6

BORING MACHINES

6.1 INTRODUCTION

The boring machine is one of the most versatile machine tools used to bore holes in large and heavy parts such as engine frames, steam engine cylinders, machine housings, etc. which are practically impossible to hold and rotate in an engine lathe or a drilling machine. Boring machines have, therefore, been developed primarily to do this. In addition to its primary purpose of boring the range of speeds and feeds provided to the various traversing components allow drilling, milling and facing to be performed with equal facility. By the fitting of simple attachments, the use of the machine can be extended still further to include screw cutting, turning, planetary grinding, or gear cutting.

6.2 TYPES OF BORING MACHINES

The boring machines may be classified under the four headings :

1. Horizontal boring machine.
   (a) Table type.
   (b) Floor type.
   (c) Planer type.
   (d) Multiple head type.
2. Vertical boring machine.
   (a) Vertical turret lathe.
   (b) Standard vertical boring machine.
3. Precision boring machine.
4. Jig boring machine.
   (a) Vertical milling machine type.
   (b) Planer type.

6.3 HORIZONTAL BORING MACHINE

In a horizontal boring machine, the work is supported on a table which is stationary and the tool revolves in a horizontal axis. A horizontal boring machine can perform boring, reaming, turning, threading, facing, milling, grooving, recessing and many other operations with suitable tools. Workpieces which are heavy, irregular, unsymmetrical or bulky can be conveniently held and machined. Different types of horizontal boring machines have been designed to suit different purposes. Fig.6.1 illustrates a horizontal boring machine.

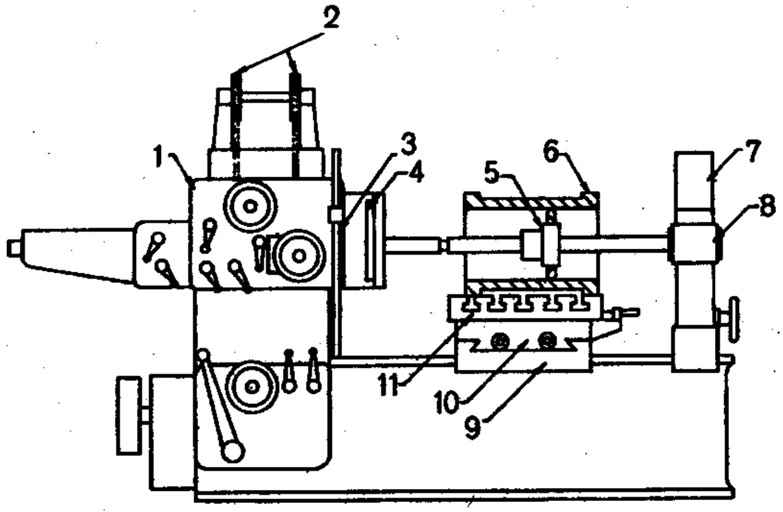


Figure 6.1 Horizontal boring machine

1. Headstock, 2. Pulley for counter balancing weight of headstock, 3. Headstock elevating screw, 4. Boring head, 5. Boring cutter on boring bar, 6. Work, 7. End supporting column, 8. Bearing block, 9. Saddle, 10 Cross-slide, 11. Table.

Table type horizontal boring machine : The table type is the most common of all horizontal boring machines. This is so named, because the work is mounted on the table which is adjustable and feed is given by hand or power, lengthwise or crosswise with respect to the bed of the machine. The headstock may be adjusted vertically on the column and the spindle has a horizontal feed

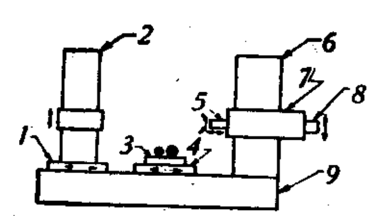


Figure 6.2 Table type horizontal boring machine

1. Column base, 2. End supporting column, 3. Table, 4. Saddle, 5. Spindle, 6. Headstock supporting column, 7. Headstock, 8. Motor, 9. Bed.

motion. The machine essentially consists of a bed, headstock supporting column, end supporting column, headstock, saddle and table, and boring bar. The table, saddle and headstock may be adjusted by leadscrews using micrometer dials. This type of machine is suitable for general purpose work where other operations, in addition to boring, are required to be performed. A block diagram of a table type machine is shown in Fig.6.2.

Floor type horizontal boring machine : The floor type horizontal boring machine having no table uses a stationary floor-plate on which T-slots are provided to hold the work. The headstock supporting column and the end supporting column and the end supporting column are mounted on the runways which are placed at right angles to the spindle axis. Thus any crosswise adjustment or cross-feed movement is provided by the spindle itself and not by the work. This is so designed for holding very large and heavy workpieces which are difficult to be mounted and adjusted on a table. A block diagram of a floor-type machine is shown in Fig.6.3.

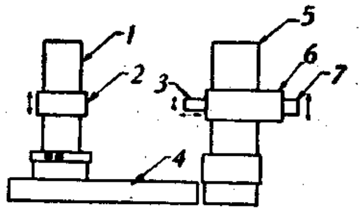


Figure 6.3 Floor type horizontal boring machine

1. End supporting column, 2. Column base, 3. Spindle, 4. Floor plate, 5. Headstock, 7. Motor.

Planer type horizontal boring machine : The planer type horizontal boring machine resembles the table type but table slides directly on the bed instead of on a saddle and reciprocates at right angles to the spindle similar to a planer. The end supporting column and headstock supporting column may be adjusted towards or away from the table for accommodating different widths of work. This type of machine is suitable for supporting a long work. A block diagram of a planer type machine shown in Fig.6.4.

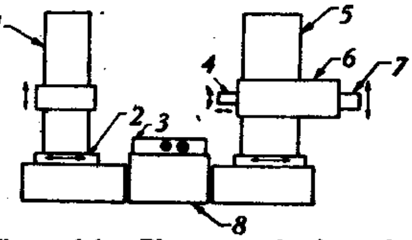


Figure 6.4 Planer type horizontal boring machine

1. End supporting column, 2. Column base, 3. Table, 4. Spindle 5. Headstock supporting column, 6. Headstock, 7. Motor, 8. Bed.

Multiple head type horizontal boring machine : The machine resembles a double housing planer or a plano-miller. The table is supported on a long bed on which it reciprocates. There are two vertical columns at two sides of the bed, nearly at the middle of the bed. The two columns are bridged by a crossrail. The machine may have two, three or four headstocks. This type of machine may be used both as a horizontal and vertical machine. The machining operations can be performed simultaneously at different work surfaces. A block diagram of the machine is shown in Fig.6.5.

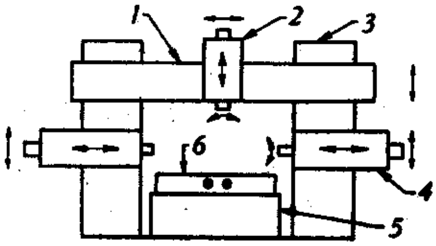


Figure 6.5 Multiple head type horizontal boring machine

1. Crossrail, 2,4. Headstocks, 3. Column, 5. Bed, 6. Table.

6.4 PART OF A HORIZONTAL BORING MACHINE

The different parts of a horizontal; boring machine are illustrates in Fig.6.1

Bed : The bed is that part of the machine which is fitted on the floor of the shop and has a box like casting. The bed supports the columns, tables and other parts of the machine.

Headstock supporting column : The column provides support to the headstock and guides it up and down accurately by the guide ways provided on the face of the column. The column which is hollow houses the counterweights of the headstock, and is heavily ribbed to add rigidity. Some columns are stationary, others may be made to slide along the bed.

End supporting column : The end supporting column situated at the other end of the bed houses the bearing block for supporting a long boring bar. The column may be adjusted on the sideways of the bed towards or away from the spindle for supporting different lengths of boring bars or it may be moved at right angles to the spindle as in the case of a floor type machine.

Headstock : The headstock mounted on the column supports, drives, and feeds the tool. The spindle revolves within a quill. The spindle provides rotary movement to the tool and the quill may be moved longitudinally to provide feeding movement of the boring cutter or any other tool mounted on the spindle. The spindle nose is provided with a taper hole for receiving taper shanks of the boring bar or any other tool. The headstock may be moved up and down on the column for setting the tool for different heights of the work. The headstock and the end supporting bearing block are raised or lowered in unison by the help of screws.

Saddle and table : The table supports the work and is therefore provided with T-slots for clamping the work or for holding various devices. The saddle permits the work to be moved longitudinally on the bed. The table may be moved crosswise on the saddle. These movements may be slow or rapid and is performed by hand or power.

Boring bars : The boring bar supports the cutter for boring operations on jobs having large bore diameters. For short holes the bar may be supported on the headstock spindle end only, whereas for long work the bar is supported on the spindle end and on the column bearing block.

6.5 SIZE OF A HORIZONTAL BORING MACHINE

The size of a horizontal boring machine is specified by the diameter of its spindle in mm. The diameter of the spindle varies from 75 to 355 mm. To specify a boring machine fully other important dimensions such as spindle motor horse power, column heights, size of the table or size of the floor plate, spindle speeds, feeds and length of feeds, floor space required, weight of the machine, etc. should also be stated.

6.6 BORING MACHINE MECHANISM

The machine contains different controls for movements of the different parts of the machine. A table type machine has the following movements :

1. The headstock and the end supporting block may be moved up and down.
2. The spindle may be rotated. The spindle has different speeds.
3. The spindle may be, moved in or out by hand or power for feeding.
4. The saddle and the table may be moved by hand or power.
5. The columns may be moved by hand or power.

All these movements may be given independently or in combination. As all the contrôls are housed in a particular position of the machine the operator may give a closer attention to the work while controlling the machine.

6.7 WORK HOLDING DEVICES FOR HORIZONTAL BORING

The work may be supported on the table by the conventional work holding devices or by special fixtures. Conventional work holding devices comprise of T-bolts and clamps, angle plates, step blocks, etc. Special jigs are used in mass production work. The jig locates the work and supports and guides the boring bar.

6.8 HORIZONTAL BORING MACHINE OPERATIONS

In boring, the work remains stationary and the tool is rotated. Holes are bored by using boring bars. Multiple holes may be bored one after another by changing the position of the workpiece and aligning it each time with the boring bar. To bore a hole, the boring bar is fitted to the spindle and the cutter is adjusted in the boring bar

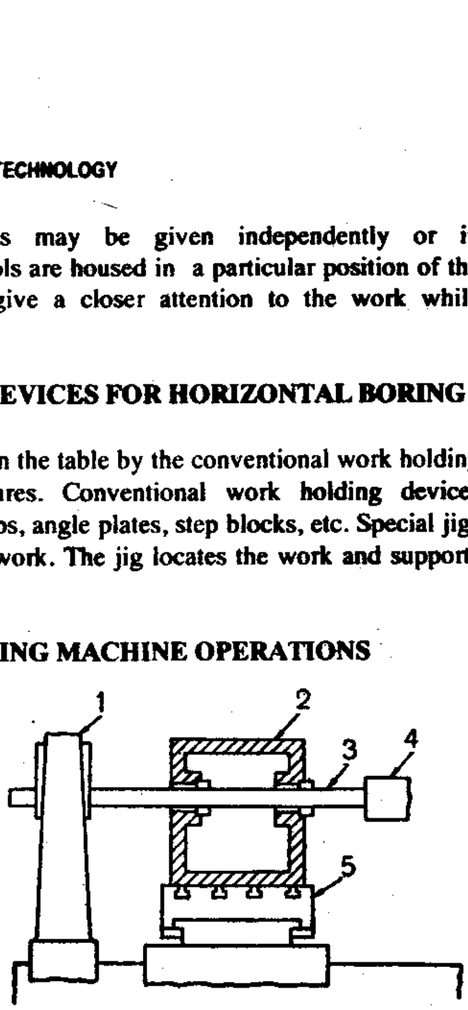


Figure 6.6 Boring machine operation
1. End supporting column, 2. Work,
3. Boring bar, 4. Spindle, 5. Table.

to the required dimension and a light cut is then taken. The bore is measured, required speed and feed adjusted and the cut is then completed. Fig.6.6 illustrates a boring operation.

In a boring machine, for milling operation, and type of milling cutter may be fitted to the spindle. Facing cutter is used for machining flat vertical surfaces. For face milling operation, the tool or work may be fed to complete the cut. End mills are used to produce grooves and slots. Fig.6.7 illustrates a face milling operation.

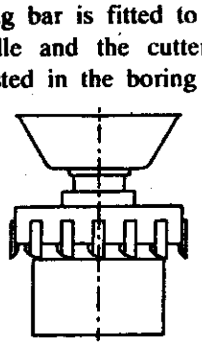


Figure 6.7 Face milling operation

All other operations such as drilling, reaming, counterboring, tapping and spotfacing operations may be performed similar to boring operations. Fig.6.8 illustrates a drilling operation.

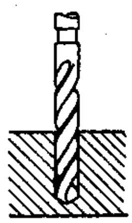


Figure 6.8 Drilling operation

6.9 BORING TOOL MOUNTINGS FOR HORIZONTAL BORING

The different equipment for mounting cutters in a horizontal boring machine are :

1. Boring bar.
2. Boring head or cutter head .
3. Facing head.

Boring bar : Ordinary boring operations are carried out with tools mounted on a bar held in spindle having Morse taper hole. The maximum diameter of the bar employed is ordinarily not larger than the spindle diameter, and the length is such that it can reach the end column support. A boring bar should be of maximum diameter and minimum length to reduce bending or vibration and it may be supported in various ways to suit to different types of workpieces. The different methods of supporting boring bars are described below.

Supported by spindle : For boring blind holes, bars are used to be supported at the spindle end only. This type of bar is called *stub bar*.

Supported by spindle and end column : While boring long open holes, boring bars are supported at the spindle end and by a bearing block at the other end mounted on the end supporting column. This type of bar is called *line bar*. Fig.6.6 illustrates a line bar.

Supported by the workpiece : In some types of work, the bar may be supported in the bored holes of the work by bushings. This type of support takes much of setting time, and is used in stray jobs where only one or two similar articles are machined that do not call for a special jig to be manufactured. Fig.6.9 illustrates a boring bar supported by the bushings in the workpiece.

Supported by boring fixture : In mass production work boring jigs are used. They locate, guide and support the bars at intermediate points. Fig.6.10 illustrates a boring bar which is supported by a boring fixture.

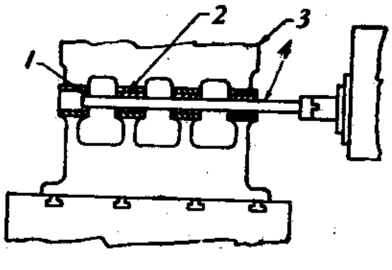


Figure 6.9 Boring bar supported by workpiece

1. Boring tool, 2. Bushing, 3. Work, 4. Boring bar.

Boring bars used for boring smaller diameter holes are made of manganese-chrome alloy steel annealed to relieve internal stress. Heat treated bars of medium carbon steel alloyed with chromium and manganese are used where severe cutting condition exists.

Method of attaching cutters on boring bars : There are various methods of attaching cutters to boring bars. Slots are cut at intervals along the entire length of the bar so that the cutter may be set at the required position. Different types of cutters are used for different classes of work. The most important type of cutter is a *fly cutter*. It consist of a single point cutting tool mounted on a bar. The adjustment of the fly cutter may be made by a micrometer dial. Fig.6.11 illustrates a fly cutter.

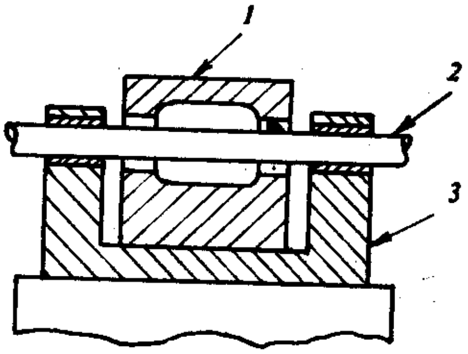


Figure 6.10 Boring bar supported by boring fixture

1.Work, 2. Boring bar, 3. Boring fixture.

Double cutters are widely used in production boring as the machining time is reduced to a great extent compared to that of a single fly cutter. Fig.6.12 illustrates a double cutter.

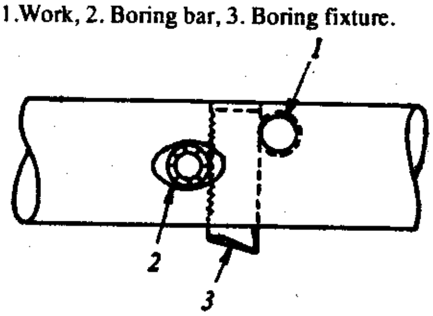


Figure 6.11 Fly cutter

1.Lock screw, 2. Micrometer dial, 3. cutter.

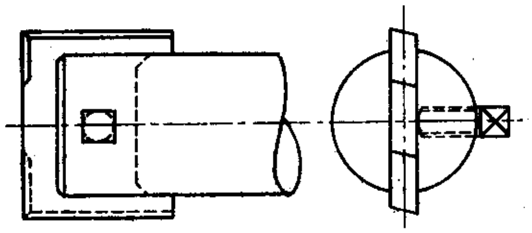


Figure 6.12 Double cutter

Boring head or cutter head : The boring heads are used for mounting cutters while machining large diameter holes where a standard boring bar is unsuitable due to smaller diameter or excessive overhang of the cutter. Boring heads having maximum permissible diameter are bolted or keyed on the spindle. They hold two or more cutters. This device amply supports the tool and reduces machining time due to the larger number of cutting edges. The cutters may be adjusted by micrometer dials. Fig.6.13 illustrates a boring head.

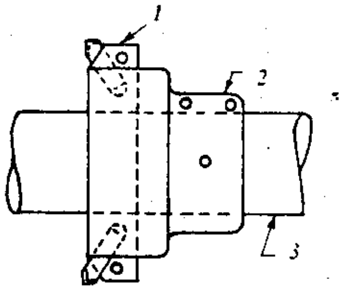


Figure 6.13 Boring head
1. Cutter, 2. Boring head, 3. Boring bar.

Facing head : The facing heads are mounted on the end of the spindle. It comprises of a flange provided with a diametrical slide-way on which the tool carrying a bracket may be adjusted. The bracket may be fed radially or located and clamped at the centre for supporting along boring

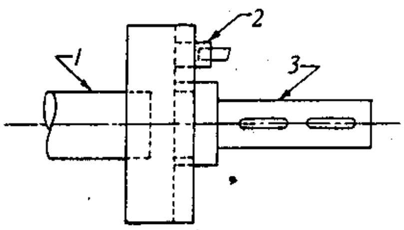


Figure 6.14 Facing head
1. Spindle, 2. Tool on sliding bracket, 3. Boring bar.

bar. The facing head enables enlarging of large diameter holes, facing and external turning operations. Fig.6.14 illustrates a facing head.

6.10 BORING TOOL

Cutting tools used in boring bars are of different shapes and sizes for different types of operations. Fig.6.15 illustrates a typical boring tool.

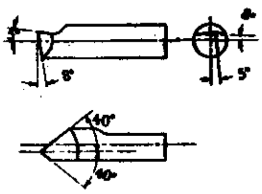


Figure 6.15 Boring tool

6.11 VERTICAL BORING MACHINE

A vertical boring machine illustrated in Fig.6.16 is so named because the work rotates on a horizontal table about a vertical axis and the tool is stationary except for the feed. The machine may be looked upon as a vertical lathe with its headstock resting on the floor and its large faceplate or chuck lying in a horizontal plane. This specific design of the machine provides certain distinct advantages over a lathe for a particular class of work. The advantages are :

1. Large diameter and heavy workpieces, similar to chucking jobs on a lathe, may be set up more conveniently and quickly than on a lathe. It is easier to lay a workpiece down on the table rather than to hang it up.
2. The table and the work it carries rotate in a horizontal plane, and there is no overhang as in the case of a lathe spindle, and consequently any chance of bending the spindle which supports the heavy workpiece is eliminated.
3. The table being horizontal, the diameter of the table may be designed as large as possible to support large workpieces.
4. Multiple tooling may be adapted in the case of a vertical boring machine with its turret type tool post increasing the rate of production.

A vertical boring machine is particularly adapted for holding and machining large, heavy, and cumbersome workpieces. The typical works are : large gear blanks, locomotive and rolling stock tires, steam and water turbine castings, fly wheels, large flanges and number of circular shaped parts. The size of the work is limited by the diameter of the table. The machine can take only circular cut.

The vertical boring machine is of two types : (1) vertical turret lathe, and (2) standard vertical boring machine.

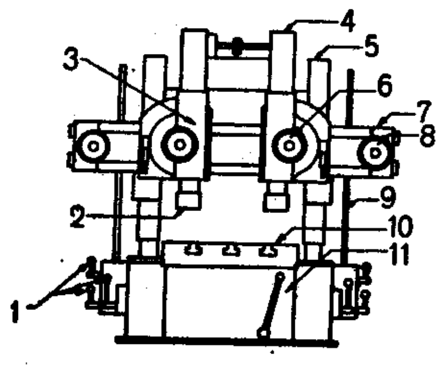


Figure 6.16 Vertical boring machine
1. Feed adjusting levers, 2. Tool box, 3. Tool head assembly, 4. Ram, 5. Housing, 6. Handwheel for ram adjustment, 7. Crossrail, 8. Fine hand adjustment for ram, 9. Crossrail elevating screw, 10. Table, 11. Bed.

Vertical turret lathe : This type of boring machine combines the advantages of the vertical boring mill and the turret lathe. A vertical boring machine of smaller size is called a vertical turret lathe. It has an indexable turret mounted upon the crossrail above the table for multiple tooling. A four station square turret side-head which enables facing, turning under-cutting and many other operations is mounted at the side of the lathe. The crossrail may have vertical adjustments and for ease of operation it is counter balanced. The turret mounted on the saddle may be moved crosswise by hand or power. The turret may also be moved in a vertical plane. The side-head also has up and down and to and fro adjustments from the centre of the table. The machine is suitable for boring and turning railroad wheels, piston rings, gear blanks, etc. A vertical turret lathe is shown in Fig.6.17

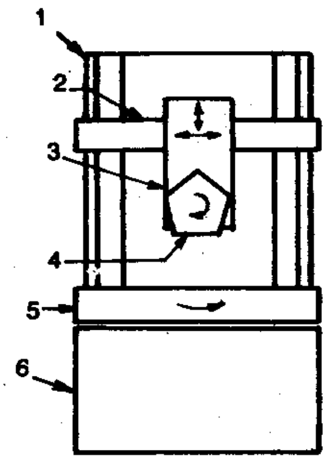


Figure 6.17 Vertical turret lathe
1. Housing, 2. Crossrail, 3. Saddle, 4. Turret, 5. Table, 6. Bed.

Standard vertical boring machine : Vertical boring machines are larger in size than vertical turret lathe and there is no turret head. The machine is provided with two vertical heads and one or two side-heads. The tool-heads are mounted on the crossrail which may be adjusted up and down. The saddle of the tool-head may be fed crosswise and the tool head ram fed in vertical direction. The ram heads can be swiveled to incline the ram upto 60° on either side of the vertical axis for machining tapers. The machine is particularly intended for boring large, cylindrical and symmetrical workpieces. Turbine castings, locomotive tires, etc. are some of the common examples which need vertical boring machine. A standard vertical boring machine is shown in Fig.6.16.

6.12 VERTICAL BORING MACHINE PARTS

Bed : The bed of a boring machine consists of a hollow circular casting grouted on the floor. The top of the bed is finished to provide a bearing surface for the table. It houses the spindle and a pinion for rotating the table.

Table : The boring machine table which may be rotated is a circular casting mounted on the top of the bed. The horizontal surface of the table is finished and is provided with T-slots or chuck jaws for holding and clamping the work. Underside of the table may be provided with bevel gear teeth which meshes with a driving pinion. In large machines, a helical pinion meshes with a gear attached to the underside of the table.

Housing : The housings are two vertical members which rise from the two sides of the bed, They are made of ribbed construction to ensure rigidity of the machine. The housings are joined at the top by a cross member. The vertical front face of the housings are accurately machined to form guideways on which the crossrail slides.

Crossrail : The crossrail is the horizontal member of the rectangular casting mounted on the two front faces of the housings. The crossrail may be moved up and down by rotating screws for accommodating different heights of work. The vertical front face of the crossrails is accurately finished for holding and sliding the saddle of the toolhead.

Tool-head assembly : It comprises saddle, ram and tool post. The saddle is mounted on the crossrail and may be made to slide on it to generate flat horizontal surface by the tool. The ram holding the toolpost may be made to slide up and down in the saddle perpendicular to the table to generate cylindrical surface or at an angle to the table surface to generate taper. The rams are also counterbalanced for ease of operation.

6.13 SIZE OF A VERTICAL BORING MACHINE

The size of a vertical boring machine is specified by the diameter of its table or chuck expressed in mm. It can also be specified by the swing diameter of the largest work which can be accommodated in the machine.

The size of a vertical turret lathe varies from 600 to 2000 mm. The size of a standard vertical boring machine is as high as 6000 mm.

6.14 WORK HOLDING DEVICES FOR VERTICAL BORING MACHINE

Most of the works done on a vertical boring machine are held in chuck jaws. The chucks may be independent, universal or combination chuck. The chuck jaws are used for holding moderately regular workpieces on the table. Irregular workpieces are held directly on the table by clamps and T-bolts. In some cases the finished face of the workpiece is made to rest directly on the table and the job is then clamped. This maintains accuracy of the work. In quantity production, jigs are used to hold the work. In every case, the work should be accurately centered on the table.

6.15 VERTICAL BORING MACHINE OPERATIONS

A vertical boring machine may generate a horizontal flat surface, produce cylindrical turned surface, bore internal hole, perform cutting-off, necking or forming operations, and generate internal or external taper surfaces.

For machining a flat horizontal surface, the ram and the crossrail is locked at the desired position and the saddle is fed crosswise while the work revolves on the table. Depth of cut is given by the ram. Fig.6.18 shows the operation for production of a flat surface. For generating a cylindrical surface, the saddle is clamped to prevent any horizontal movement of the ram, and the ram is fed downwards. Fig.6.19 shows the cylindrical turning operation. Larger diameter holes are bored by feeding

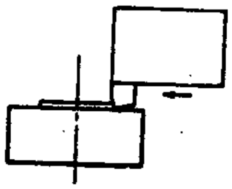


Figure 6.18 Machining flat surface

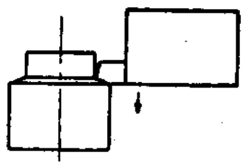
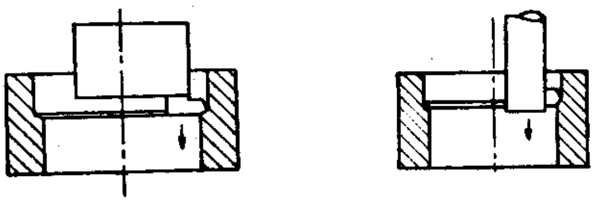


Figure 6.19 Turning cylindrical surface

the tool-head directly within the work and the smaller diameter holes are bored by using a boring bar attached to the tool-head. Fig.6.20(a) and Fig.6.20(b) show boring operations by a toolhead and a boring bar respectively.



(a) (b)

Figure 6.20 (a) Boring by tool head (b) Boring by boring bar

Cutting off, necking, and forming operations are performed by crossfeed movement of the saddle. Fig.6.21 shows parting-off operation and Fig.6.22 illustrates forming operation in a vertical boring machine.

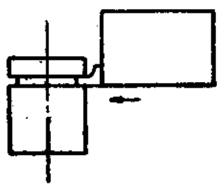


Figure 6.21 Cutting off and necking operation

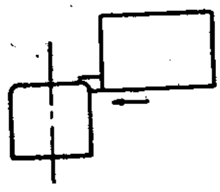


Figure 6.22 Forming operation

Conical or taper surfaces are turned by swiveling the toolhead to the required angle. When a conical surface having a large included angle which is beyond the range of the swiveling arrangement of the toolhead is turned, a combined cross and downfeed is applied simultaneously on the tool to cut the required taper. Fig.6.23(a) and 6.23(b) show internal and external taper turning operations.

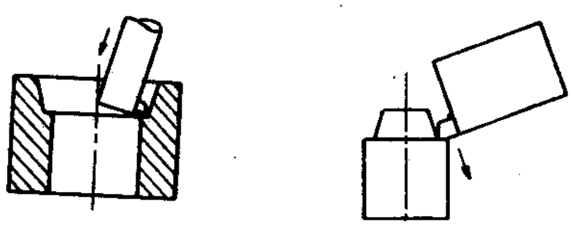


Figure 6.23 (a) Taper boring operation (b) Taper turning operation

6.16 VERTICAL BORING MACHINE TOOLS

The vertical boring machine tools are similar to lathe tools as regards rake, clearance and other cutting angles. For boring operation, the clearance angle of the tool is greater than that in turning or facing tool. The tool may be right and left handed, roughing, and finishing.

6.17 PRECISION BORING MACHINE

The precision boring machine uses single point tools to machine surfaces rapidly and accurately. Cemented carbide and diamond tipped single point tools are operated at a very high cutting speed to produce accurately sized holes with a fine surface finish. The feeding movement may be provided by the tool or by the work. The machine may be horizontal or vertical type.

6.18 JIG BORING MACHINE

The jig boring machine is the most accurate of all machine tools. This was first developed in the year 1910 in Switzerland and used as a locating machine. The real jig borer was first built in the year 1917 by Pratt and Whitney.

Jig boring machines are now used for production of jigs, fixtures, tools and other precision parts which require high degree of accuracy. They are characterized by provisions of highest accuracy through rigidity, low thermal expansion and precise means of measuring distance for accurately locating and spacing holes. The machining accuracy is very high, within a range of 0.0025 mm. A jig boring machine resembles in appearance to a vertical milling machine, but so far its operation and accuracy are concerned there cannot be any comparison between the two.

The spindle and other parts of the machine are extremely rigid to resist deflection and the vibration is minimum. The spindle runs in preloaded antifriction bearings. The spindle housings are made of invar having a very low coefficient of linear expansion. The jig boring machine requires to be operated in temperature controlled rooms where temperature can be maintained constant. This is essential to prevent inaccuracy in the machine and in the work being manufactured due to thermal expansion of the metal. Fig.6.24 shows the block diagram of a jig boring machine.

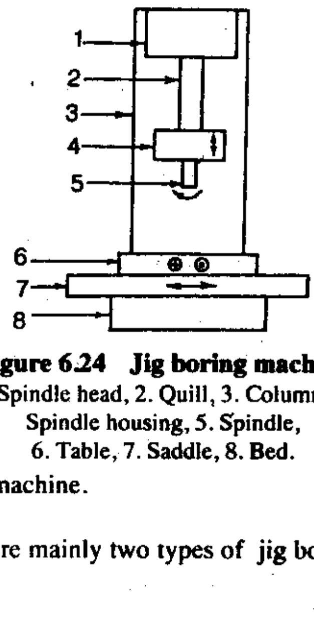


Figure 6.24 Jig boring machine
1. Spindle head, 2. Quill, 3. Column, 4. Spindle housing, 5. Spindle, 6. Table, 7. Saddle, 8. Bed.

Types of jig boring machines : There are mainly two types of jig boring machines :

1. Vertical milling machine type.
2. Planer type.

Vertical milling machine type : It resembles in construction to a vertical milling machine. The spindle rotates on a vertical column and the horizontal table rests on the bed in front of the column. The positioning of the work mounted on the table may be obtained by compound movements of the table, perpendicular and parallel to the column face.

Planer type : It consists of two vertical columns at the two sides of the table and is mounted on the base. The table has reciprocating movement for adjustment of the work. The spindle is mounted on the crossrail bridging the two vertical columns. In a planer type jig borer, two co-ordinate movements for hole location are provided by the longitudinal movement of the table and the cross movement of the spindle along the crossrail.

6.19 METHODS OF LOCATING HOLES IN JIG BORING

Holes should be bored on jigs and fixtures at specified distances from the two square sides of the work. Accurate positioning is essential for producing accurate jigs, fixtures, dies, etc. The most important operation in a jig boring machine is the accurate way of positioning a hole. The accurate way of locating a hole in a jig boring machine may be secured by any one of the following methods :

1. Leadscrew method
2. Mechanical and electrical gauging method
3. Optical measuring method

Leadscrew method : The leadscrew method is the most common and quick method of positioning the work below the spindle. Both longitudinal and crossfeed leadscrew are rotated by a specified amount. Any error in the leadscrew due to backlash, wear or manufacturing defect may be corrected by using a compensating device.

Mechanical and electrical gauging method : Mechanical gauges such as gauge blocks or end measures are placed against a stop on the table and a dial indicator is fitted at the outer end of the trough. The movement of the table is now governed by the length of the end measures. The table may be adjusted both in longitudinal and crosswise direction to locate the hole accurately.

Electrical gauging devices are also sometimes adopted.

Optical measuring method : The scales used for measuring the movement of the table are enclosed within the machine to prevent it from any damage or wear. The movement of the table is adjusted by the leadscrew or by hydraulic means, but the positioning of the table along the two axis are performed by using the enclosed scale which may be observed through a microscope.

6.20 JIG BORING OPERATIONS

The jig boring machines are primarily designed to produce precision dies, gauges, and jigs. They can also be used as a measuring machine to check up a job already manufactured in other machines. Workpieces are clamped on the table by T-bolts and straps, and single point boring tools are used for enlarging holes. Single point tools are preferred to multipoint tools as a single point tool enables maximum accuracy in locating holes and produces better surface finish.

REVIEW QUESTIONS

1. Classify and list boring machines.
2. What are the different horizontal boring machines ? List them and specify their suitability.
3. How a horizontal boring machine is specified ?
4. List the methods / equipment for mounting cutters in a horizontal boring machine.
5. What is a boring bar ? Describe its utility.
6. Describe in brief the different operations that can be performed on a horizontal boring machine.
7. Describe in brief the various types of operations that can be performed by a vertical boring machine.
8. What are the differences between a vertical turret lathe and a vertical boring machine ? Explain.
9. What are the extra facilities in a jig boring machine over an ordinary boring machine ?
10. What are the different methods used to locate holes in jig boring ? Describe them in brief.