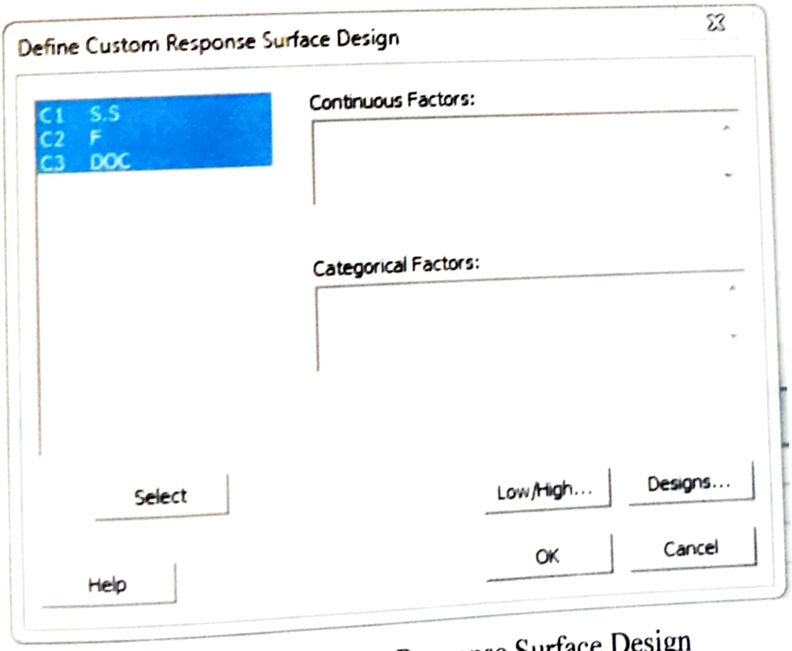
○ 2-level factorial (default generators) (2 to 15 factors)
○ 2-level factorial (specify generators) (2 to 15 factors)
○ 2-level split-plot (hard-to-change factors) (2 to 7 factors)
○ Plackett-Burman design (2 to 47 factors)
● General full factorial design (2 to 15 factors)

Number of factors: 3

Fig 5.1: Factorial design model

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

Stat – DOE – Factorial – Define Response Surface Design



C1 S.S
C2 F
C3 DOC

Fig 5.2: Custom Response Surface Design

Step 3: Analyse the Custom Response design

Stat – DOE – Response Surface – Analyse Response Design

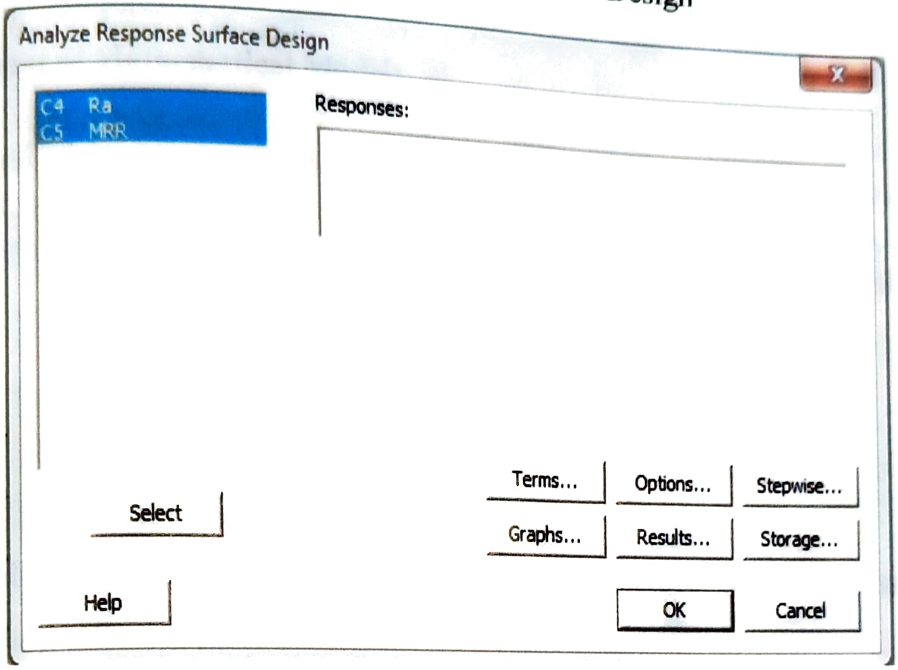


Fig 5.3: Analyse Response Surface Design

CHAPTER-6

RESULTS AND DISCUSSIONS

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.

$$Y = \square + \square 1\ x1 + \square 2\ x2 + \ldots\ldots\_\ \square x\ xx + \square$$

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

$$Y = \beta 0 + \sum^{k}_{i=1} \beta_o x_o + \sum^{k}_{i=1} \beta ii\ \ i2 + \sum \quad \sum_{i<j} \beta ij\ xixj + \text{€}$$

- Y is the corresponding response
- Xi are the cutting parameters
- (1,2,…….k) are code levels of quantitative process variables
- The terms are the second order regression coefficients
- Second term is 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 and these models were tested by applying Analysis Of Variance (ANOVA)) technique F-ratio was calculated and compared, with the standard values for 95% confidence level. If the calculated value is less than the F-table values the model is consider==- 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 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. **Estimate d 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 useful to construct an equation representing the relationship between the response and the factors.

6.3 GraphsObtained

Contour Plots

- Contour and surface plots are useful 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 clearer picture 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 shows that as the lines are diverging towards spindle speed and feed. these two parameters have vital effect on machining process.

A 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.

OBSERVATION TABLE FOR BRASS:

Table 6.1 : experimental values of brass work piece

SPEED	FEED	DIAMETER	TEMP	MRR	thrust	torque	eccentricity	WEIGHT
(rpm)	(mm/rev)	(mm)	(°c)	(mm³/sec)	(kgm)	(kgf)	(cm)	(kg)
180	0.13	8	27.4	24.32	15	12	1.7	0.72
180	0.13	10	25.2	30.4	26	14	3	0.87
180	0.13	12	27.2	31.92	21	14	3.1	1.042
180	0.21	8	29.2	29.46	19	16	1.7	0.708
180	0.21	10	25	51.56	35	13	3	0.851
180	0.21	12	28.2	51.56	36	20	3.1	1.01
180	0.33	8	29.8	54.02	21	20	1.9	0.694
180	0.33	10	27.6	69.45	32	17	3	0.833
180	0.33	12	30.1	57.88	46	29	3.1	0.985
280	0.13	8	28.3	28.37	15	15	1.8	0.682
280	0.13	10	26.8	47.29	23	11	3	0.813
280	0.13	12	28.4	64.92	24	10	3	0.95
280	0.21	8	31.4	45.83	17	17	1.8	0.67
280	0.21	10	28.2	68.78	28	18	3	0.795
280	0.21	12	33.8	102.05	30	11	3	0.933
280	0.33	8	29.6	60.03	21	20	2	0.66
280	0.33	10	29.6	72.03	33	20	2.8	0.783
280	0.33	12	33	92.09	35	20	3.1	0.901
450	0.13	8	29.8	41.8	17	15	1.7	0.649
450	0.13	10	30	72.2	22	11	1.8	0.764
450	0.13	12	37	64.6	35	23	3.1	0.916
450	0.21	8	29.8	61.39	20	10	0.5	0.639
450	0.21	10	31.2	98.23	26	15	1.8	0.748
450	0.21	12	38	92.09	26	18	3.1	0.901
450	0.33	8	34.9	67.52	35	13	0.5	0.632
450	0.33	10	33.4	115.7	30	18	1.6	0.736
450	0.33	12	44	106.11	35	21	3.1	0.89

6.4 BRASS WET CONDTION RESULTS

6.4.1 Response Surface Regression: torque versus SPEED,FEED,DILL BIT DIAMETER

Model Summary

S	R-sq	R-sq(adj)	PRESS	R-sq(pred)
3.50515	60.29%	39.27%	543.335	0.00%

Coded Coefficients

Term	Coef	SE Coef	95% CI	T-Value	P-Value
Constant	13.98	1.90	(9.98, 17.98)	7.37	0.000
SPEED	-0.740	0.829	(-2.489, 1.008)	-0.89	0.384
FEED	2.777	0.831	(1.025, 4.529)	3.34	0.004
DRILL BIT DIAMETER	1.726	0.833	(-0.033, 3.484)	2.07	0.054
SPEED*SPEED	1.06	1.55	(-2.21, 4.34)	0.69	0.502
FEED*FEED	0.95	1.50	(-2.22, 4.11)	0.63	0.535
DRILL BIT DIAMETER*DRILL BIT DIAMETER	1.67	1.43	(-1.35, 4.69)	1.16	0.260
SPEED*FEED	-1.938	0.994	(-4.035, 0.160)	-1.95	0.068
SPEED*DRILL BIT DIAMETER	1.16	1.00	(-0.95, 3.27)	1.16	0.261
FEED*DRILL BIT DIAMETER	1.04	1.01	(-1.08, 3.16)	1.04	0.315

egression Equation in Uncoded Units

Torque = 68.3 - 0.0523 SPEED - 22.8 FEED - 10.03 DRILL BIT DIAMETER + 0.000058 SPEED*SPEED
+ 95 FEED*FEED + 0.417 DRILL BIT DIAMETER*DRILL BIT DIAMETER - 0.1435 SPEED*FEED
+ 0.00431 SPEED*DRILL BIT DIAMETER + 5.21 FEED*DRILL BIT DIAMETER

6.4.2 Response Surface Regression: thrust versus SPEED, FEED, DRILL BIT DIAMETER

Model Summary

S	R-sq	R-sq(adj)	PRESS	R-sq(pred)
4.70733	76.50%	64.05%	1339.03	16.45%

Coded Coefficients

Term	Coef	SE Coef	95% CI	T-Value	P-Value	VIF
Constant	26.98	2.55	(21.61, 32.35)	10.60	0.000	
SPEED	-0.31	1.11	(-2.66, 2.03)	-0.28	0.781	1.03
FEED	4.95	1.12	(2.60, 7.31)	4.44	0.000	1.02

DRILL BIT DIAMETER	5.86	1.12	(3.50, 8.23)	5.24	0.000	1.02
SPEED*SPEED	2.76	2.08	(-1.64, 7.15)	1.32	0.203	1.02
FEED*FEED	-0.35	2.02	(-4.60, 3.90)	-0.17	0.865	1.01
DRILL BIT DIAMETER*DRILL BIT DIAMETER	-2.33	1.92	(-6.39, 1.72)	-1.21	0.241	1.00
SPEED*FEED	-0.56	1.34	(-3.37, 2.26)	-0.42	0.683	1.02
SPEED*DRILL BIT DIAMETER	-1.96	1.34	(-4.79, 0.88)	-1.46	0.164	1.01
FEED*DRILL BIT DIAMETER	0.49	1.35	(-2.35, 3.34)	0.37	0.719	1.01

Regression Equation in Uncoded Units

thrust = -78.3 - 0.0157 SPEED + 54 FEED + 16.31 DRILL BIT DIAMETER + 0.000151 SPEED*SPEED
- 35 FEED*FEED - 0.583 DRILL BIT DIAMETER*DRILL BIT DIAMETER - 0.0411 SPEED*FEED
- 0.00725 SPEED*DRILL BIT DIAMETER + 2.47 FEED*DRILL BIT DIAMETER

6.4.3 Response Surface Regression: DRILL BIT temperature versus SPEED, FEED, DRILL BIT DIAMETER

Model Summary

S	R-sq	R-sq(adj)	PRESS	R-sq(pred)
1.25552	94.08%	90.94%	74.6788	83.50%

Coded Coefficients

Term	Coef	SE Coef	95% CI	T-Value	P-Value
Constant	28.928	0.679	(27.496, 30.360)	42.61	0.000
SPEED	3.293	0.297	(2.667, 3.920)	11.09	0.000
FEED	1.835	0.298	(1.208, 2.463)	6.17	0.000
DRILL BIT DIAMETER	1.856	0.299	(1.227, 2.486)	6.22	0.000
SPEED*SPEED	0.266	0.556	(-0.907, 1.438)	0.48	0.639
FEED*FEED	-0.225	0.537	(-1.358, 0.909)	-0.42	0.681
DRILL BIT DIAMETER*DRILL BIT DIAMETER	3.106	0.513	(2.024, 4.187)	6.06	0.000
SPEED*FEED	0.730	0.356	(-0.021, 1.482)	2.05	0.056
SPEED*DRILL BIT DIAMETER	2.153	0.358	(1.397, 2.910)	6.01	0.000
FEED*DRILL BIT DIAMETER	0.473	0.360	(-0.287, 1.232)	1.31	0.207

Regression Equation in Uncoded Units

DRILL BIT temperature = 120.1 - 0.0770 SPEED - 12.0 FEED - 17.66 DRILL BIT DIAMETER
+ 0.000015 SPEED*SPEED - 22.5 FEED*FEED
+ 0.776 DRILL BIT DIAMETER*DRILL BIT DIAMETER + 0.0541 SPEED*FEED
+ 0.00798 SPEED*DRILL BIT DIAMETER + 2.36 FEED*DRILL BIT DIAMETER

6.4.4 Response Surface Regression: MATERIAL REMOVAL versus SPEED, FEED, DRILL BIT DIAMETER

Model Summary

S	R-sq	R-sq(adj)	PRESS	R-sq(pred)
10.2805	89.16%	83.43%	4529.20	72.69%

Coded Coefficients

Term	Coef	SE Coef	95% CI	T-Value	P-Value
Constant	83.53	5.56	(71.80, 95.26)	15.03	0.000
SPEED	17.82	2.43	(12.69, 22.95)	7.33	0.000
FEED	16.18	2.44	(11.04, 21.32)	6.64	0.000
DRILL BIT DIAMETER	14.27	2.44	(9.11, 19.42)	5.84	0.000
SPEED*SPEED	-7.46	4.55	(-17.06, 2.14)	-1.64	0.119
FEED*FEED	-9.20	4.40	(-18.49, 0.08)	-2.09	0.052
DRILL BIT DIAMETER*DRILL BIT DIAMETER	-9.74	4.20	(-18.59, -0.89)	-2.32	0.033
SPEED*FEED	1.40	2.92	(-4.75, 7.55)	0.48	0.638
SPEED*DRILL BIT DIAMETER	3.90	2.94	(-2.30, 10.09)	1.33	0.202
FEED*DRILL BIT DIAMETER	0.20	2.95	(-6.02, 6.42)	0.07	0.946

Regression Equation in Uncoded Units

MATERIAL REMOVAL RATE = -344 + 0.222 SPEED + 542 FEED + 51.1 DRILL BIT DIAMETER
- 0.000409 SPEED*SPEED - 920 FEED*FEED
- 2.44 DRILL BIT DIAMETER*DRILL BIT DIAMETER + 0.104 SPEED*FEED
+ 0.0144 SPEED*DRILL BIT DIAMETER + 1.0 FEED*DRILL BIT DIAMETER

6.4.5 Response Surface Regression: ECCENTRCITY OF hole versus SPEED, FEED, DRILL BIT DIAMETER

Model Summary

S	R-sq	R-sq(adj)	PRESS	R-sq(pred)
0.323148	89.73%	84.29%	5.27791	69.46%

Coded Coefficients

Term	Coef	SE Coef	95% CI	T-Value	P-Value
Constant	2.647	0.175	(2.278, 3.015)	15.15	0.000
SPEED	-0.3645	0.0764	(-0.5257, -0.2033)	-4.77	0.000
FEED	-0.0727	0.0766	(-0.2342, 0.0889)	-0.95	0.356
DRILL BIT DIAMETER	0.8082	0.0768	(0.6461, 0.9703)	10.52	0.000
SPEED*SPEED	-0.270	0.143	(-0.572, 0.031)	-1.89	0.076
FEED*FEED	0.088	0.138	(-0.204, 0.380)	0.64	0.533

DRILL BIT DIAMETER*DRILL BIT DIAMETER	-0.261	0.132	(-0.539, 0.017)	-1.98	0.064
SPEED*FEED	-0.1337	0.0916	(-0.3270, 0.0597)	-1.46	0.163
SPEED*DRILL BIT DIAMETER	0.2373	0.0923	(0.0426, 0.4319)	2.57	0.020
FEED*DRILL BIT DIAMETER	0.0658	0.0927	(-0.1297, 0.2613)	0.71	0.487

Regression Equation in Uncoded Units

ECCENTRCITY OF hole = -5.10 + 0.00014 SPEED - 4.94 FEED + 1.357 DRILL BIT DIAMETER
- 0.000015 SPEED*SPEED + 8.8 FEED*FEED
- 0.0653 DRILL BIT DIAMETER*DRILL BIT DIAMETER - 0.00990 SPEED*FEED
+ 0.000879 SPEED*DRILL BIT DIAMETER + 0.329 FEED*DRILL BIT DIAMETER

Response Optimization: ECCENTRCITY OF hole, Drill bit temperature, thrust, torque,material removal rate

Parameters

Response	Goal	Lower	Target	Upper	Weight	Importance
ECCENTRCITY OF hole	Minimum		0.5	3.1	1	1
MATERIAL REMOVAL RATE	Maximum	24.32	115.7		1	1
DRILL BIT temperature	Minimum		25.0	44.0	1	1
Thrust	Minimum		15.0	46.0	1	1
Torque	Minimum		10.0	29.0	1	1

Solution

Solution	SPEED	FEED	DRILL BIT DIAMETER	ECCENTRCITY OF hole Fit	MATERIAL REMOVAL RATE Fit	DRILL BIT temperature Fit	thrust Fit	torque Fit
1	450	0.257273	8	0.637329	70.0345	32.1365	24.2158	13.0928

Solution	Composite Desirability
1	0.704925

Multiple Response Prediction

Variable	Setting
SPEED	450
FEED	0.257273
DRILL BIT DIAMETER	8

```
Response                     Fit    SE Fit   95% CI              95% PI
ECCENTRCITY OF hole          0.637  0.199    (0.217, 1.058)      (-0.164, 1.438)
MATERIAL REMOVAL RATE        70.03  6.34     (56.66, 83.41)      (44.55, 95.52)
DRILL BIT temperature        32.137 0.774    (30.503, 33.770)    (29.025, 35.248)
Thrust                       24.22  2.90     (18.09, 30.34)      (12.55, 35.88)
Torque                       13.09  2.16     (8.53, 17.65)       (4.40, 21.78)
```

Response Optimization

Many designed experiments involve determining optimal conditions that will produce the "best" value for the response.

Depending on the design type (factorial, response surface, or mixture), the operating conditions that can control may include one or more of the following design variables: factors, components, process variables, or amount variables.

In product development, there is need to determine the input variable settings that result in a product with desirable properties (responses). Since each property is important in determining the quality of the product, there is need to consider these properties simultaneously. Optimal settings of the design variables for one response may be far from optimal or even physically impossible for another response. Response optimization is a method that allows for compromise among the various responses.

- Response Optimizer – Provides with an optimal solution for the input variable combinations and an optimization plot. The optimization plot is interactive; we can adjust input variable settings on the plot to search for more desirable solutions.
- Overlaid Contour Plot – Shows how each response considered relates to two continuous design variables (factorial and response surface designs) or three continuous design variables (mixture designs), while holding the other variables in the model at specified levels. The contour plot allows visualizing an area of compromise among the various responses.

Response Optimizer

Stat > DOE > Response Surface > Response Optimizer

Use response optimization to help identify the combination of input variable settings that jointly optimize a single response or a set of responses. Joint optimization must satisfy the requirements for all the responses in the set, which is measured by the composite desirability. Minitab calculates an optimal solution and draws a plot. The optimal solution serves as the starting point for the plot. This optimization plot allows to interactively changing the input variable settings to perform sensitivity analyses and possibly improve the initial solution. The optimization plot as shown signifies the affect of each factor (columns) on the responses or composite desirability (rows). The vertical red lines on the graph represent the current factor settings. The numbers displayed at the top of a column show the current factor level settings (in red). The horizontal blue lines and numbers represent the responses for the current factor level. Minitab calculates maximum material removal rate.

Contour and surface plots for brass:

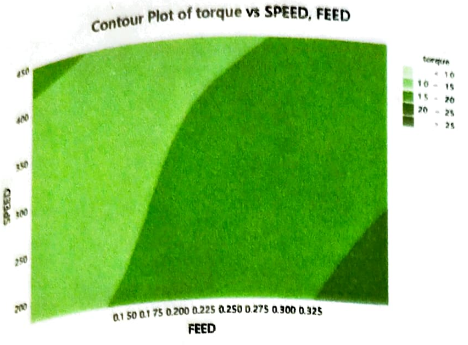


Fig 6.1: contour plot of torque vs speed, feed

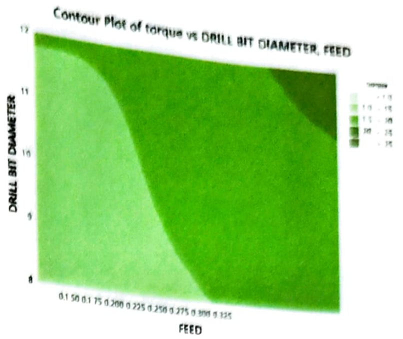


fig 6.2: contour plot of torque vs drill bit dia, feed

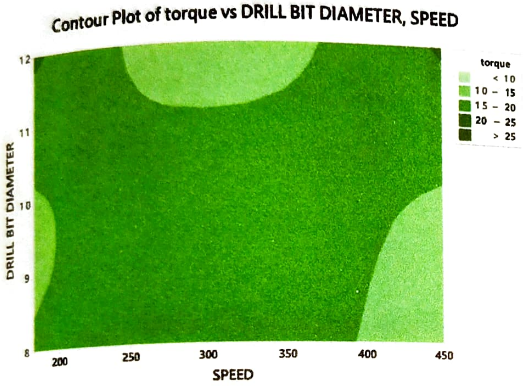


fig 6.3: contour plot of torque vs drill bit dia , speed

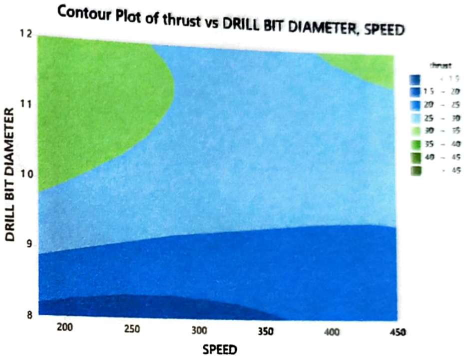


fig: 6.4 contour plot of thrust vs drill bit dia, speed

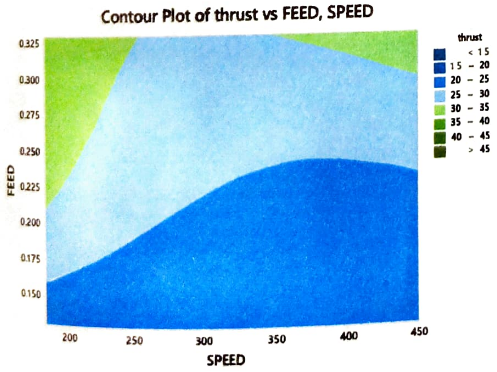


Fig 6.5: contour plot of thrust vs feed, speed

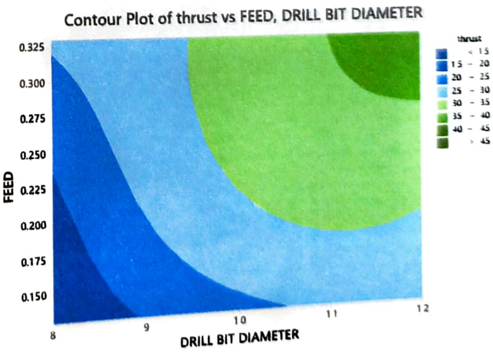


fig 6.6: contour plot of thrust vs feed, drill bit diameter

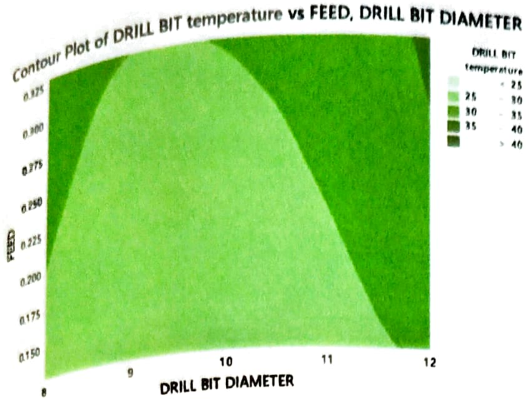


Fig : 6.7 contour plot of drill bit temperature vs feed, drill bit dia

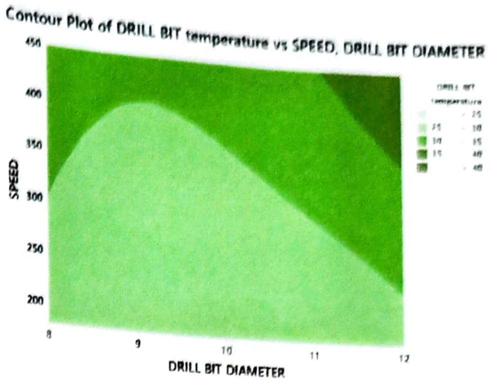


fig :6.8 contour plot of drill bit temp vs speed, drill bit dia

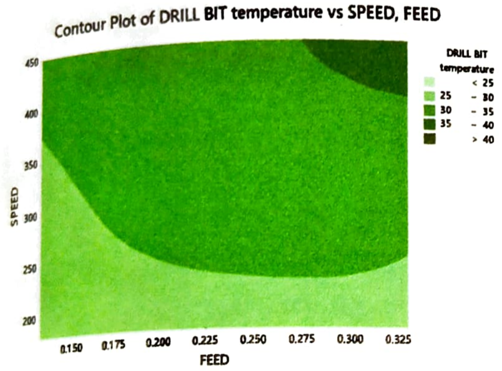


Fig: 6.9 contour plot of drill bit temperature vs speed, feed

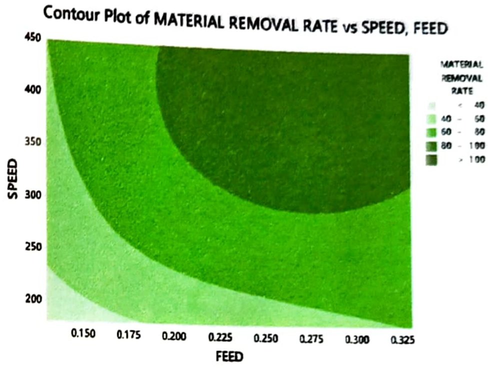


fig 6.10:contour plot of material removal rate vs speed, feed

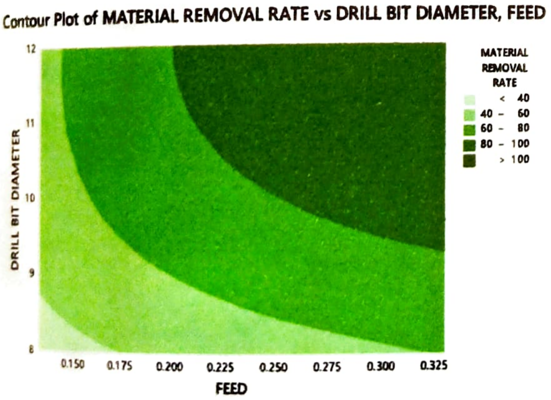


Fig 6.11: contour plot of MRR vs drill bit dia, feed

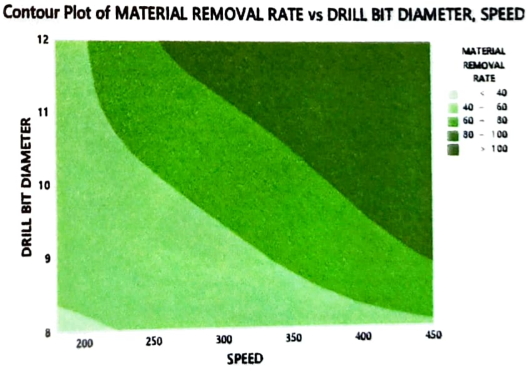


fig 6.12: countour plot of MRR vs drill bit dia ,speed

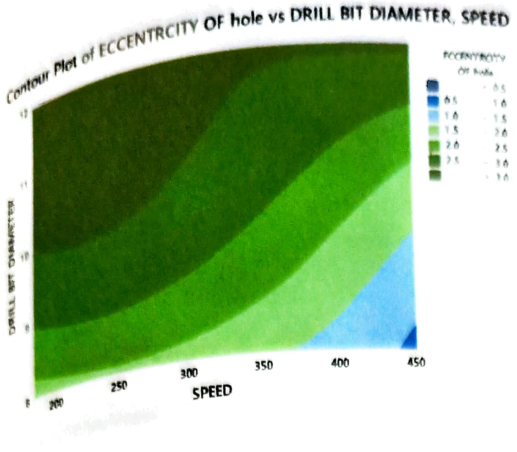


Fig 6.13 : contour plot of eccentricity of hole vs drill bit dia vs speed

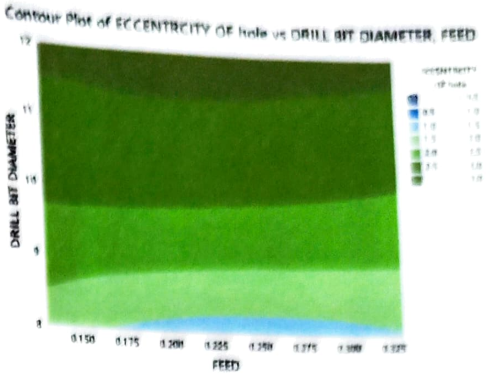


fig 6.14: contour plot of eccentricity of hole vs drill bit dia,feed

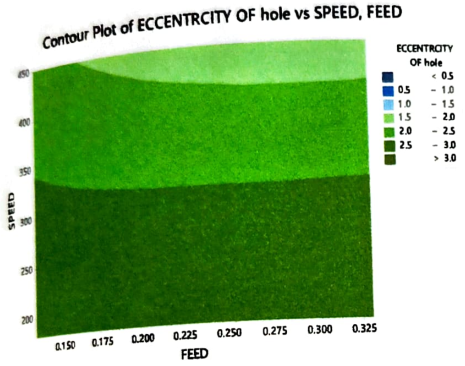


Fig 6.15 : contour plot of eccentricity of hole vs speed,feed

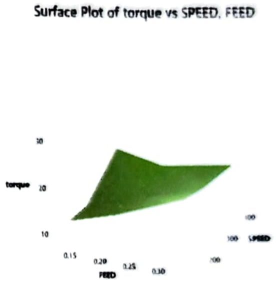


Fig 6.16: surface plot of torque vs speed,feed

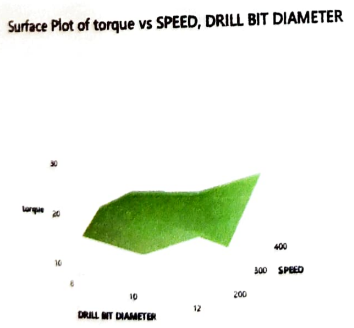


Fig 6.17: surface plot of torque vs speed,drill bit dia

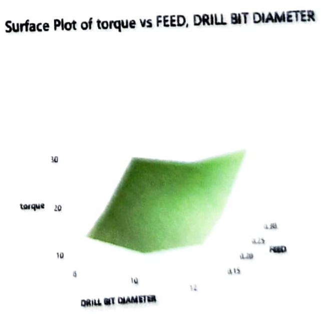


Fig 6.18: surface plot of torque vs feed, drill bit dia

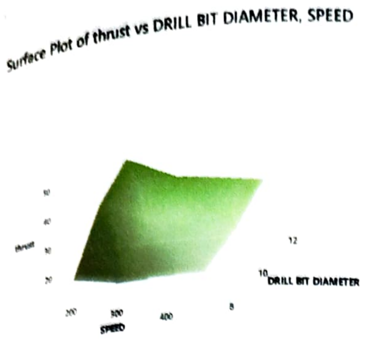


Fig 6.19: surface plot of thrust vs speed,drill bit dia

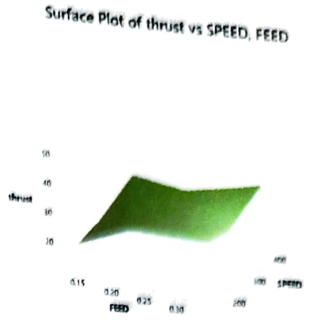


Fig 6.20: surface plot of thrust vs speed,feed

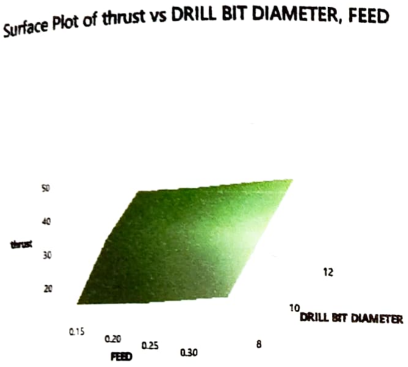


Fig 6.21: surface plot of thrust vs feed, drill bit dia

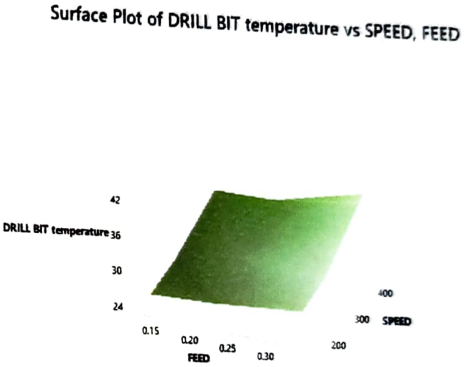


Fig 6.22: surface plot of drill bit temp vs speed, feed

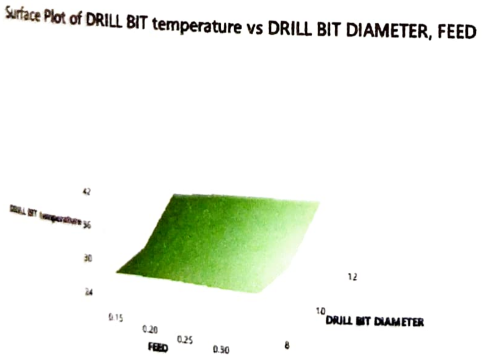


Fig 6.23: surface plot of drill bit temp vs drill bit dia, fees

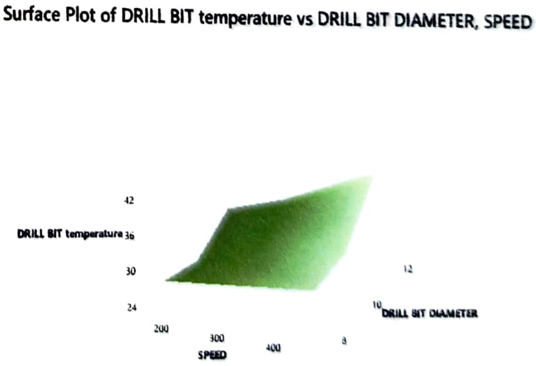


Fig 6.24: surface plot of drill bit temp vs drill bit dia, speed

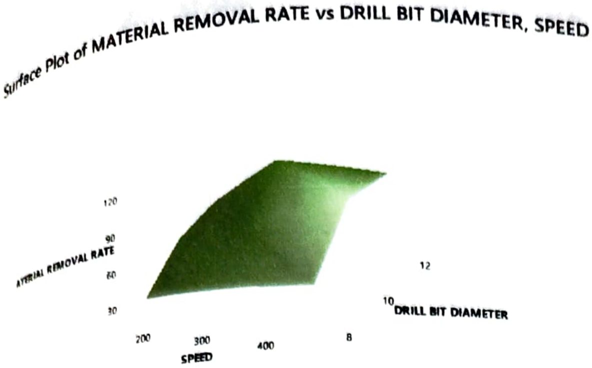


Fig 6.25: surface plot of mrr vs drill bit dia ,speed

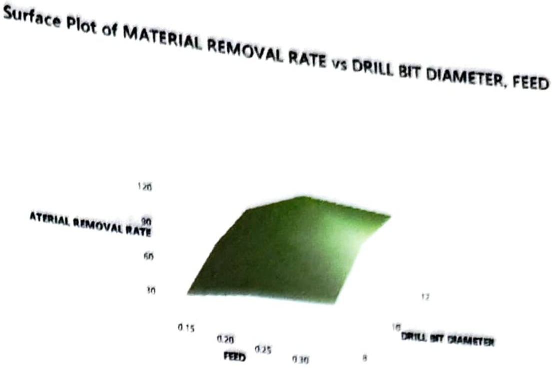


Fig 6.26: surface plot of mrr vs drill bit dia ,feed

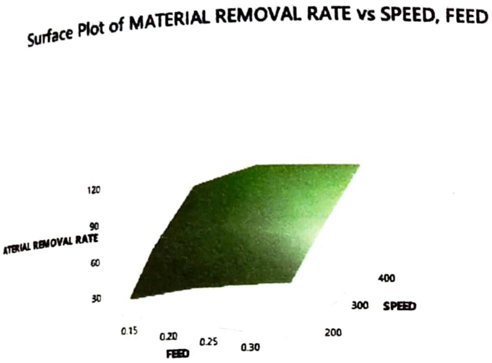


Fig 6.27: surface plot of mrr vs speed, feed

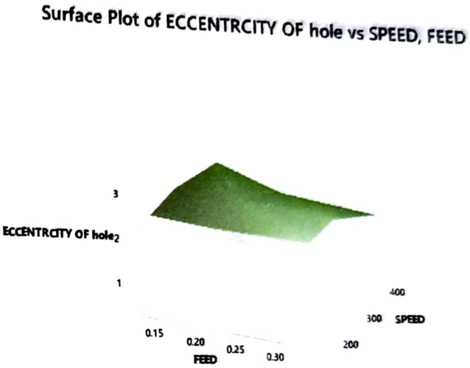


Fig 6.28: surface plot of eccentricity of hole vs speed,feed

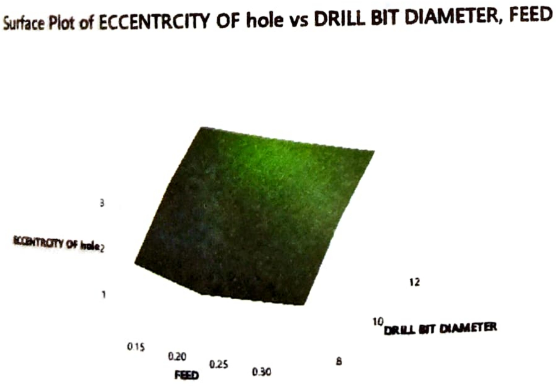


Fig 6.29: surface plot of eccentricity of hole vs bit dia ,feed

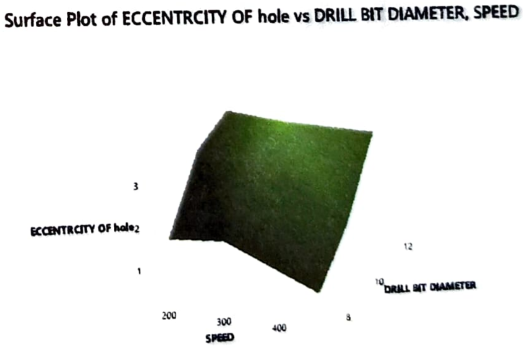


Fig 6.30: surface plot of eccentricity of hole vs drill bit dia,speed

6.5 BRONZE WET CONDITION RESULTS:

Table 6.2 : experimental values of bronze work piece

SPEED (rpm)	FEED (mm/rev)	diameter (mm)	temp (°c)	mrr (mm^3/sec)	eccentricity (cm)	WEIGHT (kg)	TORQUE (kgf)	THRUST (kgm)
180	0.13	8	25	16.23	1.5	0.676	13	14
180	0.13	10	28	31.02	2.9	0.822	47	20
180	0.13	12	30	28.06	3	1.011	21	19
180	0.21	8	27.6	28.63	1.7	0.663	12	20
180	0.21	10	26	50.116	2.9	0.802	17	19
180	0.21	12	33	62.04	3	0.983	13	22
180	0.33	8	26.6	44.75	1.6	0.65	12	14
180	0.33	10	26.8	76.23	2.8	0.783	15	24
180	0.33	12	32	71.25	2.9	0.991	16	32
280	0.13	8	30.1	48.75	1.5	0.638	5	11
280	0.13	10	28.2	45.96	2.7	0.761	5	16
280	0.13	12	31.8	41.36	3	0.948	8	20
280	0.21	8	32.4	44.54	1.6	0.625	10	13
280	0.21	10	29.2	66.81	2.8	0.748	13	22
280	0.21	12	34	85.37	2.9	0.925	8	22
280	0.33	8	32.9	75.85	1.5	0.613	8	17
280	0.33	10	29.6	81.68	2.9	0.729	12	26
280	0.33	12	34	110.85	2.9	0.905	8	27
450	0.13	8	36.4	44.32	1.6	0.601	16	19
450	0.13	10	34	66.48	1.7	0.712	13	18
450	0.13	12	34	59.96	2.9	0.881	7	18
450	0.21	8	32.2	65.63	0.6	0.589	11	14
450	0.21	10	35	71.6	1.6	0.698	12	22
450	0.21	12	31	119.3	3	0.861	14	23
450	0.33	8	36	93.75	0.6	0.579	15	18
450	0.33	10	35	112.51	1.6	0.686	16	28
450	0.33	12	33	159.39	2.9	0.843	18	26

6.5.1 Response Surface Regression: TORQUE versus SPEED, FEED, DRILL BIT DIAMETER

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
6.71197	51.24%	25.43%	0.00%

Coded Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	8.96	3.63	2.47	0.024	
SPEED	-2.20	1.59	-1.39	0.184	1.03
FEED	-0.52	1.59	-0.32	0.750	1.02
DRILL BIT DIAMETER	0.53	1.60	0.33	0.743	1.02
SPEED*SPEED	8.66	2.97	2.92	0.010	1.02
FEED*FEED	2.20	2.87	0.77	0.455	1.01
DRILL BIT DIAMETER*DRILL BIT DIAMETER	-4.72	2.74	-1.72	0.103	1.00
SPEED*FEED	3.67	1.90	1.93	0.071	1.02
SPEED*DRILL BIT DIAMETER	-1.25	1.92	-0.65	0.524	1.01
FEED*DRILL BIT DIAMETER	0.44	1.92	0.23	0.822	1.01

Regression Equation in Uncoded Units

TORQUE = -36.5 - 0.332 SPEED - 214 FEED + 24.8 DRILL BIT DIAMETER + 0.000475 SPEED*SPEED
+ 220 FEED*FEED - 1.181 DRILL BIT DIAMETER*DRILL BIT DIAMETER + 0.272 SPEED*FEED
- 0.00462 SPEED*DRILL BIT DIAMETER + 2.19 FEED*DRILL BIT DIAMETER

6.5.2 Response Surface Regression: THRUST versus SPEED, FEED, DRILL BIT DIAMETER

MODEL SUMMARY

S	R-sq	R-sq(adj)	R-sq(pred)
2.47934	83.86%	75.31%	56.33%

Coded Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	20.94	1.34	15.62	0.000	
SPEED	0.109	0.586	0.19	0.855	1.03
FEED	3.163	0.588	5.38	0.000	1.02
DRILL BIT DIAMETER	3.890	0.589	6.60	0.000	1.02
SPEED*SPEED	1.28	1.10	1.17	0.260	1.02
FEED*FEED	0.09	1.06	0.09	0.932	1.01
DRILL BIT DIAMETER*DRILL BIT DIAMETER	-2.28	1.01	-2.25	0.038	1.00
SPEED*FEED	-0.039	0.703	-0.05	0.957	1.02
SPEED*DRILL BIT DIAMETER	-0.839	0.708	-1.19	0.252	1.01

FEED*DRILL BIT DIAMETER	1.941	0.711	2.73	0.014	1.01

Regression Equation in Uncoded Units

THRUST = -43.2 - 0.0117 SPEED - 68.8 FEED + 12.08 DRILL BIT DIAMETER + 0.000070 SPEED*SPEED
+ 9 FEED*FEED - 0.569 DRILL BIT DIAMETER*DRILL BIT DIAMETER - 0.0029 SPEED*FEED
- 0.00311 SPEED*DRILL BIT DIAMETER + 9.70 FEED*DRILL BIT DIAMETER

6.5.3 Response Surface Regression: DRILL BIT TEMPERATURE versus SPEED, FEED, DRILL BIT DIAMETER

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
1.74580	80.85%	70.71%	55.58%

Coded Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	31.105	0.944	32.95	0.000	
SPEED	2.853	0.413	6.91	0.000	1.03
FEED	0.449	0.414	1.09	0.293	1.02
DRILL BIT DIAMETER	0.592	0.415	1.43	0.172	1.02
SPEED*SPEED	-0.964	0.773	-1.25	0.229	1.02
FEED*FEED	0.053	0.747	0.07	0.944	1.01
DRILL BIT DIAMETER*DRILL BIT DIAMETER	1.578	0.713	2.21	0.041	1.00
SPEED*FEED	-0.203	0.495	-0.41	0.688	1.02
SPEED*DRILL BIT DIAMETER	-1.823	0.498	-3.66	0.002	1.01
FEED*DRILL BIT DIAMETER	-0.087	0.501	-0.17	0.865	1.01

Regression Equation in Uncoded Units

DRILL BIT TEMPERATURE = 31.6 + 0.1254 SPEED + 11.1 FEED - 5.37 DRILL BIT DIAMETER
- 0.000053 SPEED*SPEED + 5.3 FEED*FEED
+ 0.394 DRILL BIT DIAMETER*DRILL BIT DIAMETER - 0.0150 SPEED*FEED
- 0.00675 SPEED*DRILL BIT DIAMETER - 0.43 FEED*DRILL BIT DIAMETER

6.5.4 Response Surface Regression: MATERIAL REMOVAL versus SPEED, FEED, DRILL BIT DIAMETER

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
10.0889	93.57%	90.16%	83.22%

Coded Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	77.30	5.46	14.17	0.000	
SPEED	21.82	2.39	9.15	0.000	1.03
FEED	25.26	2.39	10.57	0.000	1.02
DRILL BIT DIAMETER	16.32	2.40	6.80	0.000	1.02
SPEED*SPEED	-6.00	4.46	-1.34	0.196	1.02
FEED*FEED	-3.96	4.32	-0.92	0.372	1.01
DRILL BIT DIAMETER*DRILL BIT DIAMETER	-0.27	4.12	-0.06	0.949	1.00
SPEED*FEED	6.79	2.86	2.37	0.030	1.02
SPEED*DRILL BIT DIAMETER	5.64	2.88	1.96	0.067	1.01
FEED*DRILL BIT DIAMETER	8.21	2.89	2.84	0.011	1.01

Regression Equation in Uncoded Units

MATERIAL REMOVAL RATE = 23 + 0.044 SPEED - 134 FEED - 6.5 DRILL BIT DIAMETER
- 0.000329 SPEED*SPEED - 396 FEED*FEED
- 0.07 DRILL BIT DIAMETER*DRILL BIT DIAMETER + 0.503 SPEED*FEED
+ 0.0209 SPEED*DRILL BIT DIAMETER + 41.0 FEED*DRILL BIT DIAMETER

6.5.5 Response Surface Regression: ECCENTRCITY OF HOLE versus SPEED, FEED, DRILL BIT DIAMETER

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.308604	90.06%	84.80%	70.99%

Coded Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	2.516	0.167	15.08	0.000	
SPEED	-0.3277	0.0730	-4.49	0.000	1.03
FEED	-0.0682	0.0731	-0.93	0.364	1.02
DRILL BIT DIAMETER	0.8124	0.0734	11.07	0.000	1.02
SPEED*SPEED	-0.196	0.137	-1.44	0.169	1.02
FEED*FEED	0.030	0.132	0.23	0.823	1.01
DRILL BIT DIAMETER*DRILL BIT DIAMETER	-0.283	0.126	-2.25	0.038	1.00
SPEED*FEED	-0.0824	0.0875	-0.94	0.360	1.02
SPEED*DRILL BIT DIAMETER	0.1668	0.0881	1.89	0.075	1.01
FEED*DRILL BIT DIAMETER	0.0537	0.0885	0.61	0.552	1.01

Regression Equation in Uncoded Units

ECCENTRCITY OF HOLE = -6.50 - 0.00042 SPEED - 2.83 FEED + 1.566 DRILL BIT DIAMETER
- 0.000011 SPEED*SPEED + 3.0 FEED*FEED
- 0.0708 DRILL BIT DIAMETER*DRILL BIT DIAMETER - 0.00610 SPEED*FEED
+ 0.000618 SPEED*DRILL BIT DIAMETER + 0.269 FEED*DRILL BIT DIAMETER

Response Optimization: ECCENTRCITY OF HOLE, MATERIAL REMOVAL RATE ,DRILL BIT TEMPERATURE , THRUST, TORQUE

Parameters

Response	Goal	Lower	Target	Upper	Weight	Importance
ECCENTRCITY OF HOLE	Minimum		0.60	3.0	1	1
MATERIAL REMOVAL RATE	Maximum	16.23	159.39		1	1
DRILL BIT TEMPERATURE	Minimum		25.00	36.4	1	1
THRUST	Minimum		11.00	32.0	1	1
TORQUE	Minimum		5.00	47.0	1	1

Solution

Solution	SPEED	FEED	DRILL BIT DIAMETER	ECCENTRCITY OF HOLE Fit	MATERIAL REMOVAL RATE Fit	DRILL BIT TEMPERATURE Fit	THRUST Fit	TORQUE Fit
1	259.091	0.307778	8	1.54100	61.6578	30.5033	15.6209	4.98787

Solution	Composite Desirability
1	0.600100

Multiple Response Prediction

Variable	Setting
SPEED	259.091
FEED	0.307778
DRILL BIT DIAMETER	8

Response	Fit	SE Fit	95% CI	95% PI
ECCENTRCITY OF HOLE	1.541	0.163	(1.196, 1.886)	(0.804, 2.278)
MATERIAL REMOVAL RATE	61.66	5.34	(50.40, 72.92)	(37.58, 85.74)
DRILL BIT TEMPERATURE	30.503	0.924	(28.554, 32.452)	(26.336, 34.670)
THRUST	15.62	1.31	(12.85, 18.39)	(9.70, 21.54)
TORQUE	4.99	3.55	(-2.51, 12.48)	(-11.03, 21.01)

Contour and surface plots for bronze :

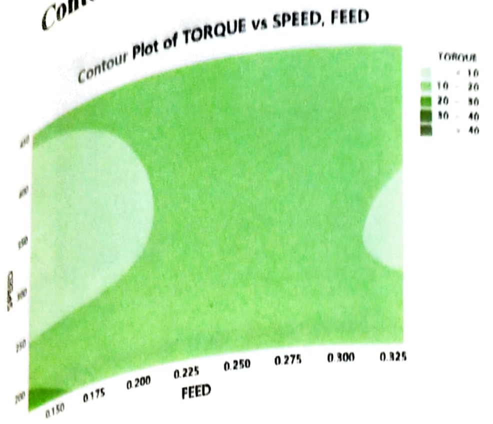


Fig 6.31 contour plot of torque vs speed,feed

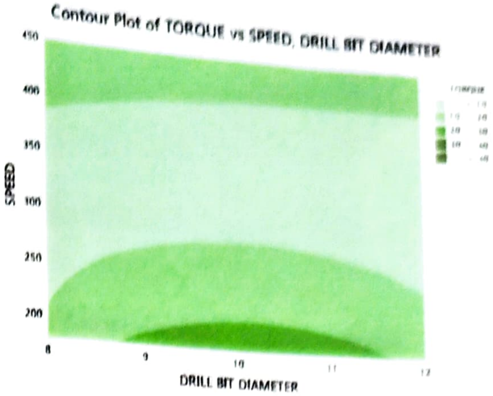


Fig 6.32 contour plot of torque vs speed,drill bit dia

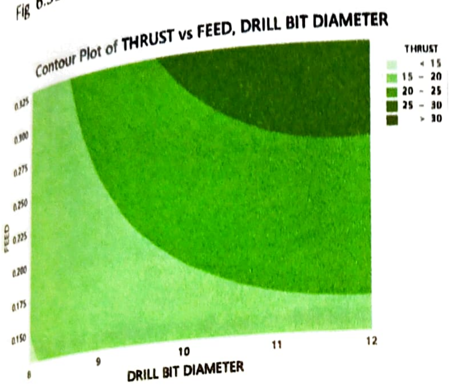


Fig 6.33 contour plot of thrist vs feed,drill bit dia

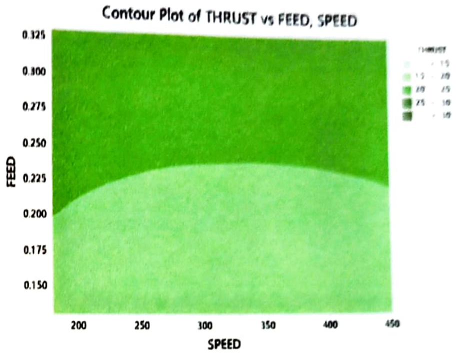


Fig 6.34 contour plot of thrust vs feed, speed

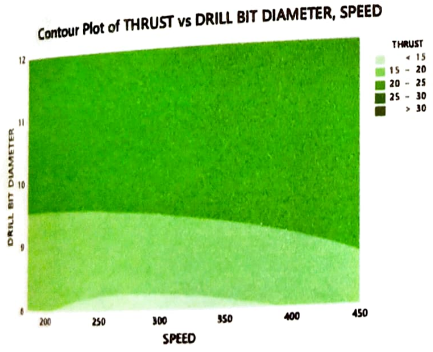


Fig 6.35 contour plot of thrust vs drill bit dia,speed

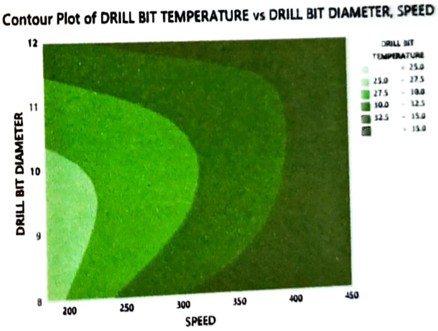


Fig 6.36 contour plot of drill bit dia vs drill bit dia,speed

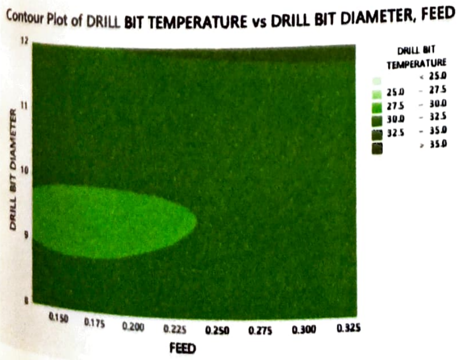


Fig 6.37 contour plot of drill bit dia vs drill bit dia,feed

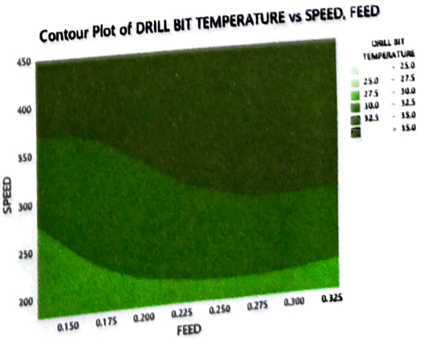


Fig 6.38 contour plot of drill bit temp vs speed,fee

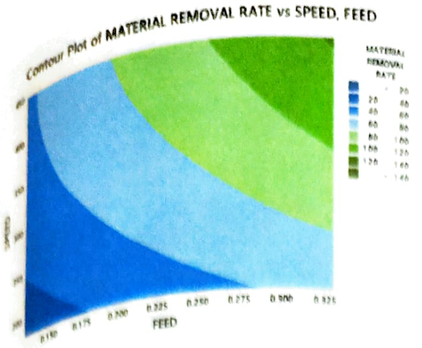


Fig 6.39 contour plot of mrr vs speed,feed

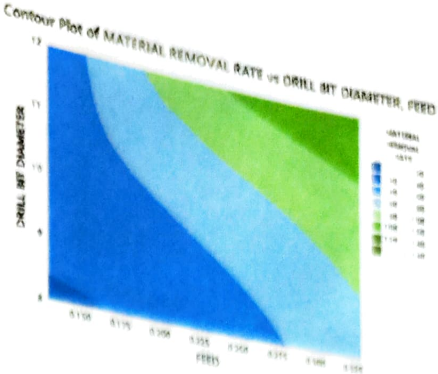


Fig 6.40 contour plot of mrr vs drill bit dia,feed

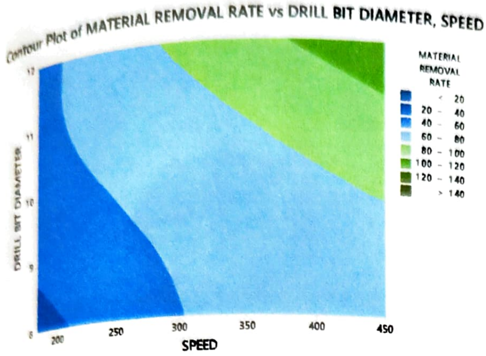


Fig 6.41 contour plot of mrr vs drill bit dia,speed

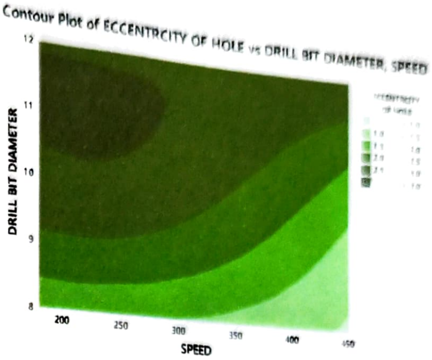


Fig 6.42 contour plot of eccentricity of hole vs drill bit dia,speed

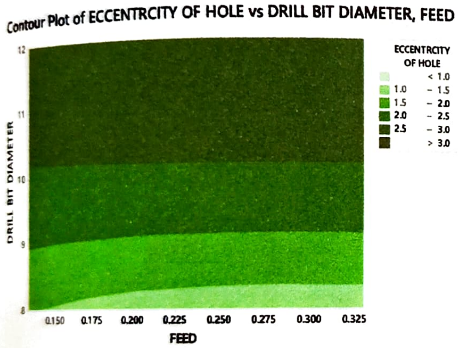


Fig 6.43 contour plot of eccentricity of hole vs drill bit dia,feed

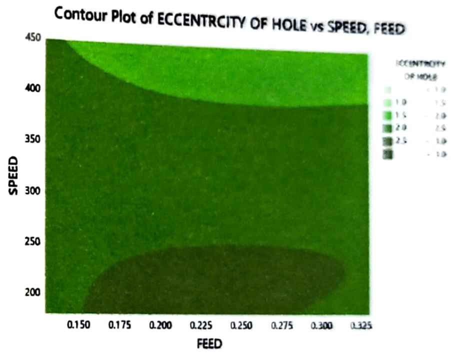


Fig 6.44 contour plot of eccentricity of hole vs speed,feed

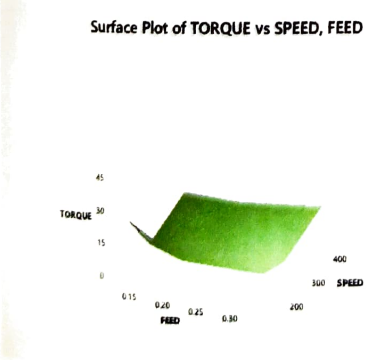


Fig 6.45 surface plot of torque vs speed,feed

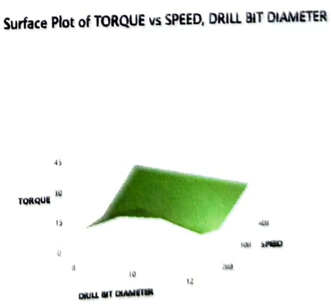


Fig 6.46 surface plot of torque vs speed,drill bit dia

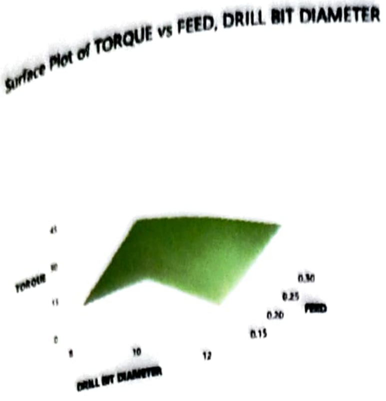


Fig 6.47 surface plot of torque vs feed, drill bit dia

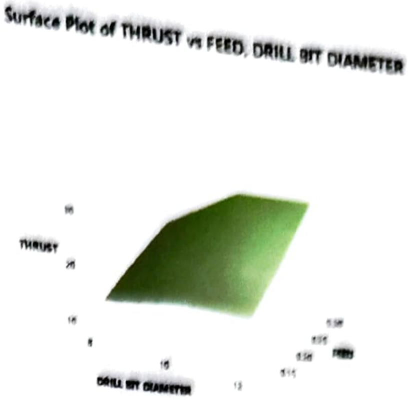


Fig 6.48 surface plot of thrust vs feed,drill bit dia

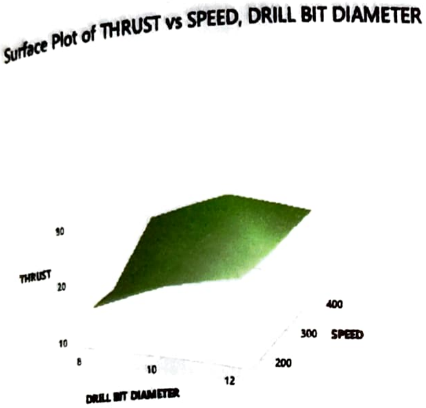


Fig 6.49 surface plot of thrust vs speed, drill bit dia

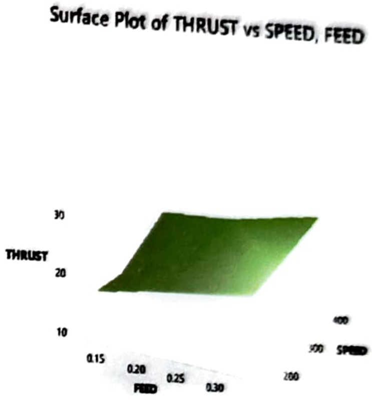


Fig 6.50 surface plot of thrust vs speed,feed

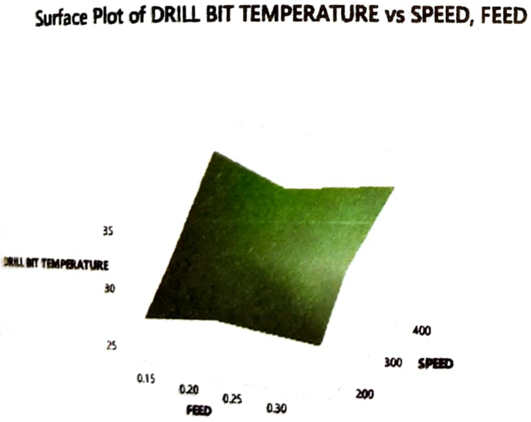


Fig 6.51 surface plot of drill bit temp vs speed,fee

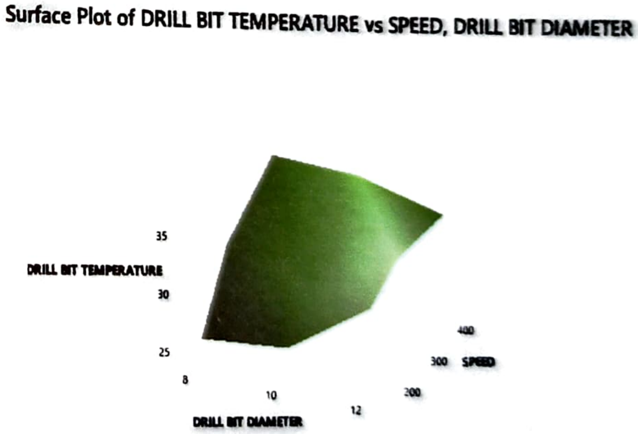


Fig 6.52 surface plot of drill bit temp vs speed, drill bit dia

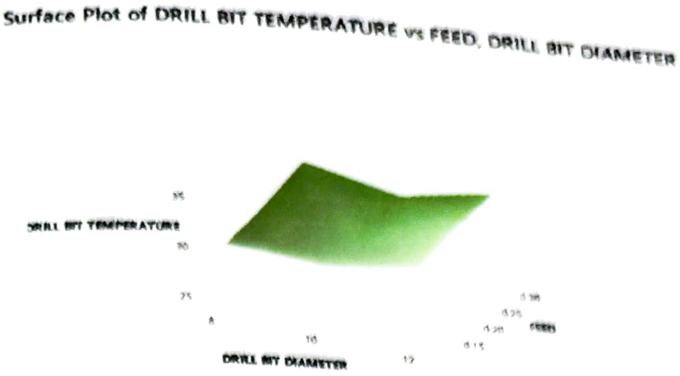


Fig 6.53 surface plot of drill bit temp vs feed,drill bit dia

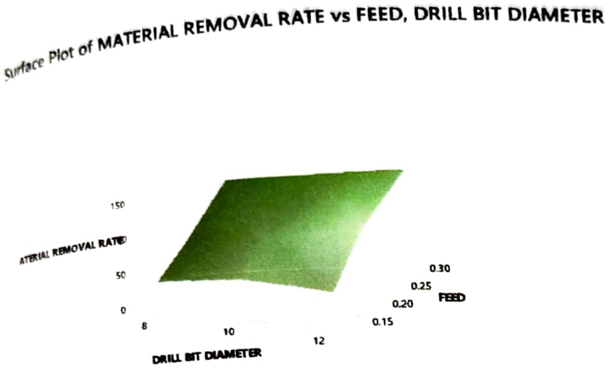


Fig 6.54 surface plot of mrr vs feed, drill bit dia

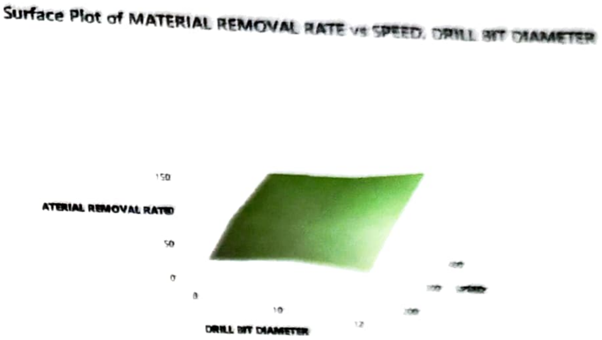


Fig 6.55 surface plot of mrr vs. speed, drill bit dia

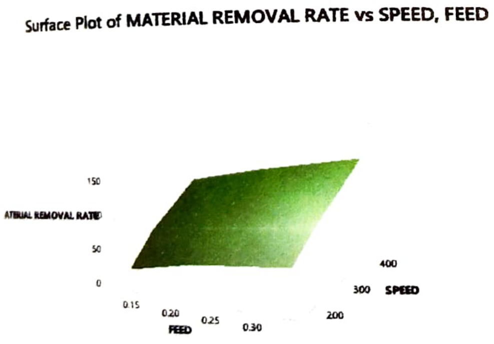


Fig 6.56 surface plot of mrr vs speed,feed

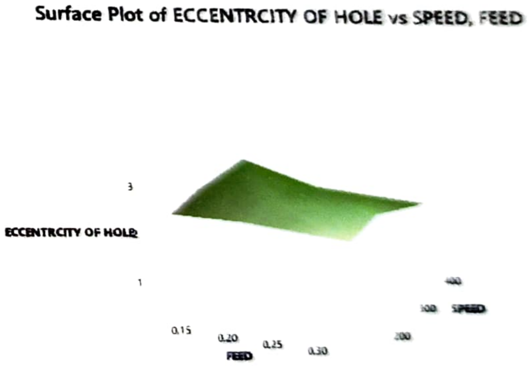


Fig 6.57 surface plot of eccentricity of hole vs speed,feed

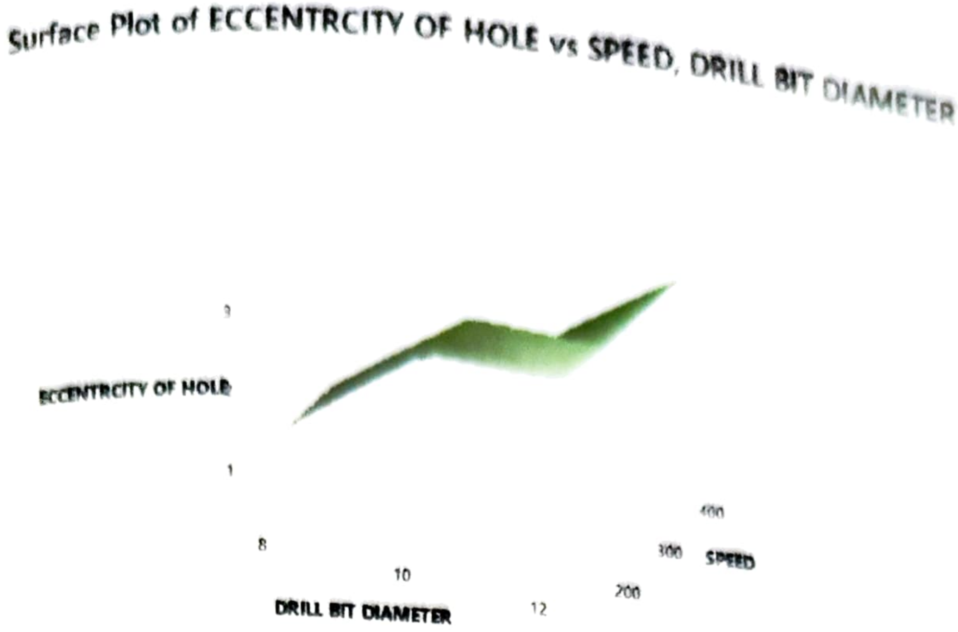


Fig 6.58 surface plot of eccentricity of hole vs speed, drill bit dia

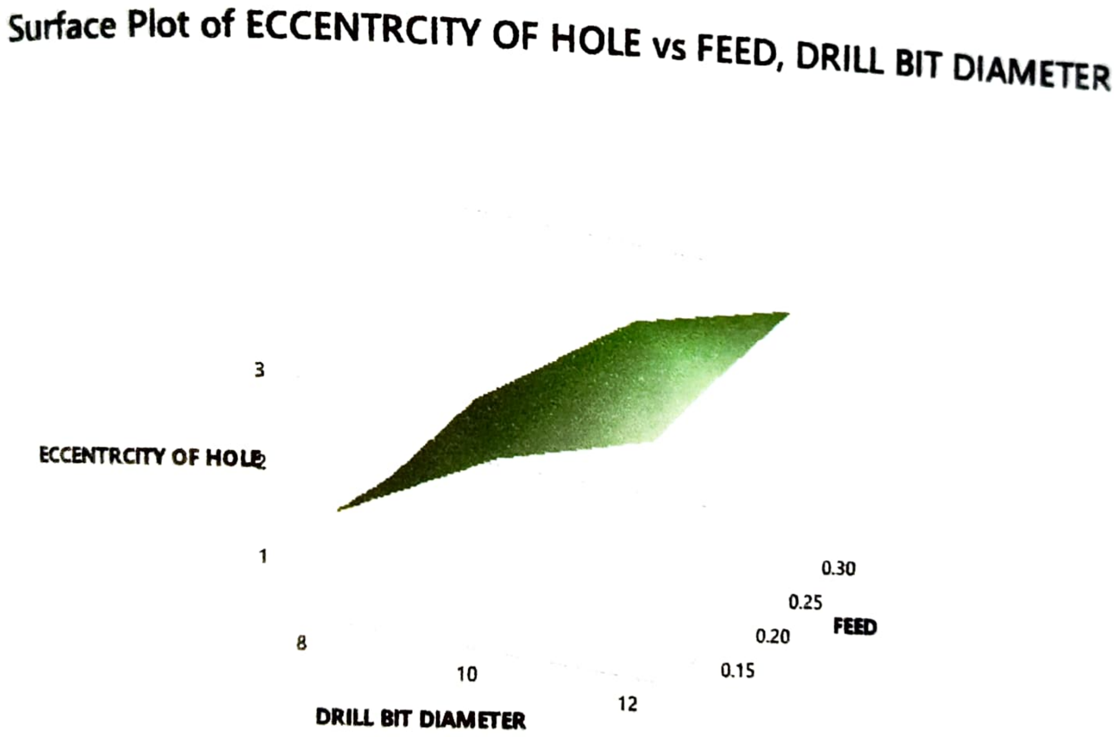


Fig 6.60 surface plot of eccentricity of hole vs feed , drill bit

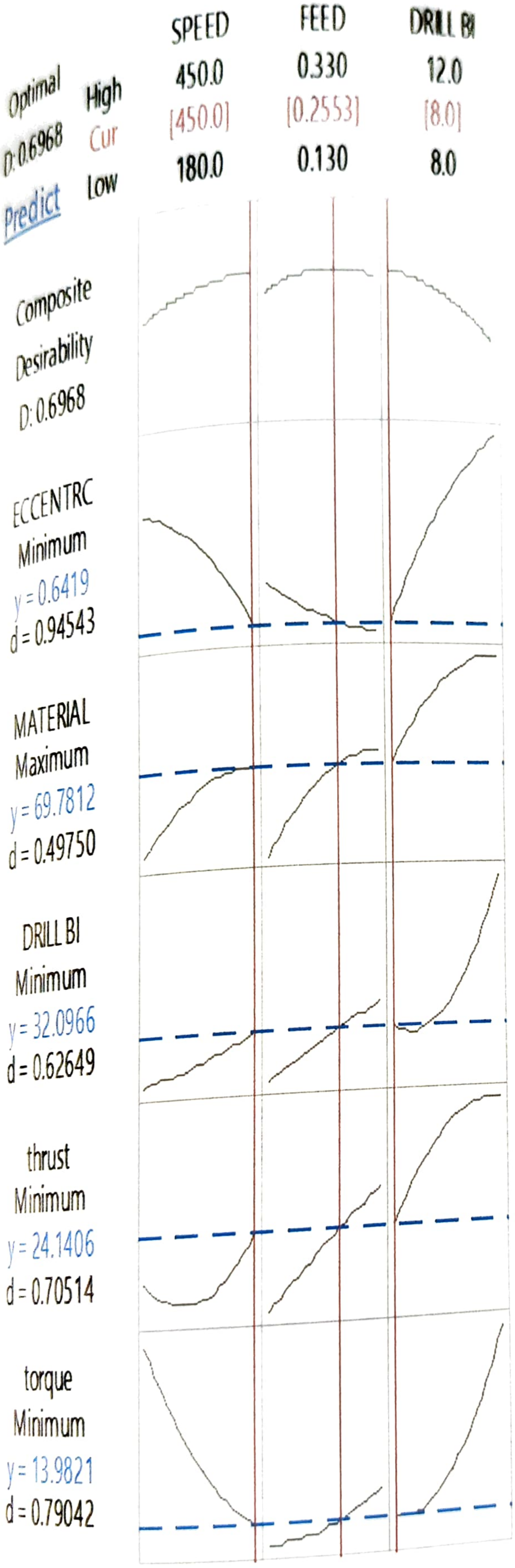


Fig 6.61 : optimization of brass work piece

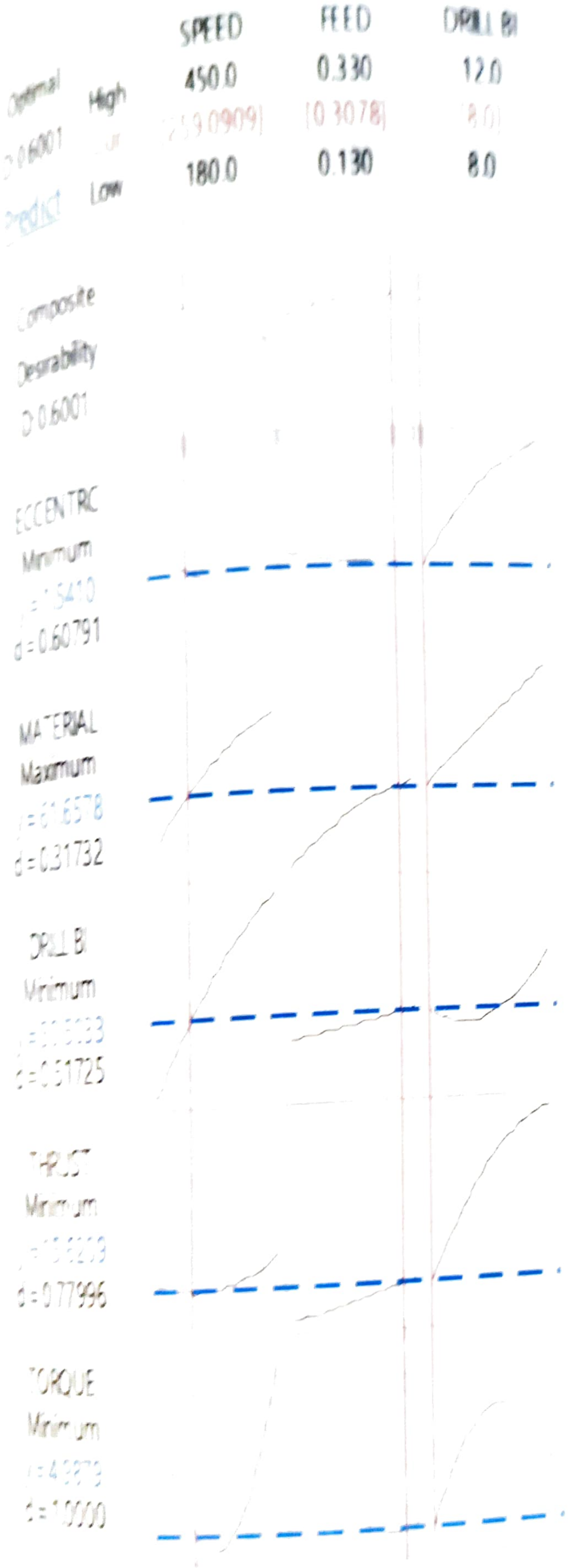


Fig 6.62 : optimization of bronze work piece

Chapter 6

CONCLUSION

In the present work response optimization problems has been solved by using an optimal parameteric combination of input parameters such as Speed, feed and drill bit diameter.

These optimal parameters ensures in producing high surface quality turned product.Responce Surface Methodology is successfully implemented for optimizing the input parameters.

This project produces a direct equation with combination of controlled parameterswhich can be used in industries to know the value of Surface Response instead of machining.

The implementation of this gives direct equation in manufacturing industries

- Reduces the manual effort
- Reduces the production cost
- Reduces the manufacturing time
- Increases the quality of the product which is the ultimate goal of an industry

Bronze:

Hence we conclude that the optimal solution for the temperature of 30.5°C,material removal rate of 61.6578 mm/sec,torque of 4.98 kgf,eccentricity of hole is 1.541 cm,thrust of 15.62 kgmis obtained when speed = 259rpm,feed=0.30 mm/rev and drill bit diameter= 8mm by using BCPL Oil.

Brass:

Hence we conclude that the optimal solution for the temperature of 32.13°C,material removal rate of 70.03 mm3/sec,torque of 13.0928kgf ,eccentricity of hole is 0.6373cm ,thrust of 24.2158kgm is obtained when speed = 450rpm,feed=0.257 mm/rev and drill bit diameter= 8 mm by using BCPL Oil.

By the optimal solutions of both brass and bronze we can say optimal solution of brass is better than optimal solution of bronze for the given input parameters.

FUTURE SCOPE

- The factors like tool wear and the chip thickness can also be studied so that the research becomes more useful.
- The cylindricity,ecentricity,roundness of all the drill hole can also be studied.
- Output parameters can also be increased and multi objective optimization can be done by taking more than two parameters into account.
- Optimization can also be done regarding the cost of machining in economical view.

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