DESIGN, ANALYSIS, ASSEMBLY AND INSTALLATION OF MULTI SPINDLE DRILLING MACHINE

A PROJECT THESIS

Submitted by

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In fulfillment for the award of the degree of

BACHELOR OF ENGINEERING

In

Mechanical Engineering

V.V.P. Engineering College, Rajkot

Gujarat Technological University
Ahmedabad

November, 2012

DECLARATION

We hereby declare that the project entitled "**DESIGN, ANALYSIS, ASSEMBLY AND INSTALLATION OF MULTI SPINDLE DRILLING MACHINE**" submitted in partial fulfillment for the degree of **Bachelor of Engineering** in **Mechanical Engineering** to Gujarat Technological University, **Ahemdabad**, is a bonafide record of the project work carried out at **V.V.P. ENGINEERING COLLEGE** under the supervision of **Dr. J.P.MEHTA** and that no part of the IDP has been presented earlier for any degree, diploma, associate ship, fellowship or other similar title of any other university or institution.

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CERT I F ICATE

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This is to certify that the IDP entitled " **DESIGN, ANALYSIS, ASSEMBLY AND INSTALLATION OF MULTI SPINDLE DRILLING MACHINE"** has been carried out by **SHRENIK SANGHAVI , JAYESH AMBWANI** under my guidance in fulfillment of the degree of Bachelor of Engineering in Mechanical Engineering (7^{th} Semester) of Gujarat Technological University, Ahmadabad during the academic year 2012-13.

Guide: **Head of the Department:**

ACKNOWLEDGEMENT

The completion of this project and this report owes itself to the invaluable help and support of **Dr. J. P. Mehta**, Professor and Head of the Department of Mechanical Engineering, V.V.P. Engineering College, Rajkot. I would also like to express my gratitude towards **Mr. Brijesh Garala,** owner of Industrial Automation Services, Rajkot, for his assistance and guidance for the designing concepts.

TO WHOMSOEVER IT MAY CONCERN

This is to certify that **SHRENIK SANGHAVI , JAYESH AMBWANI** of **V.V.P. ENGINEERING COLLEGE**, has worked on a Industry Defined Project of **INDUSTRIAL AUTOMATION SERVICES**. The work embodied in this project entitled , " **DESIGN, ANALYSIS, ASSEMBLY AND INSTALLATION OF MULTI SPINDLE DRILLING MACHINE**" has been carried out in partial fulfillment for the degree of Bachelor of Engineering. He/She has undergone the project for the required period. During this period we found him/her sincere, honest and diligent. We wish all success in his/her future endeavors.

INDUSTRIAL AUTOMATION SERVICES

Mr. BRIJESH GARALA

DATE:

Abstract

It's a project of designing a gang drilling machine, which is to be used for a special purpose, thus it is a Special Purpose Machine (SPM). The company has their own requirements for the drilling operation, and so for that a multi-spindle gang drilling machine is to be designed.

The company has their own requirement for to drill multi holes on a single plate at a time, to increase the productivity and reduce the cost. In comparison with manual operation, this automatic technique is far effective in per day production, so such machine has to be developed to fulfill requirements. The company wants to produce plates with multiple holes on it, in mass production. For that they need an automatic multi-spindle drilling machine. The PCD for the hole is fixed for the production, and the diameter and thickness of are 11mm and 18mm respectively.

As it is having multi spindles driven by a single motor with help of gear box, it can drill multi holes on the plate at the same time. As it is having fixed PCD, so once it is to be set, then it can work thoroughly, increasing the productivity and reducing cost.

As it is a project based on a year time period, the designing and the assembly will be done during the 7th semester and analysis of machine and installation of it will be done in 8th semester.

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LIST OF SYMBOLS, ABBREVIATIONS AND NOMENCLATURE

Symbol	Abbreviations
v	Cutting speed
D	Diameter of drill
n	Speed of rotation
K	Material Factor
P	Power
T	Torque
T_h	Thrust
MRR	Material Removal Rate
F	Force
σ	Tensile stress
τ	Shear stress
A	Cross sectional area
d	Diameter of shaft
j	Polar moment of Inertia
G	Modulus of rigidity
θ	Angle of twist
l	length of shaft
d_P	Diameter of smaller pulley
D_P	Diameter of larger pulley
m	Module of gear
z	Number of teeth
h_a	Addendum
h_f	Deddendum
c	Clearance
h_k	Working depth
h	Hole depth
s	Tool thickness
P_t	Tangential force
P_r	Radial force
α	Pressure angle
E	Modulus of Elasticity
F_A	Axial load
F_R	Radial load
P	Equivalent dynamic load
V	Race rotation factor
C_0	Static load capacity
C	Dynamic load capacity

L_{10}	**Rated bearing life (in million revolution)**
L_{10h}	**Rated bearing life (hours)**
X	**Radial factor**
Y	**Thrust factor**
R_A	**Reaction at A**
R_B	**Reaction at B**
s	**Service Factor**

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1.0 Introduction of drill

1.1 Introduction

Drilling is the operation of producing circular hole in the work-piece by using a rotating cutter called DRILL. 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.

1.2 Drilling Machine

It is the simplest and accurate machine used in production shop. The work piece is held stationary i.e. clamped in position and the drill rotates to make a hole. A drilling machine, called a drill press, is used to cut holes into or through metal, wood, or other materials. Drilling machines use a drilling tool that has cutting edges at its point. This cutting tool is held in the drill press by a chuck or Morse taper and is rotated and fed into the work at variable speeds. Drilling machines may be used to perform other operations like countersinking, boring, counter boring, spot facing, reaming, and tapping. The size or capacity of the drilling machine is usually determined by the largest piece of stock that can be centre-drilled. Other ways to determine the size of the drill press are by the largest hole that can be drilled, the distance between the spindle and column, and the vertical distance between the worktable and spindle.

1.3 Types of Drilling machine

1) Based on construction:

Portable,

Sensitive,

Radial,

Up-right,

Gang,

Multi-spindle

2) Based on Feed:

Hand driven

Power driven

1.4 Components of drilling machine

Spindle:

The spindle holds the drill or cutting tools and revolves in a fixed position in a sleeve.

Sleeve:

The sleeve or quill assembly does not revolve but may slide in its bearing in a direction parallel to its axis. When the sleeve carrying the spindle with a cutting tool is lowered, the cutting tool is fed into the work: and when it's moved upward, the cutting tool is withdrawn from the work. Feed pressure applied to the sleeve by hand or power causes the revolving drill to cut its way into the work a fraction of an mm per revolution.

Column:

The column is cylindrical in shape and built rugged and solid. The column supports the head and the sleeve or quill assembly.

Head:

The head of the drilling machine is composed of the sleeve, a spindle, an electric motor and feed mechanism. The head is bolted to the column.

Worktable:

The worktable is supported on an arm mounted to the column. The worktable can be adjusted vertically to accommodate different heights of work or it can be swung completely out of the way. It may be tilted up to 90 degree in either direction, to allow long pieces to be end or angle drilled.

Base:

The base of the drilling machine supports the entire machine and when bolted to the floor, provides for vibration-free operation and best machining accuracy. The top of the base is similar to the worktable and may be equipped with t- slot for mounting work too large for the table.

Hand Feed:

The hand- feed drilling machines are the simplest and most common type of drilling machines in use today. These are light duty machine that are operated by the operator, using a feed handled, so that the operator is able to "feel" the action of the cutting tool as it cuts through the work piece. These drilling machines can be bench or floor mounted.

Power feed:

The power feed drilling machine are usually larger and heavier than the hand feed ones they are equipped with the ability to feed the cutting tool in to the work automatically, at preset depth of cut per revolution of the spindle these machines are used in maintenance for medium duty work or the work that uses large drills that require power feed larger work pieces are usually clamped directly to the table or base using t –bolts and clamps by a small work places are held in a vise. A depth –stop mechanism is located on the head, near the spindle, to aid in drilling to a precise depth.

1.5 Sensitive or Bench Drilling Machine

This type of drill machine is used for very light works. Figure.1.1 illustrates the sketch of sensitive drilling machine.

The vertical column carries a swiveling table the height of which can be adjusted according to the work piece height. The table can also be swung to any desired position. At the top of the column there are two pulleys connected by a belt, one pulley is mounted on the motor shaft and other on the machine spindle. Vertical movement to the spindle is given by the feed handle by the operator. Operator senses the cutting action so it is called as sensitive drilling machine. It drills holes from 1.5 to 15mm

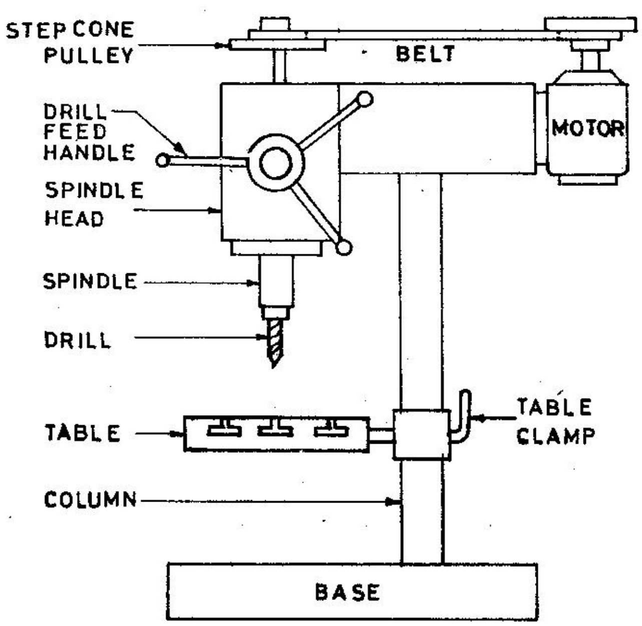

Figure.1.1. Sensitive Drilling Machine

1.6 Up-Right Drilling Machine

These are medium heavy duty machines. It specifically differs from sensitive drill in its weight, rigidity, application of power feed and wider range of spindle speed. Figure.1.2 shows the line sketch of up-right drilling machine. This machine usually has a gear driven mechanism for different spindle speed and an automatic or power feed device. Table can move vertically and radially. It drills holes up to 50 mm.

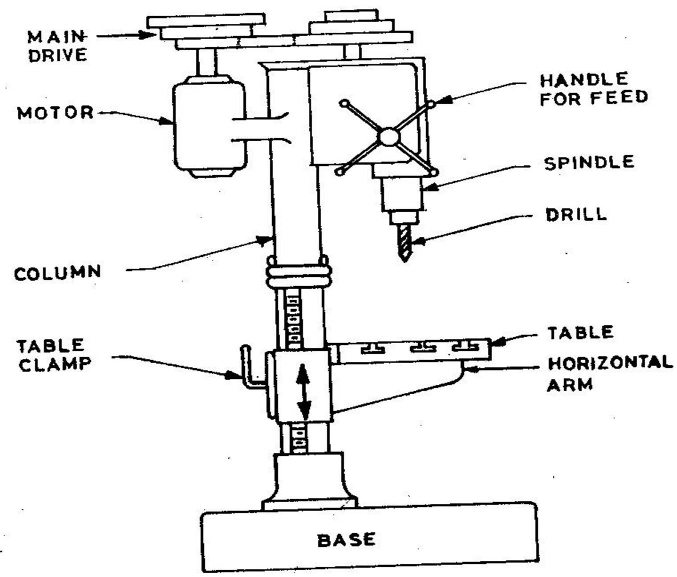

Figure.1.2. Up-Right Drilling Machine

1.7 Radial Drilling Machine

It is the largest and most versatile machine used for drilling medium to large and heavy work pieces. Radial drilling machine belong to power feed type. The column in radial drilling machine supports the radial arm, drill head and motor. Figure.1.3 shows the line sketch of radial drilling machine.

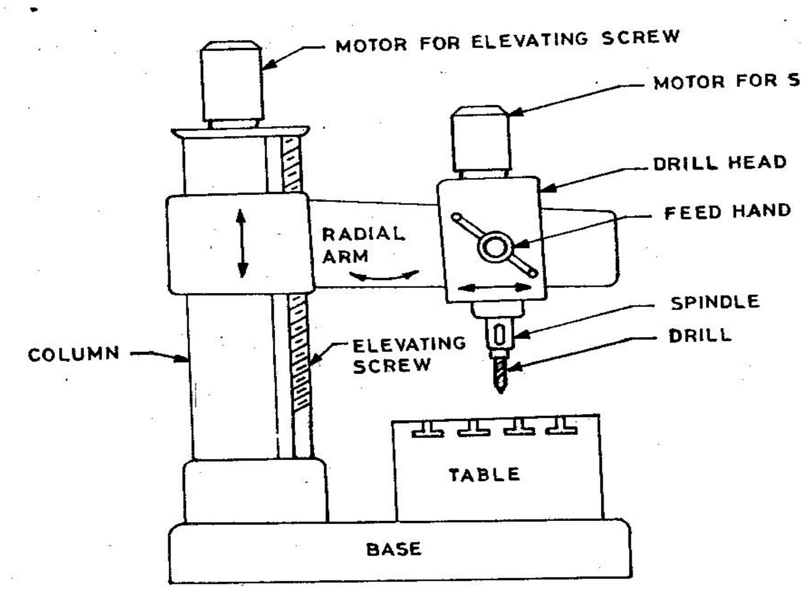

Figure.1.3. Radial Drilling Machine

The radial arm slides up and down on the column with the help of elevating screw provided on the side of the column, which is driven by a motor. The drill head is mounted on the radial arm and moves on the guide ways provided the radial arm can also be swiveled around the column. The drill head is equipped with a separate motor to drive the spindle, which carries the drill bit. A drill head may be moved on the arm manually or by power. Feed can be either manual or automatic with reversal mechanism.

1.8 Drill Materials

The two most common types are

1. HSS drill - Low cost
2. Carbide tipped drills - high production and in CNC machines

Other types are:

1. Solid Carbide drill
2. Tin coated drills
3. Carbide Coated Masonry drills
4. Parabolic drills
5. Split point drill

Following figures show various types of drills.

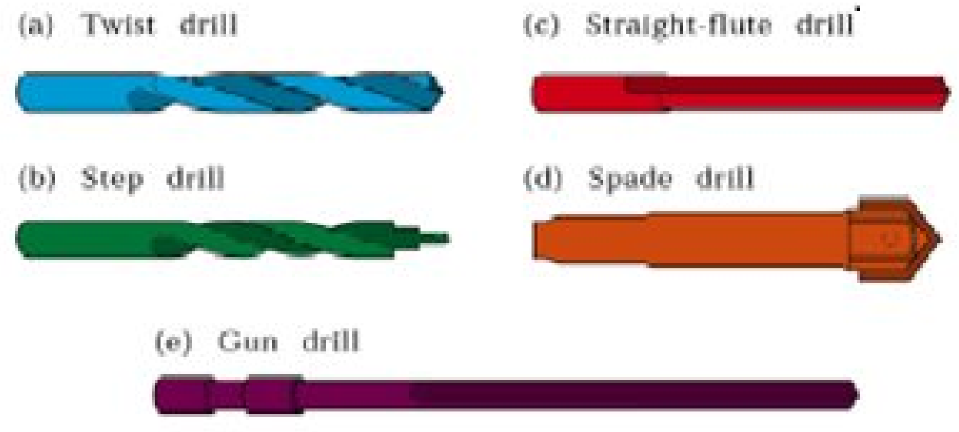

Figure.1.4. Types of twist drills

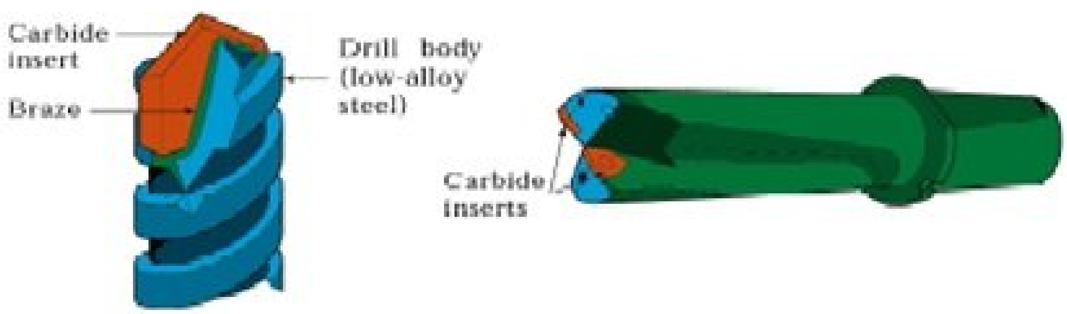

Figure.1.5. Carbide tip in drill bits

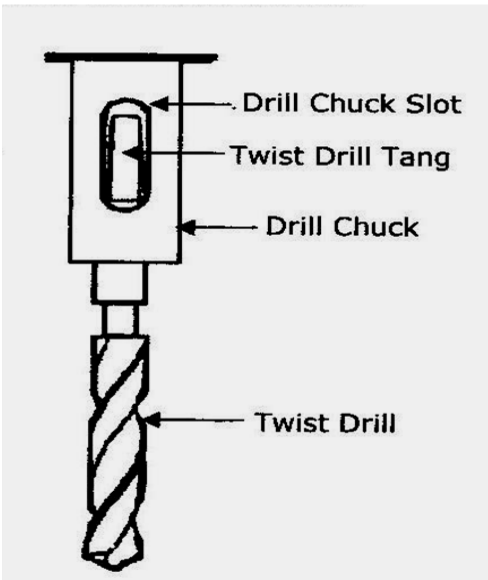

Figure.1.6. Drill fixed to a spindle

1.9 Drill Tool Geometry

Body:

That portion of drill extending from its extreme point to the commencement of the neck, if present; otherwise extending to the commencement of shank.

Body clearance:

That portion of body surface which is reduced in diametric to provide diameter clearance.

Face:

The portions of the flute surface adjust to the lip on which the chip impinges as it cut from the work.

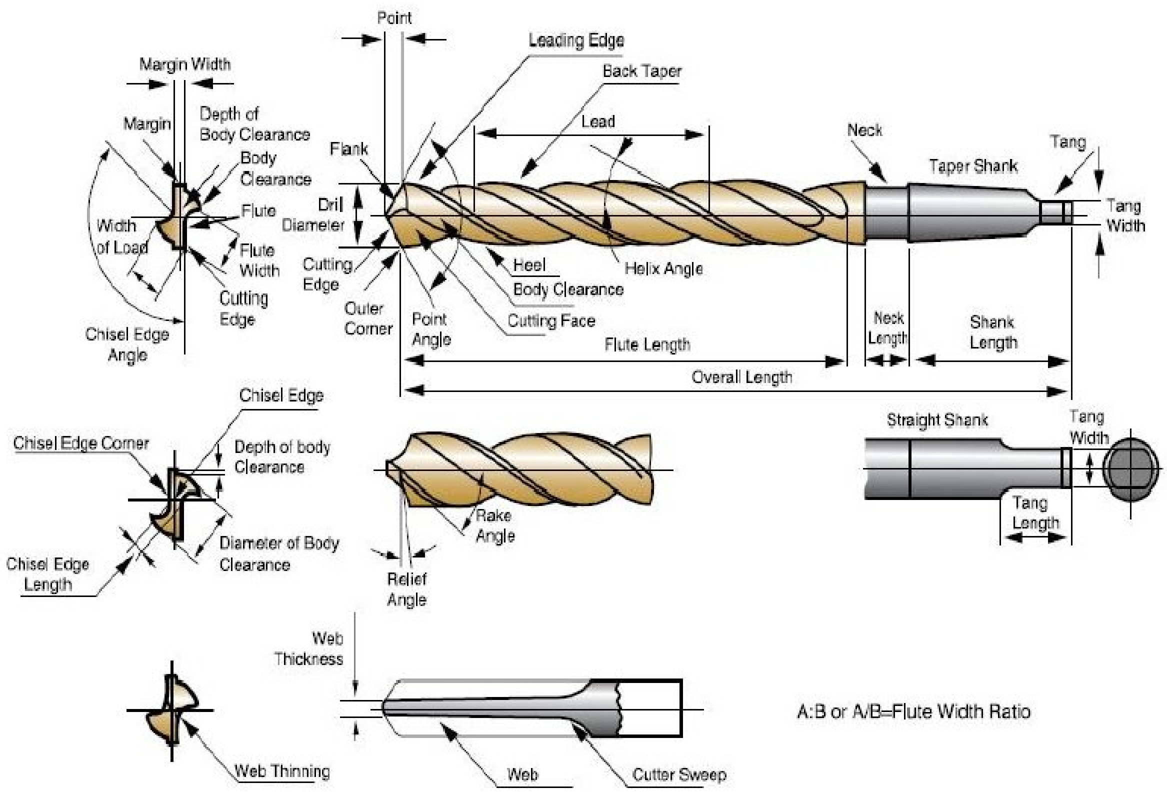

Figure.1.7. Nomenclature of twist drill

Flutes:

It is the groove in the body in drill which provides lip. The functions of flutes are to form the cutting edge on point, to allow chip to escape, to cause the chips to curl, to permit the cutting fluid to cutting edges.

Heel:

The edge formed by the intersection of the flutes surface & the body clearance.

Land:

The cylindrically ground surface on leading edge of the drill flutes. The width of land is measured at right angles to the flute helix. Land keeps the drill aligned.

Shank:

It is that part of drill by which is held & drive. The most common type of shank is the Taper shank and straight shank. The taper shank provides means of centering &holding the drill by friction in tapered end of spindle.

Tang:

The flattened end of taper shank intended to fit in to a drill slot in spindle, socket or drill holder. The tang ensures positive drive of drill from the drill spindle.

Chisel edge angle:

The obtuse angle include between the chisel edge and lip as viewed from end of the drill. The usual value of this angle varies from 120^o to 135^o.

Helix angle or Rack angle:

The helix angle or rack angle is the angle formed by the leading edge of land with plane having axis of drill. The usual value of rack angle is 30^o, although it may vary up to 40^o for different materials. Smaller the rack angle, greater will be the torque required to drive the drill at given feed.

Point angle:

This the angle included between tool lips projected upon a plane parallel to the drill axis & parallel to the two cutting lips. The usual point angle 118^o, but for harder steel alloys, the angle increases.

Lip clearance angle:

The angle formed by the flank & a plane at right angles to the drill axis. The angle is normally measures at the periphery of drill. The clearance angle is 12^o in most cases. The clearance angle should be minimum to add rigidity & strength to the cutting edge.

1.10 Tool holding devices

Figure.1.8 and Figure.1.9 shows the different work holding and drill drift device. The different methods used for holding drill in a drill spindle are.

1. By directly fitting in the spindle hole.
2. By using drill sleeve
3. By using drill socket

4. By using drill chuck

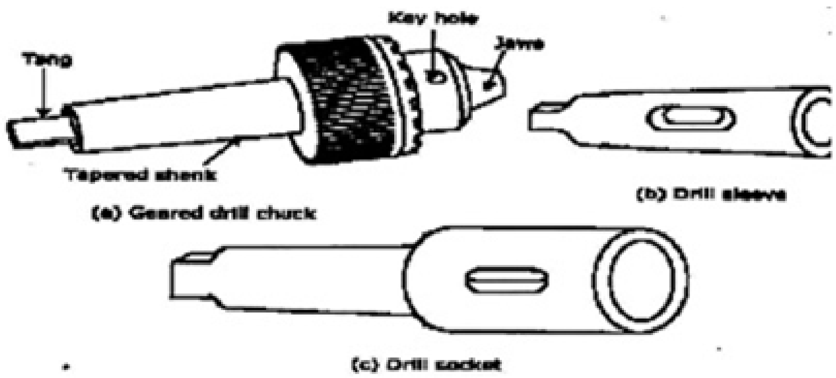

Figure.1.8. Different types of work holding device

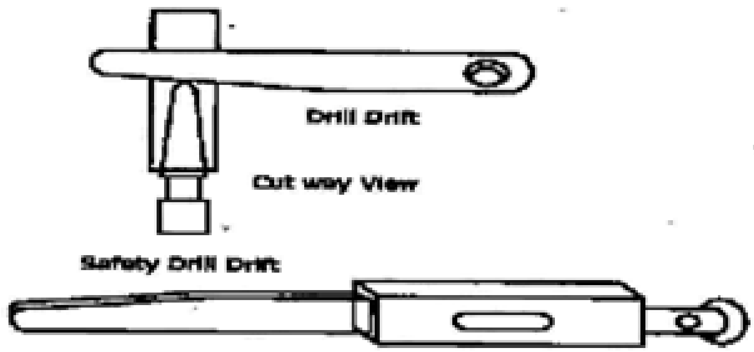

Figure.1.9. Different types of drill drift device

1.11 Drilling operations

Operations that can be performed in a drilling machine are

1. Drilling
2. Reaming
3. Boring
4. Counter boring
5. Countersinking
6. Tapping

Drilling:

It is an operation by which holes are produced in solid metal by means of revolving tool called ‘Drill’. Fig. 1.10 shows the various operations on drilling machine.

Reaming:

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

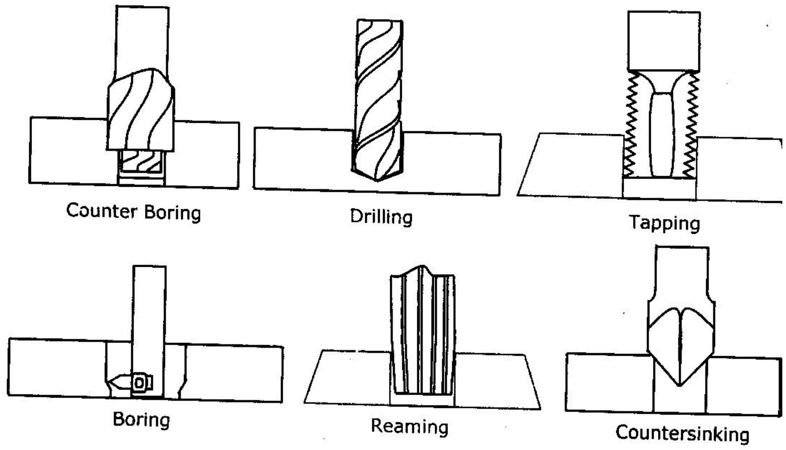

Figure.1.10. Various operations on drilling machine

Boring:

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

Counter Bore:

This operation uses a pilot to guide the cutting action to accommodate the heads of bolts. Fig. 1.11 illustrates the counter boring, countersunk and spot facing processes.

Countersink:

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

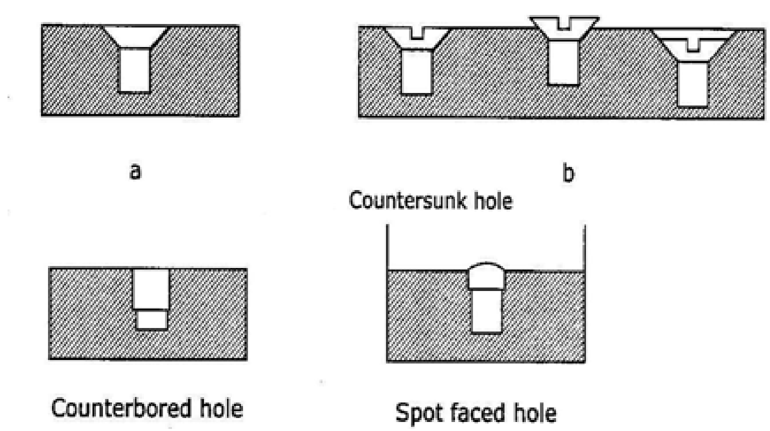

Figure.1.11. Counter boring, countersunk and spot facing

Tapping:

Tapping is the process by which internal threads are formed. It is performed either by hand or by machine. Minor diameter of the thread is drilled and then tapping is done. Figure.1.12 shows the tapping processes.

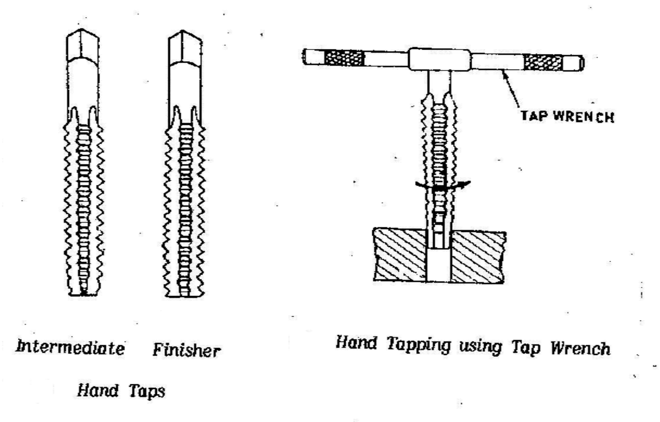

Figure.1.12. Hand taps and tapping process using tap wrench

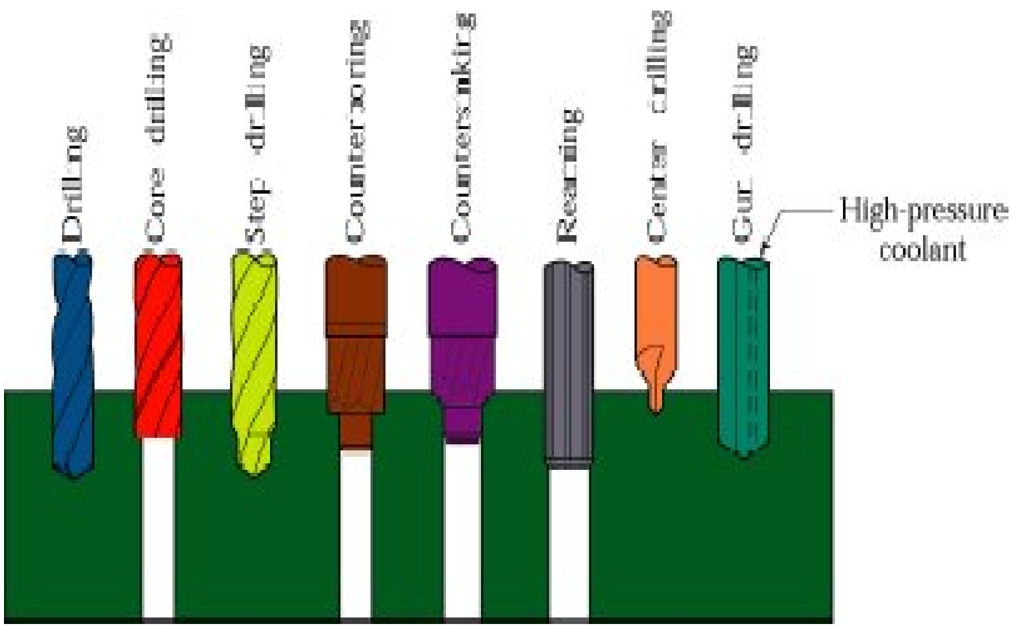

Figure.1.13. Various operations performed on drilling machine

1.12 Work Holding Devices

Machine Table Vice:

The machine vice is equipped with jaws which clamps the work piece. The vice can be bolted to the drilling table or the tail can be swung around swung around. Figure.1.14 shows the standard and swivel vice. The swivel vice is a machine wise that can be swivel through 360° on a horizontal plane.

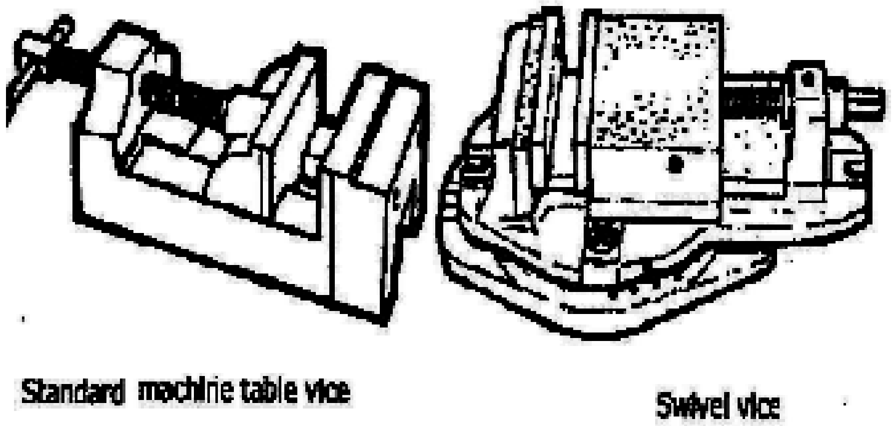

Figure.1.14. Machine Table vice.

Step Blocks:

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

Clamps:

These are small, portable vises , which bears against the work piece and holding devices. Common types of clamps are C-clamp, Parallel clamp, machine strap clamp, U-clamp etc. Figure.1.15 shows the correct and incorrect methods of mounting the work piece.

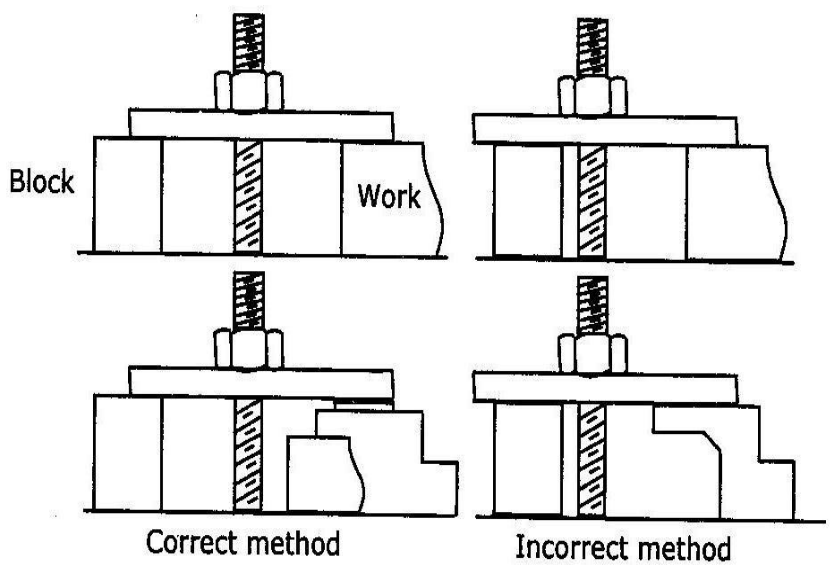

Figure.1.15. Correct and incorrect methods of clamping the work piece.

V-Blocks:

These are designed to hold round work pieces.

Angles:

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

Jigs:

The jig guides the drill through a bushing to locate and drill holes accurately.

T- Slots Bolt:

These are special bolts which has a T shaped head, which slides into the T slots of drilling machine work table.

2.0 Brief History of Drilling

2.1 Introduction of drills

The earliest drills existed some thirty-five thousand years ago. The drills consisted of little more than a pointed rock which would be spun between the hands. The next major development was the bow drill, which dates back to the ancient Hadappans and Egyptians. The drill press as a machine tool evolved from the bow drill and is many centuries old. It was powered by various power sources over the centuries, such as human effort, water wheels, and windmills, often with the use of belts. Churn drills date back to as early as Qin Dynasty China. Churn drills in ancient China were built of wood and labor intensive, but were able to go through solid rock. With the coming of the electric motor in the late 19th century, there was a great rush to power machine tools with such motors, and drills were among them. The invention of the first electric drill is credited to Arthur James Arnot and William Blanch Brain in 1889, at Melbourne, Australia. Wilhelm Fein invented the portable electric drill in 1895, at Stuttgart, Germany. In 1917, Black & Decker patented a trigger-like switch mounted on a pistol-grip handle.

2.2 Types of drills

There are many types of drills; some are powered manually, others use electricity (electric drill) or compressed air (pneumatic dril*l*) as the motive power, and a minority are driven by an internal combustion engine (for example, earth drilling augers). Drills with a percussive action (hammer drills) are mostly used in hard materials such as masonry (brick, concrete and stone) or rock. Drilling rigs are used to bore holes in the earth to obtain water or oil. Oil wells, water wells, or holes for geothermal heating are created with large drilling rigs. Some types of hand-held drills are also used to drive screws and other fasteners. Some small appliances that have no motor of their own may be drill-powered, such as small pumps, grinders, etc.

2.2.1 Hand tools

A variety of hand-powered drills have been employed over the centuries. Here are a few, starting with approximately the oldest:

- Bow drill
- Brace and bit
- Gimlet
- Breast drill, also known as an "eggbeater" drill
- Push drill, a tool using a spiral ratchet mechanism
- Pin chuck, a small hand-held jeweler's drill

2.2.2 Pistol-grip (corded) drill

Drills with pistol grips are the most common type in use today, and are available in a huge variety of subtypes. A less common type is the right-angle drill, a special tool used by tradesmen such as plumbers and electricians.

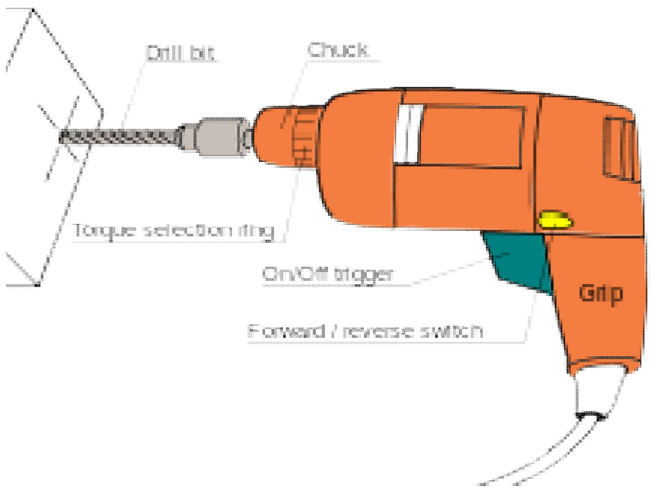

Figure.2.1. Anatomy of Pistol Grip Drill

For much of the 20th century, many attachments could commonly be purchased to convert corded electric hand drills into a range of other power tools, such as orbital sanders and power saws, more cheaply than purchasing conventional, self-contained versions of those tools (the greatest saving being the lack of an additional electric motor for each device). As the prices of power tools and suitable electric motors have fallen, however, such attachments have become much less common. A similar practice is currently employed for cordless tools where the battery, the most expensive component, is shared between various motorized devices, as opposed to a single electric motor being shared between mechanical attachments.

Figure.2.2. Drills can also be used at an angle to join two boards

2.2.3 Hammer drill

The hammer drill is similar to a standard electric drill, with the exception that it is provided with a hammer action for drilling masonry. The hammer action may be engaged or disengaged as required. Most electric hammer drills are rated (input power) at between 600 and 1100 watts. The efficiency is usually 50-60% i.e. 1000 watts of input is converted into 500-600 watts of output (rotation of the drill and hammering action).

The hammer action is provided by two cam plates that make the chuck rapidly pulse forward and backward as the drill spins on its axis. This pulsing (hammering) action is measured in Blows Per Minute (BPM) with 10,000 or more BPMs being common. Because the combined mass of the chuck and bit is comparable to that of the body of the drill, the energy transfer is inefficient and can sometimes make it difficult for larger bits to penetrate harder materials such as poured concrete. The operator experiences considerable vibration and the cams are generally made from hardened steel to avoid them wearing out quickly. In practice, drills are restricted to standard masonry bits up to 13 mm (1/2 inch) in diameter. A typical application for a hammer drill is installing electrical boxes, conduit straps or shelves in concrete.

In contrast to the cam-type hammer drill, a rotary/pneumatic hammer drill accelerates only the bit. This is accomplished through a piston design, rather than a spinning cam. Rotary hammers have much less vibration and penetrate most building materials. They can also be used as "drill only" or as "hammer only" which extends their usefulness for tasks such as chipping brick or concrete. Hole drilling progress is greatly superior to cam-type hammer drills, and these drills are generally used for holes of 19 mm (3/4 inch) or greater in size. A typical application for a rotary hammer drill is boring large holes for lag bolts in foundations, or installing large lead anchors in concrete for handrails or benches.

A standard hammer drill accepts 6 mm (1/4 inch) and 13 mm (1/2 inch) drill bits, while a rotary hammer uses SDS or Spline Shank bits. These heavy bits are adept at pulverizing the masonry and drill into this hard material with relative ease.

2.2.4 Rotary hammer drill

Figure.2.3. A rotary hammer drill used in construction

The rotary hammer drill (also known as a rotary hammer, roto hammer drill or masonry drill) combines a primary dedicated hammer mechanism with a separate rotation mechanism, and is used for more substantial material such as masonry or concrete. Generally, standard chucks and drills are inadequate and chucks such as carbide drills that have been designed to withstand the percussive forces are used. Some styles of this tool are intended for masonry drilling only and the hammer action cannot be disengaged. Other styles allow the drill to be used without the hammer action for normal drilling, or hammering to be used without rotation for chiseling.

2.2.5 Cordless drills

A cordless drill is an electric drill which uses rechargeable batteries. These drills are available with similar features to an AC mains-powered drill. They are available in the hammer drill configuration and most have a clutch, which aids in driving screws into various substrates while not damaging them. Also available are right angle drills, which allow a worker to drive screws in a tight space. While 21st century battery innovations allow significantly more drilling, large diameter holes (typically 12–25 mm (0.5–1.0 in) or larger) may drain current cordless drills quickly.

Figure.2.4. Cordless drill

For continuous use, a worker will have one or more spare battery packs charging while drilling, and quickly swap them instead of having to wait an hour or more for recharging, although there are now Rapid Charge Batteries that can charge in 10–15 minutes. Early cordless drills used interchangeable 7.2 V battery packs. Over the years battery voltages have increased, with 18 V drills being most common, but higher voltages are available, such as 24 V, 28 V, and 36 V. This allows these tools to produce as much torque as some corded drills.

Common battery types of are nickel-cadmium (NiCd) batteries and lithium-ion batteries, with each holding about half the market share. NiCd batteries have been around longer, so they are less expensive (their main advantage), but have more disadvantages compared to lithium-ion batteries. NiCd disadvantages are limited life, self-discharging, environment problems upon disposal, and eventually internally short circuiting due to dendrite growth. Lithium-ion batteries are becoming more common because of their short charging time, longer life, absence of memory effect, and low weight. Instead of charging a tool for an hour to get 20 minutes of use, 20 minutes of charge can run the tool for an hour. Lithium-ion batteries also have a constant discharge rate. The power output remains constant until the battery is depleted, something that nickel-cadmium batteries also lack, and which makes the tool much more versatile. Lithium-ion batteries also hold a charge for a significantly longer time than nickel-cadmium batteries, about two years if not used, vs. 1 to 4 months for a nickel-cadmium battery.

2.2.6 Drill Press

A drill press (also known as pedestal drill, pillar drill, or bench drill) is a fixed style of drill that may be mounted on a stand or bolted to the floor or workbench. Portable models

Figure.2.5. A drill press

with a magnetic base grip the steel work pieces they drill. A drill press consists of a base, column (or pillar), table, spindle (or quill), and drill head, usually driven by an induction motor. The head has a set of handles (usually 3) radiating from a central hub that, when turned, move the spindle and chuck vertically, parallel to the axis of the column. The table can be adjusted vertically and is generally moved by a rack and pinion; however, some older models rely on the operator to lift and reclamp the table in position. The table may also be offset from the spindle's axis and in some cases rotated to a position perpendicular to the column. The size of a drill press is typically measured in terms of swing. Swing is defined as twice the throat distance, which is the distance from the center of the spindle to the closest edge of the pillar. For example, a 16-inch (410 mm) drill press has an 8-inch (200 mm) throat distance.

Old industrial drill press designed to be driven from the power source by a flat belt

A drill press has a number of advantages over a hand-held drill:

- Less effort is required to apply the drill to the work piece.
- The movement of the chuck and spindle is by a lever working on a rack and pinion, which gives the operator considerable mechanical advantage.
- The table allows a vise or clamp to be used to position and restrain the work, making the operation much more secure.
- The angle of the spindle is fixed relative to the table, allowing holes to be drilled accurately and consistently.

Drill presses are almost always equipped with more powerful motors compared to hand-held drills. This enables larger drill bits to be used and also speeds up drilling with smaller bits

Figure.2.6. Old industrial drill press

For most drill presses—especially those meant for woodworking or home use—speed change is achieved by manually moving a belt across a stepped pulley arrangement. Some drill presses add a third stepped pulley to increase the number of available speeds. Modern drill presses can, however, use a variable-speed motor in conjunction with the stepped-pulley system. Medium-duty drill presses such as those used in machine shop (tool room) applications are equipped with a continuously variable transmission. This mechanism is based on variable-diameter pulleys driving a wide, heavy-duty belt. This gives a wide speed range as well as the ability to change speed while the machine is running. Heavy-duty drill presses used for metalworking are usually of the gear-head type.

Drill presses are often used for miscellaneous workshop tasks other than drilling holes. This includes sanding, honing, and polishing. These tasks can be performed by mounting sanding drums, honing wheels and various other rotating accessories in the chuck. This can be unsafe in some cases, as the chuck arbor, which may be retained in the spindle solely by the friction of a taper fit, may dislodge during operation if the side loads are too high.

3.0 Literature Review

The growth of Indian manufacturing sector depends largely on its productivity & quality. Productivity depends upon many factors, one of the major factors being manufacturing efficiency with which the operation /activities are carried out in the organization. Productivity can be improved by reducing the total machining time, combining the operations etc. In case of mass production where variety of jobs is less and quantity to be produced is huge, it is very essential to produce the job at a faster rate. This is not possible if we carry out the production by using general purpose machines. The best way to improve the production rate (productivity) along with quality is by use of special purpose machine. Usefulness and performance of the existing radial drilling machine will be increased by designing and manufacturing of multi spindle drilling head attachment. Multi-spindle drilling machines - such as those used to drill multiple holes in say a skateboard for the wheels - have all the drill 'heads' connected by gears to one motor. That way, the gear assembly (a) ensures the all rotate in the same direction and (b) operate at the same speed.

Enough literature has been studied regarding the drilling operation, Tuna Eren (FEBRUARY 2010) studied to achieve optimum controllable drilling parameters through the multiple regression technique to give minimum drilling cost. A. M. Takale, V. R. Naik(January-April 2012) studied about design and manufacturing of multi spindle drilling head and cycle time optimization, the machine used for multi spindle drilling head is same (Radial drilling machine) which present uses to produce the part, so machine hour rate remains unchanged. Olga Guschinskaya, Alexandre Dolgui, Nikolai Guschinsky, and Genrikh Levin(January 2007) studied about Scheduling for multi-spindle head machines with a mobile table. Ali Riza Motorcu, Abdulkadir Gullu(2006) studied about statistical process control in machining, a case study for machine tool capability and process capability. C. Brecher, M. Esser, S. Witt(2009) studied about the Interaction of manufacturing process and machine tool. Central Machine Tool Institute, Machine Tool Design Handbook, through which we had found out the optimum design steps for designing the special purpose machine. A.K.Hajra Chaudhary, Workshop Technology through which we had learned about different machining operations, parameters and mechanism of motion. V.B.Bhandari, Design of machine elements through which we had carried out design calculation regarding different machine elements

4.0 Work Implementation and Design Calculation

4.1 Introduction of project

Multi-spindle Drilling machines are used in mechanical industry in order to increase the productivity of machining systems. Such machines are equipped by spindle heads that carry multiple tools for performing machining operations. The most noteworthy aspect when using multi-spindle machines is the cycle time, due to parallel machining the total operating time is dramatically decreased. Added benefits include less chance for error, less accumulated tolerance error, and eliminate tools changes. In such a multi-spindle machine, a part to be machined is fixed on the table. It is not possible neither to fix two or more parts on the table nor use two or more tables at the same machine. Thus, in every moment only one part can be present on such a machine. No part can be loaded before the previous part is not finished.

In today’s market the customer demands the product of right quality, right quantity, right cost, & at right time. Therefore it is necessary to improve productivity as well as quality. One way to achieve this is by using multi spindle drilling machine. On the other hand, in order to meet quality requirements of final product. Another way of achieving good quality during production is to use the statistical quality control techniques at every stage of production. If the production is statistically under control the process can continue and there is no need for a change in the process. However, if it is not statistically under control, the assignable causes should be discovered and removed from the process.

4.1.1 Various Methods of Multi Spindle Head

Figure.4.1. Adjustable Multi Spindle Drilling Head

Figure.4.2. Fixed Multi Spindle Drilling Head

The various methods of multi spindle drilling head are:

Adjustable Multi Spindle Drilling Head Can be used in many components, where change the centre distance to some range. It will increase drilling capacity in single special purpose machine. These are the gear adjustable centre drilling head, in which drill Spindle is fitted on slotted plate (slotted plate is fixed in position in the gear box) and the gear is mounted on the drill spindle. By changing the gears as per required pitch circle diameter the drill spindle is adjusted in the slotted plate.

Fixed Multi Spindle Drilling Head- where it can't change the centre distance to some range. Features of both the type multi spindle drilling head are:

- By using this multi spindle drilling heads, increase the productivity is substantial.
- Time for one hole drilling is the time for multiple no. of holes drilling.
- Multi spindle drilling ensures the positional accuracy.

Multi spindle heads can be of fixed centre construction for mass and large batch production and for batch production, adjustable centre type design is offered. Here planetary gear train type fixed multi spindle drilling head is selected, because component P.C.D. is fixed (120mm) and having large batch production of the component it is easy to design & manufacture, quiet & efficient gearing.

4.2 Requirements of Industry

Raw material of Job : MS (C1008/1010)

Tooling material : HSS

No. of holes: 5 holes

Diameter of holes: 12mm

PCD: 120mm

Inner radius of circular disc: 90mm

Outer radius of circular disc: 145mm

Thickness of job: 18mm

Approximate production: 2400pieces/day

The Component drawing for which multi spindle drilling head is designed is as shown.

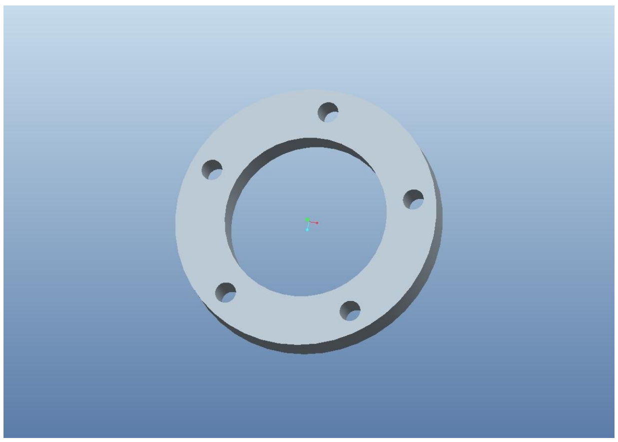

Figure.4.3. CAD Model of Component

By using this Multi Spindle Drilling head 5 holes of 12mm drill at a time. Drive is given by motion to main spindle, which drives planetary gear train fitted in the housing, then drill shafts rotate as per the gear ratio.

Layout of Multi Spindle Drilling Head is as shown.

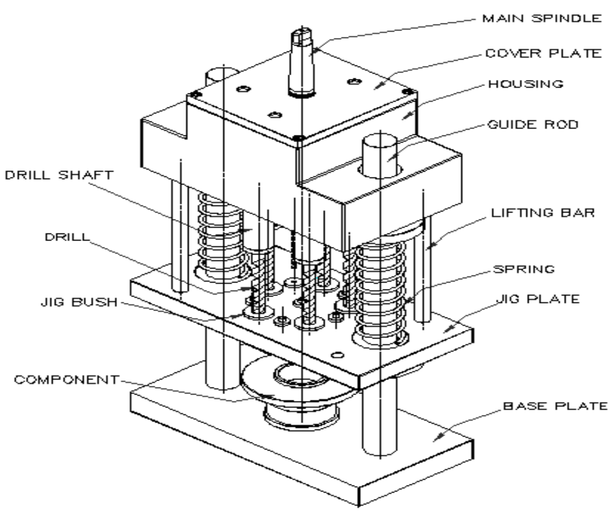

Figure.4.4. Multi Spindle Drilling Head

4.3 Manufacturing

The Multi Spindle Drilling head requires various components, the major components are gear box, drilling spindle, gear shafts, main spindle gear, drive gears, etc. It requires various machines to manufacture them like band saw machine for cutting operation, lathe machine for rough machining, drilling machine, surface grinding machine, cylindrical grinding machine, internal grinding machine, slotting machine, milling machine, hobbing machine etc.

4.4 Design Calculation

Following critical parameters are to be found out

Stroke of drilling approximately 65 mm

Non-productive time

Cutting parameter

Cutting speed

Feed depth

Material Removal Rate

Cutting force

Power

Cost comparison

Breakeven point

Calculation regarding to Drilling Parameters

Table.1. Cutting Condition

Work Material	Cutting Speed, *m/min*		
	Drilling	Reaming	Tapping
Free machining steel	20-30	11-15	9-12
Mild steels	20-23	11-14	11-12
Medium Carbon steels	14-20	9-14	8-11
Alloy steels	18-22	10-14	10-12
Tool steels	5-8	3-5	3-5
Stainless steels	12-15	9-25	8-9
Cast iron: Grey, Ductile, Malleable	20-23	12-17	9-12

Aluminium alloys	35-55	25-30	14-18
Copper alloys	30-45	20-40	9-12
Magnesium alloys	60-105	30-40	15-25
Titanium alloys	12-15	9-25	8-9

From above table cutting speed for mild steel (work piece material) 20-23 m/min

Feed

For Hole diameter 9 to 11.5 mm

Feed is 0.12-0.2 mm/rev

Diameter of drill D = 11 mm

RPM:

$Cutting\ Speed$

$$v = \frac{\pi * D * n}{1000}$$

$$n = 665.557 \approx 650\ rpm$$

$$Feed\ Rate = 0.2\ {}^{mm}/_{rev} * 650\ {}^{rev}/_{min}$$

$$= 130\ {}^{mm}/_{min}$$

Material Factor (K)

Table.2. Material Factor Selection Table

Work Material	Hardness HB	UTS kgf/mm^2	Material Factor K
Free machining steels	167	59.9	1.03
	183	63	1.42
Mild steels	121	44.1	1.07
	160	56.7	1.22
Medium carbon steels	152	55.1	1.15
	197	67.7	1.45
Alloy steels, Tool steels	163	58.3	1,56
	174	61.4	2.02
	229	78.8	2.1

	241	81.9	2.32
Stainless steels	187	64.6	1.56
	269	92.6	2.41

From Above table material factor for mild steel

$K = 1.22\ (with\ 160\ HB\ \&\ UTS\ 56.7\ {}^{kgf}/_{mm^2})$

Power at spindle (KW)

$$P = \frac{1.25 * D^2 * K * n * (0.056 + 1.55)}{10^5}$$

$$= 0.426\ KW$$

$$Power\ for\ 5\ Spindles = 5 * 0.426$$

$$= 2.13\ KW \approx 3\ hp$$

$$Assumed\ efficiency\ for\ gear\ drive = 90\%$$

$$Assumed\ efficiency\ for\ belt\ drive = 70\%$$

$$Power\ available\ at\ gear\ shaft = \frac{Power\ required}{Efficiency\ of\ gear\ train}$$

$$= 3.33\ hp$$

$$Power\ available\ at\ belt\ drive = \frac{Power\ at\ gear\ train}{Efficiency\ of\ belt\ drive}$$

$$= 4.76\ hp \approx 5\ hp$$

$$MRR = \frac{(\pi * D^2 * S * n)}{4}$$

$$= 1.35 * 10^{-5}\ {}^{m^3}/_{min}$$

$$= \frac{13500\ {}^{mm^3}/_{min}}{650\ {}^{rev}/_{min}}$$

$$= 20.769\ {}^{mm^3}/_{rev}$$

$Power\ at\ gear\ shaft = 3\ hp = 2.435\ KW$

$$P = \frac{2 *\ \pi * n * T}{60000}$$

$So, T = 36.0375\ Nm$

$T = F * R$

$$F = \frac{(36.0375 * 1000)}{30}$$

$= 1201.23\ N$

$$\sigma = \frac{F}{A}$$

$$A = \frac{\pi}{4} * d^2 = 585.96\ mm^2$$

$d = 27mm$

$$\frac{T}{j} = \frac{G * \theta}{l}$$

$l = 299.43\ mm$

$= 300\ mm$

$Checking\ the\ shaft\ in\ shear$

$$\frac{T}{j} = \frac{\tau}{r}$$

$\tau = 9.32\ {}^{N}/_{mm^2}$

$< 75\ {}^{N}/_{mm^2}$

$so\ the\ shaft\ is\ safe.$

$Now, smaller\ pulley\ diameter\ \ d_P = 75mm \approx 3\ inch$

$so, r_P = 37.5\ mm$

$Larger\ pulley\ diameter\ D_P = 150\ mm\ \approx 6\ inch$

$so, R_P = 75\ mm$

$Now, T = F_1 * R$

$$F_1 = \frac{36.0375}{0.075}$$

$F_1 = 480.5\ N$

Gear Design:

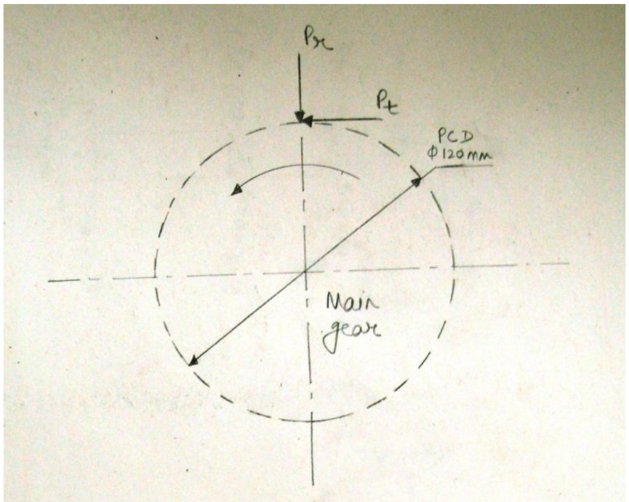

Figure.4.5.Forces acting on main gear

$PCD = 120\ mm$

$preferred\ module\ m = 4$

$m = \frac{d}{z}$

$z = \frac{120}{4} = 30\ teeth\ on\ gear$

$Addendum\ h_a = m = 4mm$

$Deddendum\ h_f = 1.25 * m = 1.25 * 4 = 5mm$

$Clearance\ c = 0.25 * m = 1\ mm$

$working\ depth\ h_k = 2 * m = 8mm$

$Whole\ depth\ h = 2.25 * m = 9mm$

$Tooth\ thickness\ s = 1.5708 * m = 6.28\ mm$

$Tooth\ space = 1.5708 * m = 6.28mm$

$Fillet\ radius = 0.4 * 4 = 1.6mm$

$P_t * \left(\frac{d}{2}\right) = M_t$

$P_t = \frac{36.0375}{0.06} = 600.625\ N$

$P_r = P_t \tan\alpha = 600.625 * \tan 20 = 218.6096\ N$

$Reactions\ at\ bearing$:

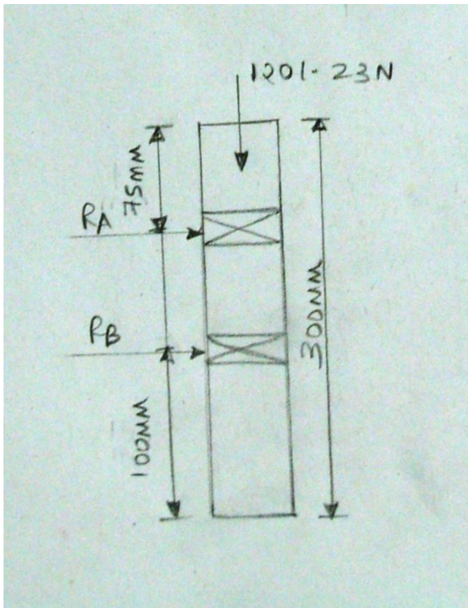

Figure.4.6.Reaction at bearing

$$\sum F_V = 0$$

$$R_A + R_B = 1081.125$$

$$\sum M_{@A} = 0$$

$$600.625 * 0.1 + R_B * 0.125 - 480.5 * 0.2 = 0$$

$$R_B = 288.3\ N$$

$$so, R_A = 792.825\ N$$

Bearing Selection:

Now, design of bearing is to be carried out as following.

$Axial\ load\ F_A = 1201.23\ N$

$Radial\ Load\ F_R = 1081.125\ N$

$Speed\ \ of\ ratation\ n = 650\ rpm$

$Service\ Factor\ s = 1$

$Assuming\ life\ of\ bearing\ 5\ years\ at\ 10\ hours\ per\ day$

$L_{10h} = 5 * 300 * 10 = 15000\ hours\ (Assuming\ 300\ working\ day\ in\ a\ year)$

$Life\ of\ Bearing$

$L_{10} = 60 * N * L_H = 60 * 650 * 15000 = 585 * 10^6\ rev = 585\ Million\ rev$

$$Now, P = X * V * F_R + Y * F_A$$

$$\frac{F_A}{F_R} = \frac{1201.23}{1081.125} = 1.11$$

$$Let\ us\ consider\ \frac{F_A}{C_0} = 0.25$$

$$so, X = 0.56\ and\ Y = 1.2$$

$$P = 0.56 * 1 * 1081.125 + 1.2 * 1201.23$$

$$= 2046.906\ N$$

$$C = P * \left(\frac{L_{10}}{10^6}\right)^{1/p}$$

$$= 17119.189\ N$$

$$Selecting\ bearing\ 6403$$

$$C_0 = 11\ kN\ and\ C = 18\ kN$$

$$\frac{F_A}{C_0} = \frac{1201.23}{11000} = 0.1092 < 0.25$$

$$Now\ as\ \frac{F_A}{C_0} = 0.1092$$

$$so\ taking\ X = 0.56\ and\ Y = 1.4$$

$$P = 0.56 * 1 * 1081.125 + 1.4 * 1201.23$$

$$= 2287.152\ N$$

$$C = P * \left(\frac{L_{10}}{10^6}\right)^{1/p}$$

$$= 19128.473\ N$$

So, bearing 6205 is selected.

4.5 Pro-E Models

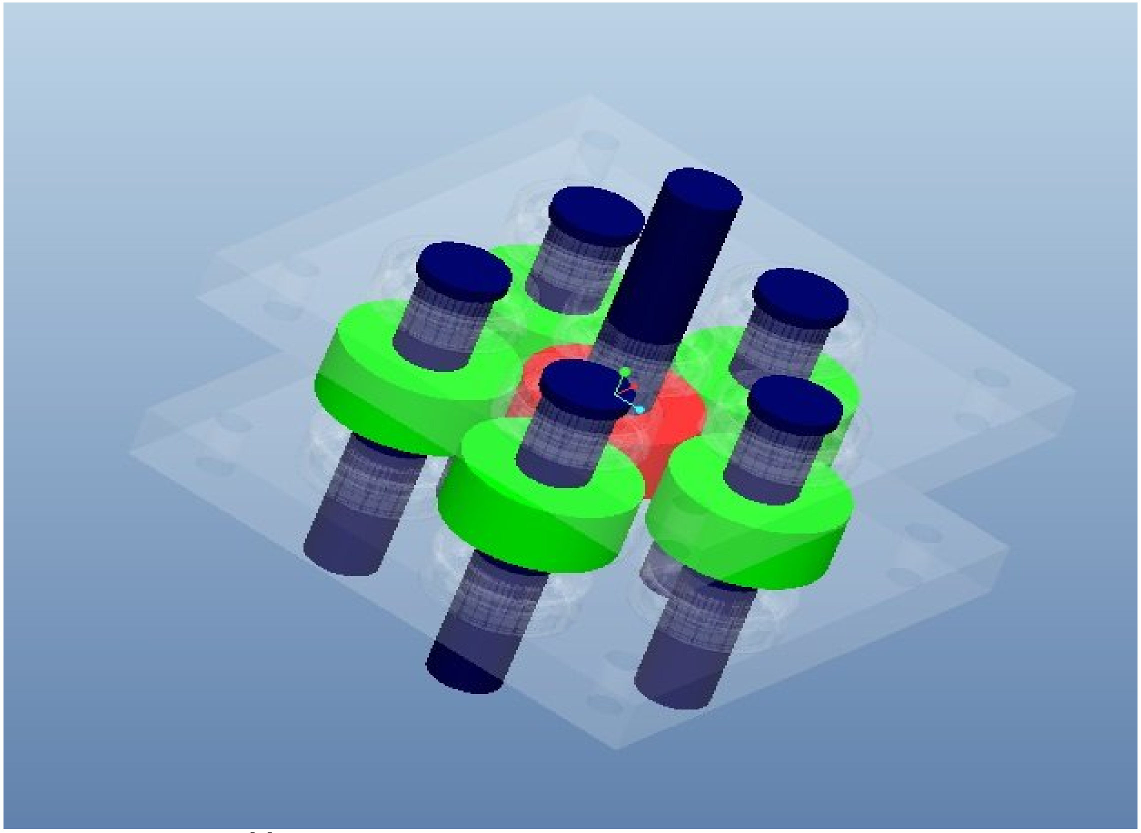

Figure.5.1. Pro-E model

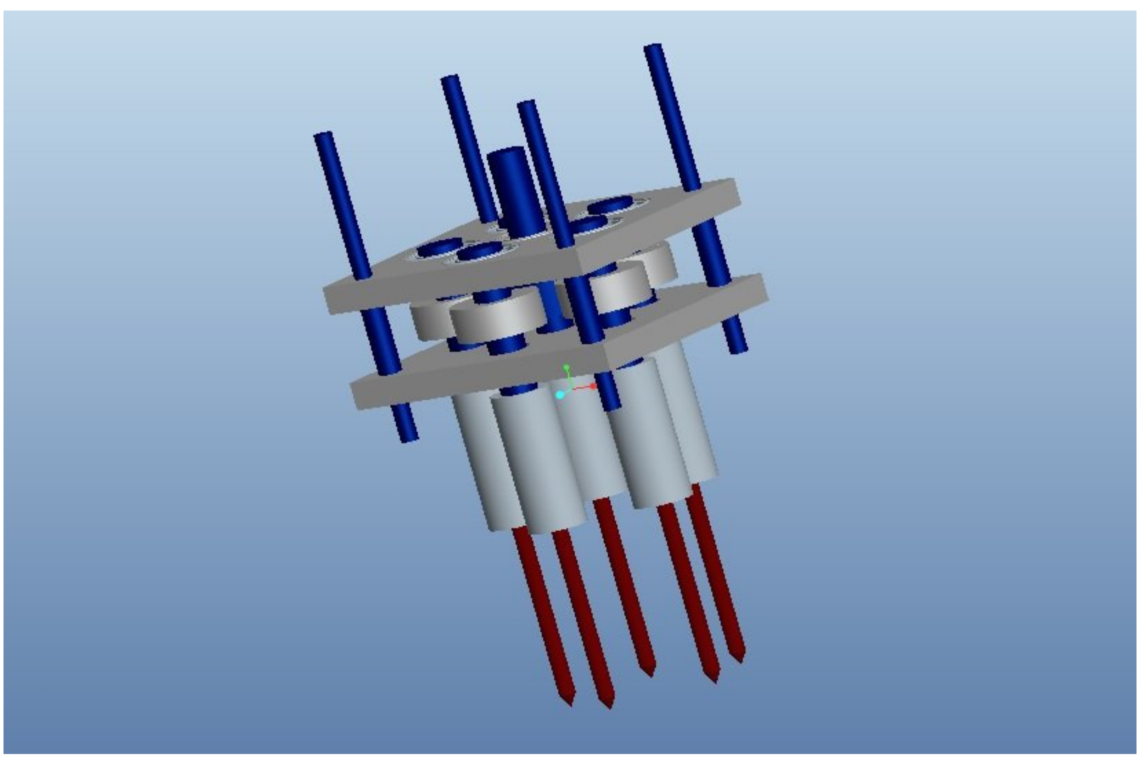

Figure.5.2. Pro-E model of head

5.0 Conclusion

1. By using multi spindle drilling head productivity is going to be increased. Because with the present process one hole produces at a time requires 12 seconds for each component i.e. 2400 parts are produced during 8 hours, but by using multi spindle drilling head cycle time approximately takes place 5 seconds i.e. 2400 parts may produce during 3.5 hours.
2. Possibility of hole missing is eliminated, because six holes drilled at a time.
3. The cost per piece is reduced. As seen in conclusion no.1 the production rate is approximately double by using multi spindle drilling machine.

6.0 Future Scope

This project work is still under process. The analysis of the Multi Spindle Drilling head under various stresses is to be done on analysis software. The further design of the body of drilling machine is to be designed and checked for the cutting force and different stresses. The structural analysis on the frame is to be done for the safety of machine and the operator. After the machine is ready for use, the breakeven analysis and cost comparison is to be carried out for the current conventional method of drilling machine

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