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RESEARCH ARTICLE

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# DESIGN AND DEVELOPMENT OF SQUARE HOLE BROACHING MACHINE

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**ABSTRACT**

Broaching machines are generally simple in construction because of no rotary motion .The broach tool is fixed to the linear spindle with adaptor .The linear spindle is coupled with pneumatic cylinder. The speed control of pneumatic cylinder is developed with the flow and pressure controls of pneumatic equipment. The machine is semi automated by using the pneumatic equipment and the limits for the movement of pneumatic cylinder piston can be operated by the limit switches.

A special fixture is to be developed to mount the component for square hole broaching operation. The machine is mounted on a bench for easy operation for operator. The broaching machine can be used for high quality production runs so the operation on broaching machine is expensive and high quality products can be machined. Here the broaching machine is designed and developed for making the square hole. It is capable of production rates as much as 25 times faster than any traditional machining process.

Broaching machines are limited to the large scale industries because high precision and accuracy so the cost of working is high but Our model is affordable to the workshop with low maintenance.

**Introduction**

Broaching is a machining process that involves the use of a multiple tooth cutting tool to remove material, called a broach. There are two main types of broaching: linear and rotary. In linear broaching, which is the more common process, the broach is run linearly against a surface of the work piece to effect the cut. Linear broaches are used in a broaching machine. Because of increasing diameter of the tool, the material removal will be in microns so we can obtain accuracy and precision on the work piece.

The shape of the machined surface is determined by the contour of the cutting edges on the broach, particularly the shape of final cutting teeth. Broaching is a highly productive method of machining. Advantages includes good surface finish, close tolerances, And the variety of possible machined surface shapes, some of them can be produced only by broaching. Owing to the complicated geometry of the broach, tooling is expensive. Broaching is a typical mass production operation.

It is a multiple tooth cutting operation with the tool reciprocating as in Sawing machine.

Machining operation completed in a single stroke. Teeth are at gradually increasing height Broach are originally developed for machining internal keyways.

It is extensively used in mass automobile component manufacture for various other surfaces.

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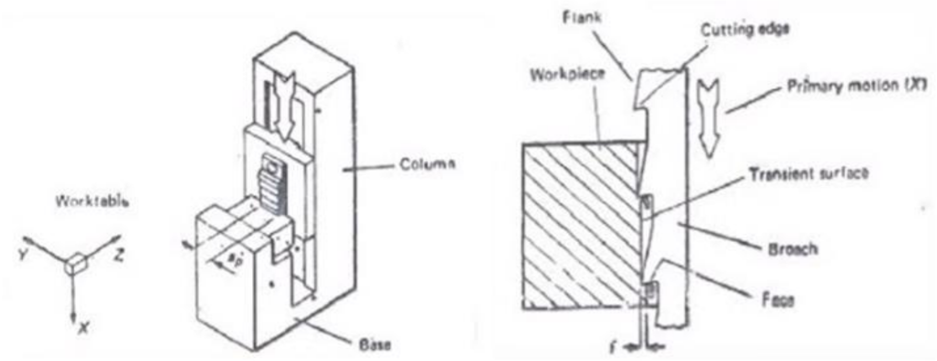

Fig. 1 Basic Components of a Broaching Machine

**Types of broaching machines :**

- Horizontal Broaching Machine
- Vertical Broaching Machine

**Horizontal Broaching Machine:-**

Mostly all the horizontal broaching machines are pull type, surface broaching, continuous broaching, and rotary broaching. Both internal and external broaching can be done. Consists of a box type bed having length is twice the length of stroke. All modern machines are provided with hydraulic drive housed in the bed. Job located in the adapter which is fitted on front vertical face. Small end is connected to hole of the job, and then connected to pulling end which is mounted on front end of ram. Ram is connected to hydraulic drive. Rear end is supported by guide.

Pull style machines are basically vertical machines laid on the side with a longer stroke. Surface style machines hold the broach stationary while the work pieces are clamped into fixtures that are mounted on a conveyor system. Continuous style machines are similar to the surface style machines except adapted for internal broaching.

Horizontal machines used to be much more common than vertical machines; however, today they represent just 10% of all broaching machines purchased. Vertical machines are more popular because they take up less space.

Broaching is often impossible without the specific broaching or keyway machines unless you have a system that can be used in conjunction with a modern machining centre or driven tooling lathe; these extra bits of equipment open up the possibility of producing keyways, splines and torx through one-hit machining.

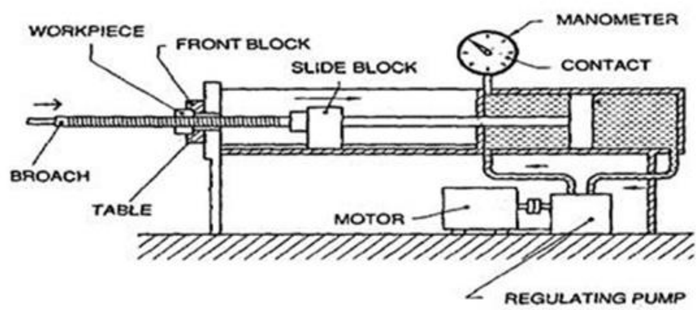

Fig. 2 Horizontal Broaching Machine

**Vertical broaching machine:**

The vertical broaching machine is preferred as it occupies less space and can be used for both Push and Pull Type of Broaching Operation. Vertical broaching refers to the type of machine that is used to broach a piece part. Vertical broaching is typically used to cut external slots, shapes, and forms. Each application of vertical broaching usually consists of a custom made tooling package, and a fixture to hold and secure the piece part. An example of a vertical broaching application would be cutting a deep slot in a large industrial valve stem.

**Vertical Broaching Advantages**

- Typically faster than traditional horizontal broaching methodology, without compromising length or size of cut

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- Machinery can be specifically matched to the part being cut, for a more efficient cutting operation.
- Well suited for cutting internal shapes and forms quickly, while still holding close tolerances.
- Extremely economical cutting process, very often superior to milling.
- Tooling can be modular in design, allowing for variations of the same basic cutting pattern.

Vertical broaching machines come in many varieties and adaptations, but in general any machine in which the ram is mounted vertically, instead of horizontally, is classified as a vertical broaching machine. In the case of surface broaching, the ram, which carries its broaching tools mounted in holders, typically moves past the piece part. The piece part is secured in a fixture using hydraulic or mechanical clamps. Some traditional vertical broaching machines are dual ram, meaning that there are actually two rams mounted on the same machine, and sharing the same hydraulic and mechanical systems. In many cases the part is secured in a shuttle table or swing table, so that the operator can load one piece to be machined, while the other ram is cutting another piece at the same time. Dual ram vertical broaching machines can also be used to cut two or more successive operations on the same part. Vertical broaching machines can also be used to cut internal shapes and forms, and can perform very much like traditional horizontal machines. In each case either the piece part is secured while the broaching tool moves past it, or the broach itself is secured while the piece part travels on a table. The former type of machine can be either of the vertical pull-down or pull-up variety (referring to the motion of the broaching tool). The latter is typically referred to as a table-up vertical broaching machine.

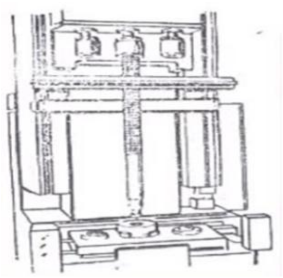


Fig. 3 Typical Vertical Broaching Machine

**Square Broach Tool Specifications** :We are machining aluminium material so we selected $m^2$ high speed tool for broach tool.

**TYPICAL CHEMISTRY**: C = 0.83; Cr = 4.15; Mo = 5.00; V = 1.90; W = 6.35

**MACHINABILITY**: When properly annealed, M2 has a machinability rating of 65 percent when compared to a 1% Carbon Steel rated at 100.

**DIMENSIONAL STABILITY**: When air quenched from the proper hardening temperature, this grade can be expected to expand approximately .001 in. per in. Note: Distortion (bending, bowing and twisting) and part geometry can add to the variations in movement of a part that is being hardened.

**THERMAL CYCLING**: In order to avoid decarburization, this grade should be annealed and/or hardened in a controlled neutral atmosphere, vacuum, or neutral salt furnace environment.

**APPLICATIONS**

M2 tool steels are suitable for making cutting tools.

**THE MATERIAL DESCRIPTION**

Length of the raw material =100mm

Thickness of the raw material =8mm

Weight of the raw material = 9.77gm

**Mode of cutting:**

The tooth rise is provided in the broach:

a) Depth wise

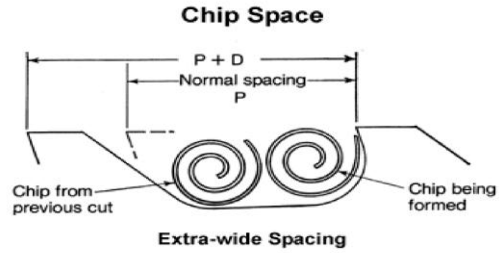
b) Side wise

c) Combination of both

If chip is removed in layers perpendicular to the axis of broach it is easy to manufacture. In other cases manufacturing becomes difficult especially for combined mode of cutting.

The choice of mode of cutting depends on the functional surface to be broached and on the strength of the component in the direction of broaching.

Selection of gullet:




Gullet is provided to accommodate the chips formed during the broaching by each of teeth which cannot escape until the enclosing adjacent teeth have cleared the component. Chip space is limited by the pitch of the tooth and in small diameter broaches.

**Pitch:** It is the distance between the two cutting edges. It depends upon

1) The chip thickness
2) Length of cut
3) Type of work material
4) Number of components

The general formula for pitch = 0.35 length of job

Or = 2.75H

Generally the pitch is constant when a tooth leaves the work, resistance will be less than the broach begins to accelerate, so next tooth starts to cut at high speed and produces a shocks.

If pitch is constant, the shocks occur at regular intervals and set up vibration. This can be reduced by using different pitches.

**FORCE CALCULATIONS**

Coefficient of friction between chip-tool interface is given by

$\mu = \tan \beta$

$Fs = \tau\, t1b / \sin\phi$

**Cutting forces of a broach**

No, of tooth cut simultaneously 'n' $n$=LP

Here L =100mm

P = 5.60

n = 17.85

= 18 tooth

**Max force in the operation of grinding:**

$F_{max}$ = a [$mm^2$ ] ×specific resistance × n

= (4.76 ×100) × 0.025 ×18

= 214.2 KN

**Estimated load =** width of cut (mm)

× Number of engaged cutting teeth

× Specific cutting resistance (KN/$mm^2$)

**=** 4.76×2.30×0.025

= 0.2737

**Safety load (KN)** = 0.2737 ×1.8 = 0.49266 KN

**Design of Vertical Broaching Machine:**

Our Vertical Broaching Machine is semi-Automated operated by Pneumatic mechanism.

The major components that are used are:-

- Pneumatic Cylinder :- 125 x 25 mm
- Plates of 5 mm thickness of dimensions :- 300 x 300 mm with Height 460 mm
- Cylindrical Pin: - Used for connecting pneumatic cylinder piston with collet.
- AC to DC Rectifier :- 220V AC to 24V DC
- Limit Switches:- 2 nos, The limit Switches are used for controlling the electrical circuit. These switches act as a limit for the piston stroke. The movement of the piston is controlled by the limit switches. The electrical circuit i.e ON and OFF is also controlled by this Actuation of limit Switches.
- FRL :- Filter Regulator Lubricator
- Direction Control Valve :- 24V

The dimensions of the frame are selected based on the Pneumatic Cylinder specifications.

As the machine is Semi Automated so the Pneumatic Equipment is controlled by the Electrical Connections.

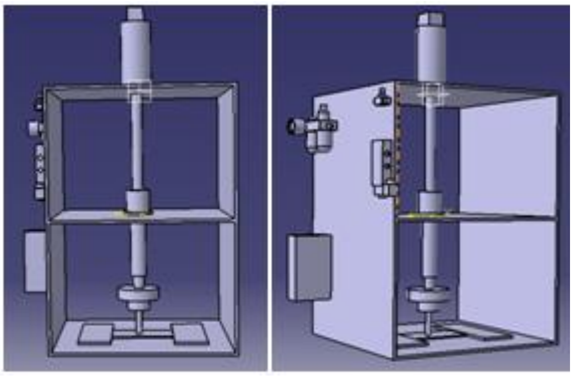


Fig. 4 Design Of Vertical Broaching Machine In CATIA SOFTWARE

**Fabrication:** Fabrication is the building of structures by cutting, bending, drilling, welding and assembling processes. It is a value added process that involves the creation of machines, parts, and structures from various raw materials.

**Following processes are used while fabricating the machine:**

- Tig Welding
- Milling
- Lathe Machine :- Turning and Facing
- Drilling
- Tapping
- Grinding
- Boring

**Tig Welding: Gas tungsten arc welding** (**GTAW**), also known as **tungsten inert gas** (**TIG**) **welding**, is an arc welding process that uses a non-consumable tungsten electrode to produce the weld. The weld area and electrode is protected from oxidation or other atmospheric contamination

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by an inert shielding gas (argon or helium), and a filler metal is normally used, though some welds, known as autogenous welds, do not require it. A constant-current welding power supply produces electrical energy, which is conducted across the arc through a column of highly ionized gas and metal vapours known as a plasma.

**Mild Steel** Plates of 5 mm thickness are used for building the frame using TIG Welding Process.

The length of the machine is 300mm, Width is 300 mm and the Height of the total machine is about 460 mm.

No. of 300 x 300 mm plates: 3

No. of 460 x 300 mm plates:2

The middle plate i.e 300 x 300 mm plate is welded at a height of 230 mm using TIG Welding.

By using tack welding using TIG Welding process the Plates are joined.

**Boring :-** Boring is made for the 3 horizontal Plates i.e at the centre of the plates in order to maintain the axis of the cylinder stroke in $90^0$.

At the top of the plate the Pneumatic Cylinder is mixed.

At the middle plate Bush is fixed for guiding the Pneumatic Cylinder piston as well as for supporting the stroke arrangements.

At the centre of the horizontal bottom plate the boring is made for the fixture arrangement through which the broach tool will pass through it.

The cylindrical pin of 80 x Ø17 mm is made for aligning Cylinder Piston rod and collet. The cylindrical pin is hardened and grounded and it is External threaded at one side and internal threaded at another end.

Turning and Facing operations are using for manufacturing Guiding Bush, Locating Bush and locating pin.

Drilling operation is made for the vertical plates for holding the pneumatic and electric equipment.

Grinding Process is used for removing irregularities and for better surface finish of the fixture plates for holding the Work piece.

**Pneumatic Connection**

**The following are the Pneumatic Equipments used:-**

- **Pneumatic Cylinder :**

Stroke: - 125 mm

Bore: - Ø25

- **FRL Unit**: Filter Regulator Lubricator, Air leaving a compressor is hot, dirty, and wet—which can damage and shorten the life of downstream equipment, such as valves and cylinders. Before air can be used it needs to be filtered, regulated and lubricated. An air line filter cleans compressed air. It strains the air and traps solid particles (dust, dirt, rust) and separates liquids (water, oil) entrained in the compressed air. Filters are installed in the air line upstream of regulators, lubricators, directional control valves, and air driven devices such as cylinders and air motors.
- **Direction Control Valve:** Direction Control valve acts as a mediator between FLR Unit and Direction Control valve which allows the pressured air from the FRL Unit to Pneumatic Cylinder. The Direction Control Valve has 2 Intel and 3 exhaust Valves. When the electric power supply is given to the DCV, the rod which is placed inside the DCV gets magnetised and pulled down and flow of pressured air from FLR is send to the Cylinder for the Piston Movement. When the electrical supply is disconnected it is demagnetized and it guides the Exhaust air from the cylinder to the outlet ports of the DCV.
- **Pressure control valve: -** Pressure Control Valve is used for regulating the pressure for our requirement.

**Electric Connections:**

- 220V AC to 24V DC Rectifier is used for Actuating the Direction control valve.
- Limit Switches are for connecting and disconnecting the electrical circuit while piston movement.
- Aluminum strip which is connected to the piston regulates the electric circuit by actuating and deactuating the Limit Switches while piston movement.

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Fig. 5 Pneumatic Circuit

**Working**:When the pressurized air from the Compressor is supplied to the FLR Unit, The pressurized air will be filtered and lubricated and will further move to the direction control valve. the direction control valve is supplied with electricity of 220V AC to 24V DC Rectifier when the push button is activated. Now the pressure is passed through DCV to PCV and then to Pneumatic Cylinder which leads to the movement of the piston and the tool will pass through the work piece and square hole is obtained. When the stoke completes, at the end of the stroke the limit switch is activated by the aluminium strip and the circuit breaks so the DCV gets deactivated and the exhaust air is send to the outlet ports of the DCV and simultaneously piston moves to its original position

Fig. 6 Final Broaching Machine

**RESULT**

The below figure illustrates the actual fabrication of Square hole Broaching machine by considering the above design specifications.

The holes on the work piece are done by using Broaching tool. When the push button is pressed then DCV will get actuated and allows the pressurized air from FRL unit then it will pass through the pneumatic cylinder and this pressurized air force causes the piston to move down towards the work piece and machining is done in the form of Square hole.

Thus the required square hole of 4.75 mm is obtained on the 3 mm thickness Aluminium sheet.

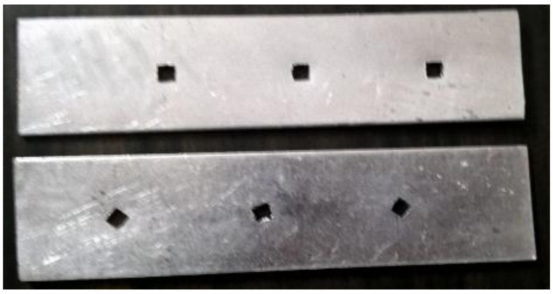

Fig. 7 Broaching Operations Performed On Test Pieces

**Conclusion**

We aimed to determine Design and Develop a Square Hole Broaching Machine for making the required shape of holes by changing the Tool and can be used for the small and medium scale industries at affordable cost. The fabrication of Square hole Broaching Machine is done by using the operations: - Tig Welding, Milling, Drilling, Grinding, Boring, Tapping, Turning and Facing. The broach obtained is a push type broach which required special equipments such as FRL, DCV, PCV and Pneumatic Cylinder to perform the process. It is kept on a work piece which is pre machined to obtain a small hole and is pressed under the radial drilling machine.

Thus the square hole of accurate hole diameter is obtained in only one pass. These square holes are mainly used in making of clocks, car sensor holes, household mixers to hold the blade.

**Acknowledgements**

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