

Module 4 General Purpose Machine Tools

Lesson

26

Broaching – Principles, Systems and Applications

Instructional objectives

This lesson will enable the students,

- (i) State and visualise the basic principle of broaching
- (ii) Describe constructional features and functioning of broaching tools
- (iii) Illustrate different broaching tools and their applications
- (iv) Classify broaching machines w.r.t. configuration and use
- (v) Identify the advantages and limitations of broaching.

(i) BASIC PRINCIPLES OF BROACHING

Broaching is a machining process for removal of a layer of material of desired width and depth usually in one stroke by a slender rod or bar type cutter having a series of cutting edges with gradually increased protrusion as indicated in Fig. 4.10.1. In shaping, attaining full depth requires a number of strokes to remove the material in thin layers step – by – step by gradually infeeding the single point tool (Fig. 4.10.1).. Whereas, broaching enables remove the whole material in one stroke only by the gradually rising teeth of the cutter called broach. The amount of tooth rise between the successive teeth of the broach is equivalent to the infeed given in shaping.

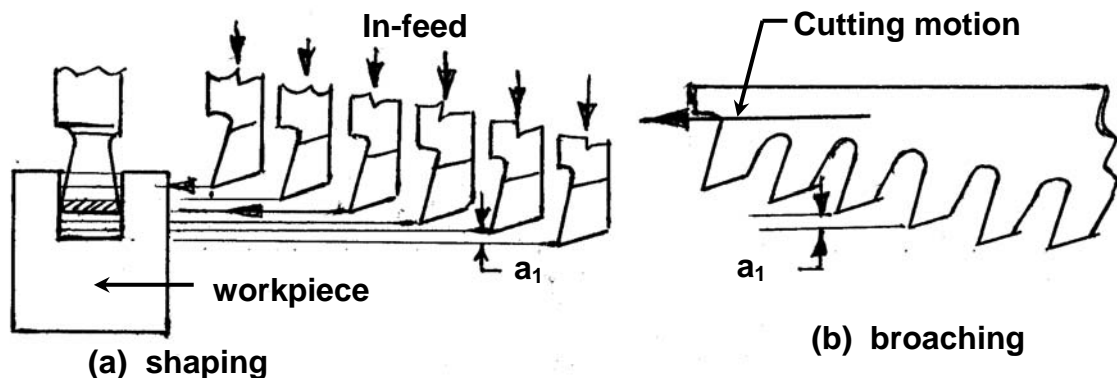


Fig. 4.10.1 Basic principle of broaching.

Machining by broaching is preferably used for making straight through holes of various forms and sizes of section, internal and external through straight or helical slots or grooves, external surfaces of different shapes, teeth of external and internal splines and small spur gears etc. Fig. 4.10.2 schematically shows how a through hole is enlarged and finished by broaching.

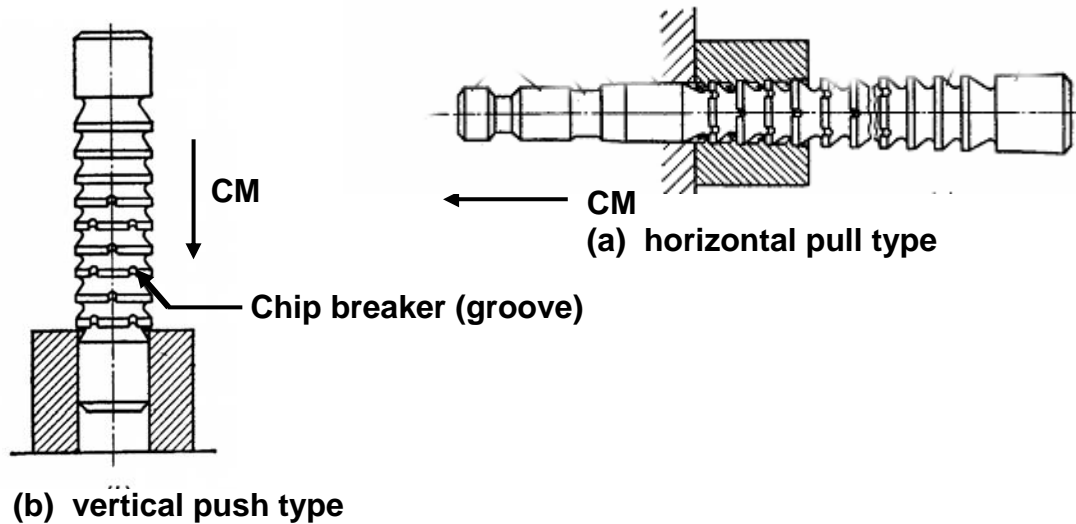


Fig. 4.10.2 Schematic views of finishing hole by broaching.

(ii) Construction And Operation Of Broaching

□ Construction of broaching tools

Construction of any cutting tool is characterised mainly by

- Configuration
- Material and
- Cutting edge geometry

• Configuration of broaching tool

Both pull and push type broaches are made in the form of slender rods or bars of varying section having along its length one or more rows of cutting teeth with increasing height (and width occasionally). Push type broaches are subjected to compressive load and hence are made shorter in length to avoid buckling.

The general configuration of pull type broaches, which are widely used for enlarging and finishing preformed holes, is schematically shown in Fig. 4.10.3.

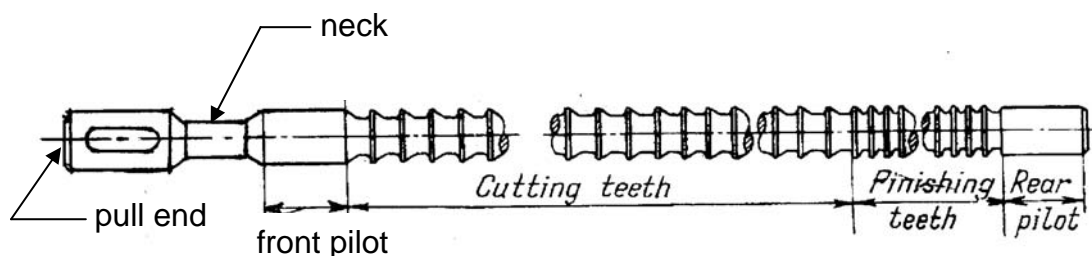


Fig. 4.10.3 Configuration of a pull type broach used for finishing holes.

The essential elements of the broach (Fig. 4.10.3) are :

- Pull end for engaging the broach in the machine

- Neck of shorter diameter and length, where the broach is allowed to fail, if at all, under overloading
- Front pilot for initial locating the broach in the hole
- Roughing and finishing teeth for metal removal
- Finishing and burnishing teeth
- Rear pilot and follower rest or retriever

Broaches are designed mostly pull type to facilitate alignment and avoid buckling. The length of the broach is governed by;

- Type of the broach; pull or push type
- Number of cutting edges and their pitch depending upon the work material and maximum thickness of the material layer to be removed
- Nature and extent of finish required.

Keeping in view that around 4 to 8 teeth remain engaged in machining at any instant, the pitch (or gap), p , of teeth is simply decided from

$$p = 1.25\sqrt{L} \text{ to } 1.5\sqrt{L}$$

where, L = length of the hole or job.

The total number of cutting teeth for a broach is estimated from,

$$T_n \geq (\text{total depth of material}) / \text{tooth rise, } a_1 \text{ (which is decided based on the tool – work materials and geometry).}$$

Broaches are generally made from solid rod or bar. Broaches of large section and complex shape are often made by assembling replaceable separate sections or inserting separate teeth for ease of manufacture and maintenance.

• **Material of broach**

Being a cutting tool, broaches are also made of materials having the usual cutting tool material properties, i.e., high strength, hardness, toughness and good heat and wear resistance.

For ease of manufacture and sharpening the complex shape and cutting edges, broaches are mostly made of HSS (high speed steel). To enhance cutting speed, productivity and product quality, now-a-days cemented carbide segments (assembled) or replaceable inserts are also used specially for stronger and harder work materials like cast irons and steels. TiN coated carbides provide much longer tool life in broaching. Since broaching speed (velocity) is usually quite low, ceramic tools are not used.

• **Geometry of broaching teeth and their cutting edges**

Fig. 4.10.4 shows the general configuration of the broaching teeth and their geometry. The cutting teeth of HSS broaches are provided with positive radial or orthogonal rake (5° to 15°) and sufficient primary and secondary clearance angles (2° to 5° and 5° to 20° respectively) as indicated in Fig. 4.10.4.

Small in-built chip breakers are alternately provided on the roughing teeth of the broach as can be seen in Fig. 4.10.2 to break up the wide curling chips

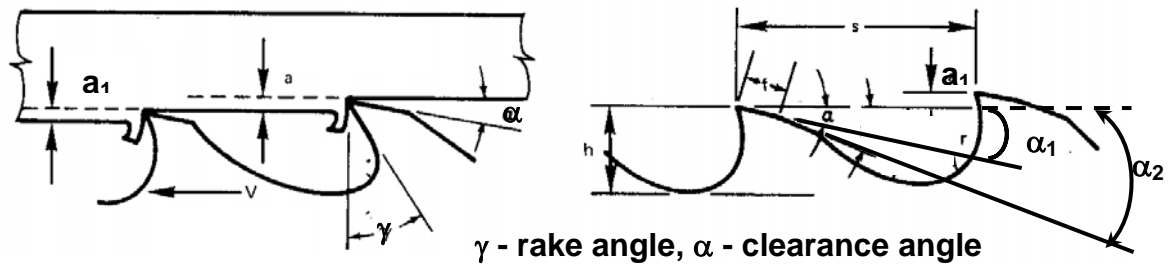


Fig. 4.10.4 Geometry of teeth of broaching tools.

and thus preventing them from clogging the chip spaces and increasing forces and tool wear. More ductile materials need wider and frequent chip breakers.

□ Broaching operation

Like any other machining, broaching is also accomplished through a series of following sequential steps :

- Selection of broach and broaching machine
- Mounting and clamping the broach in the broaching machine
- Fixing workpiece in the machine
- Planning tool - work motions
- Selection of the levels of the process parameters and their setting
- Conducting machining by the broach.

• Selection of broach and broaching machine

There are various types of broaches available. The appropriate one has to be selected based on

- type of the job; size, shape and material
- geometry and volume of work material to be removed from the job
- desired length of stroke and the broach
- type of the broaching machines available or to be used

Broaching machine has to be selected based on

- The type, size and method of clamping of the broach to be used
- Size, shape and material of the workpiece
- Strength, power and rigidity required for the broaching machine to provide the desired productivity and process capability.

• Mounting and clamping broach in the machine

The broach needs to be mounted, clamped and moved very carefully and perfectly in the tool holding device of the broaching machine which are used for huge lot or mass production with high accuracy and surface finish.

Pull type and push type broaches are mounted in different ways.

Fig. 4.10.5 typically shows a broach pull head commonly used for holding, clamping and pulling pull type broach. Just before fitting in or removing the broach from the broach pull head (Fig. 4.10.5 (a)), the sliding outer socket is

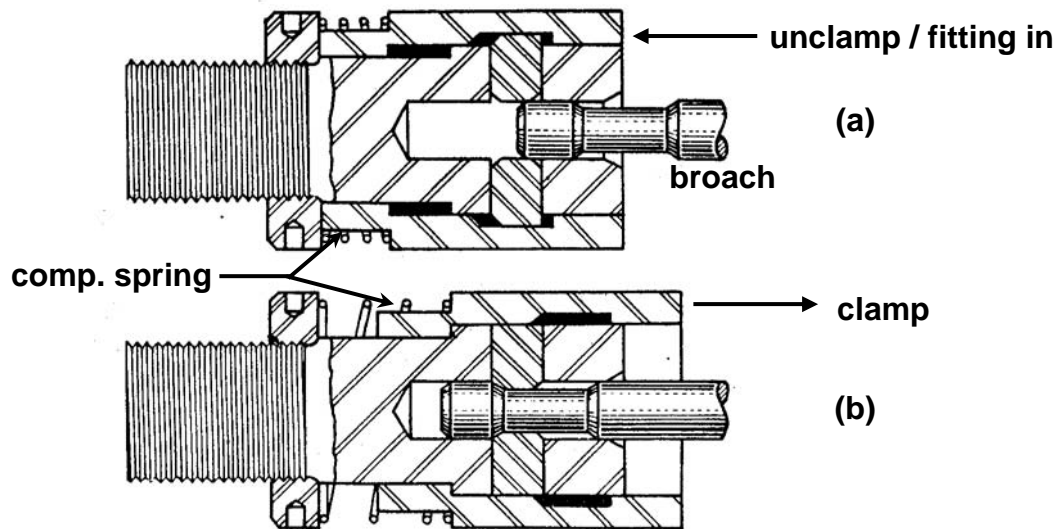


Fig. 4.10.5 Mounting and clamping pull type broach.

pushed back against the compression spring. After full entry of the pull end of the broach in the head the socket is brought forward which causes locking of the broach by the radially moving strips as shown in Fig. 4.10.5 (b). Pull type broaches are also often simply and slightly flexibly fitted by a suitable adapter and pin as can be seen in Fig. 4.10.6.

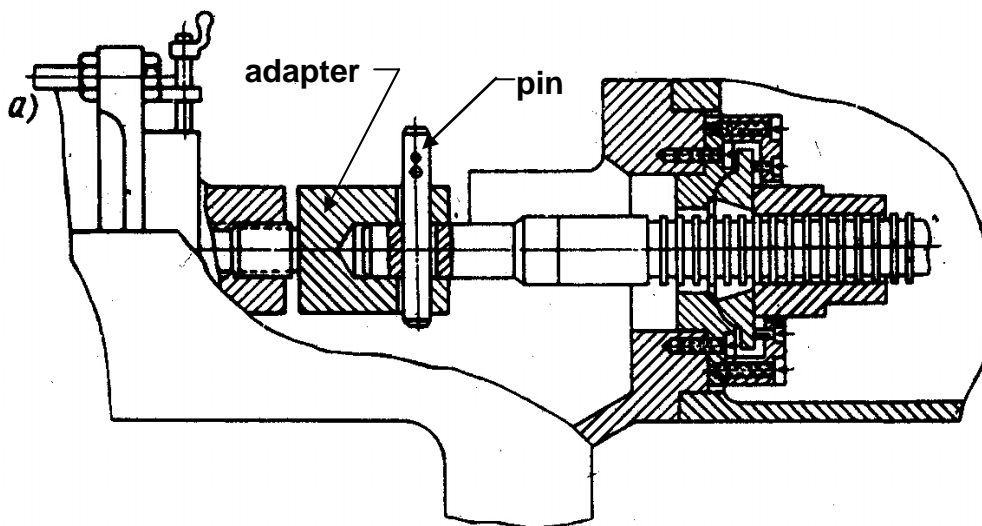


Fig. 4.10.6 Fitting pull type broach by an adapter and a pin.

- **Mounting of workpiece or blank in broaching machine**

Broaching is used for mass production and at fast rate. The blanks are repeatedly mounted one after another in an appropriate fixture where the blanks can be easily, quickly and accurately located, supported and clamped.

In broaching, generally the job remains fixed and the broach travels providing cutting velocity.

Fig. 4.10.7 schematically shows a typical method of mounting push or pull type external broach for through surfacing, slotting or contouring.

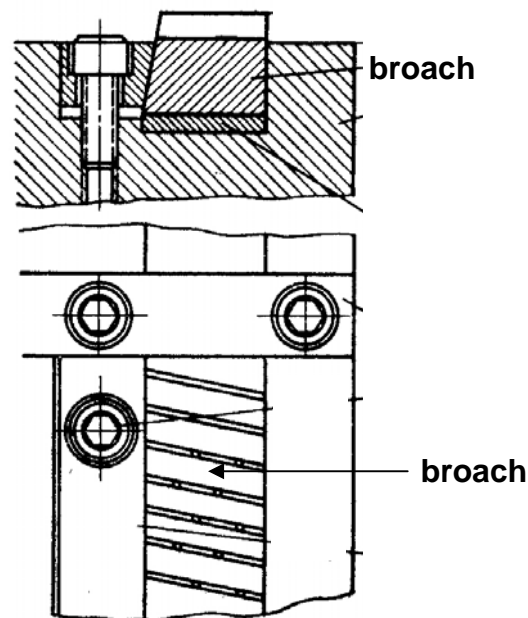


Fig. 4.10.7 Mounting external broach for surfacing and slotting.

- **Tool – work motions and process variables**

Any machining is associated with 2 to 5 tool – work motions as well as cutting velocity, feed and depth of cut as process variables. But broaching operation / machine needs only one motion which is cutting motion and is mostly imparted to the tool. In broaching feed is provided as tooth rise. The magnitude of cutting velocity, V_C is decided based on the tool – work materials and the capability of the broaching machine. In broaching metals and alloys, HSS broaches are used at cutting velocity of 10 to 20 m/min and carbide broaches at 20 to 40 m/min. The value of tooth rise varies within 0.05 mm to 0.2 mm for roughing and 0.01 to 0.04 mm for finishing teeth. Some cutting fluids are preferably used mainly for lubrication and cooling at the chip – tool interfaces.

Fig. 4.10.8 typically shows mounting of blank in fixture. But occasionally the job is travelled against the stationary broach as in continuous working type broaching machine.

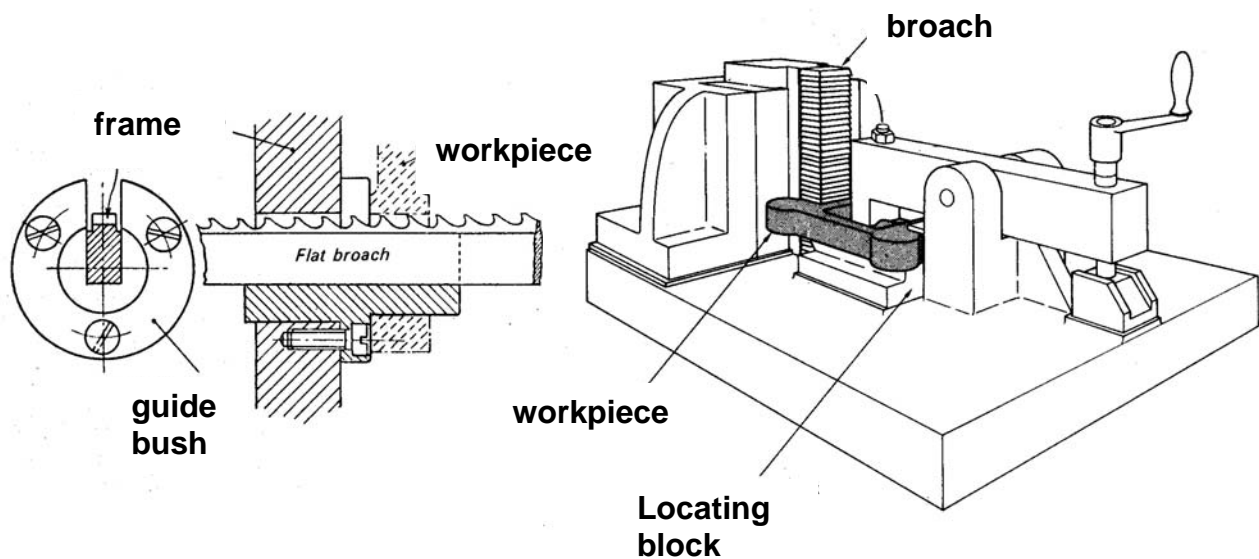


Fig. 4.10.8 Mounting blank in broaching machine.

(iv) Different Types Of Broaches And Their Applications

Broaching is getting more and more widely used, wherever feasible, for high productivity as well as product quality. Various types of broaches have been developed and are used for wide range of applications.

Broaches can be broadly classified in several aspects such as,

- Internal broaching or External broaching
- Pull type or Push type
- Ordinary cut or Progressive type
- Solid, Sectional or Modular type
- Profile sharpened or form relieved type

□ Internal and external broaching (tool)

○ Internal broaching and broaches

Internal broaching tools are used to enlarge and finish various contours in through holes preformed by casting, forging, rolling, drilling, punching etc. Internal broaching tools are mostly pull type but may be push type also for lighter work. Pull type internal broaching tools are generally provided with a set of roughing teeth followed by few semi-finishing teeth and then some finishing teeth which may also include a few burnishing teeth at the end. The wide range of internal broaching tools and their applications include;

- through holes of different form and dimensions as indicated in fig. 4.10.9
- non-circular holes and internal slots (fig. 4.10.9)
- internal keyway and splines
- teeth of straight and helical fluted internal spur gears as indicated in fig. 4.10.9

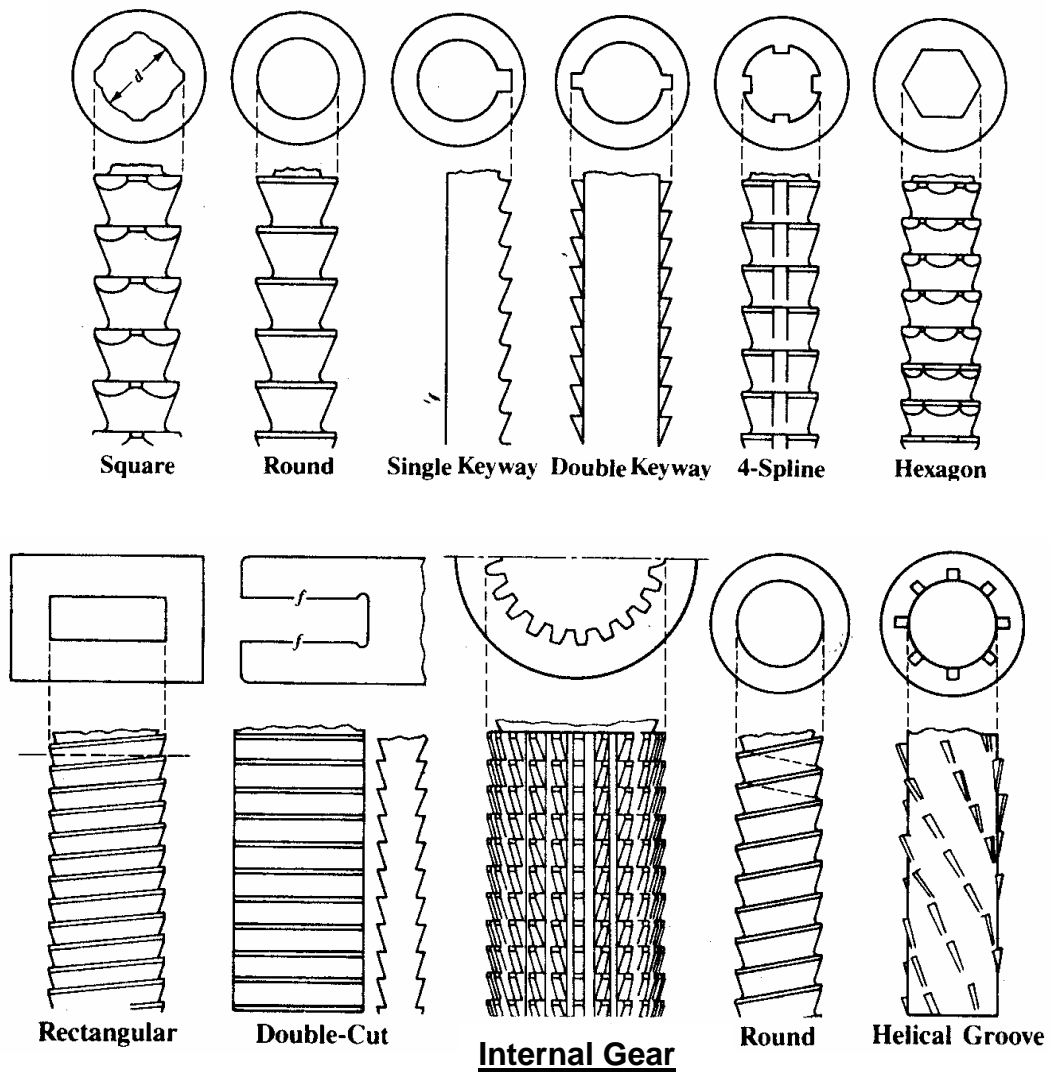


Fig. 4.10.9 Internal broaching – tools and applications.

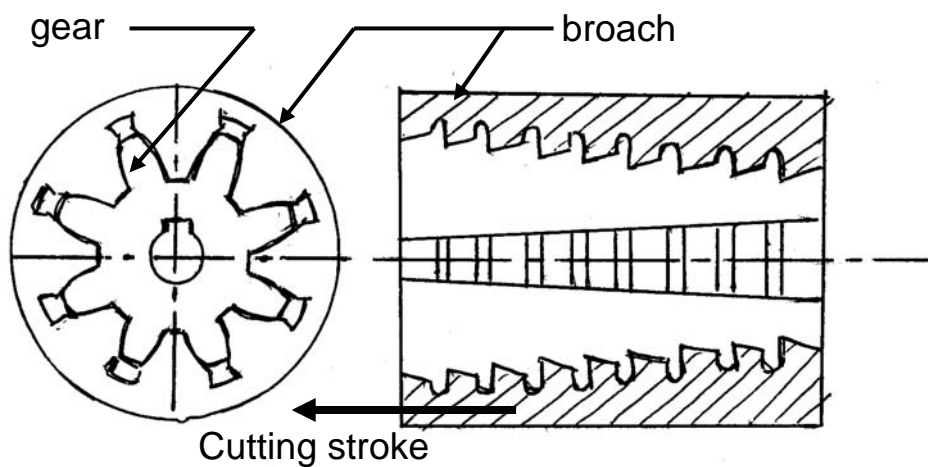


Fig. 4.10.10 Machining external gear teeth by broaching.

o External broaching

External surface broaching competes with milling, shaping and planing and, wherever feasible, outperforms those processes in respect of productivity and product quality. External broaching tools may be both pull and push type. Major applications of external broaching are :

- o un-obstructed outside surfacing; flat, peripheral and contour surfaces (fig. 4.10.11 (a))
- o grooves, slots, keyways etc. on through outer surfaces of objects (Fig. 4.10.8)
- o external splines of different forms
- o teeth of external spur gears or gear sectors as shown in Fig. 4.10.10 and Fig. 4.10.11 (b)

External broaching tools are often made in segments which are clamped in fixtures for operation.

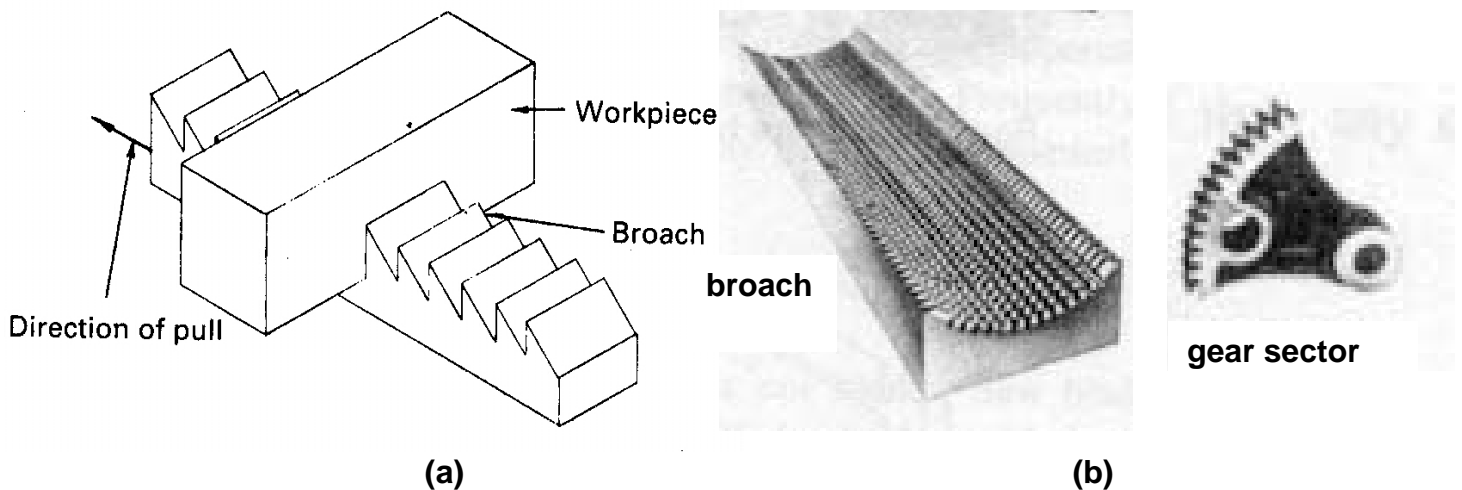


Fig. 4.10.11 Typical external broaching (a) making slot
(b) teeth of gear sector

□ Pull type and push type broaches

During operation a pull type broach is subjected to tensile force, which helps in maintaining alignment and prevents buckling.

Pull type broaches are generally made as a long single piece and are more widely used, for internal broaching in particular. Push type broaches are essentially shorter in length (to avoid buckling) and may be made in segments. Push type broaches are generally used for external broaching, preferably, requiring light cuts and small depth of material removal.

□ Ordinary – cut and Progressive type broach

Most of the broaches fall under the category of Ordinary – cut type where the teeth increase in height or protrusion gradually from tooth to tooth along the length of the broach. By such broaches, work material is removed in thin

layers over the complete form. Whereas, Progressive – cut type broaches have their teeth increasing in width instead of height. Fig. 4.10.12 shows the working principle and configuration of such broach.

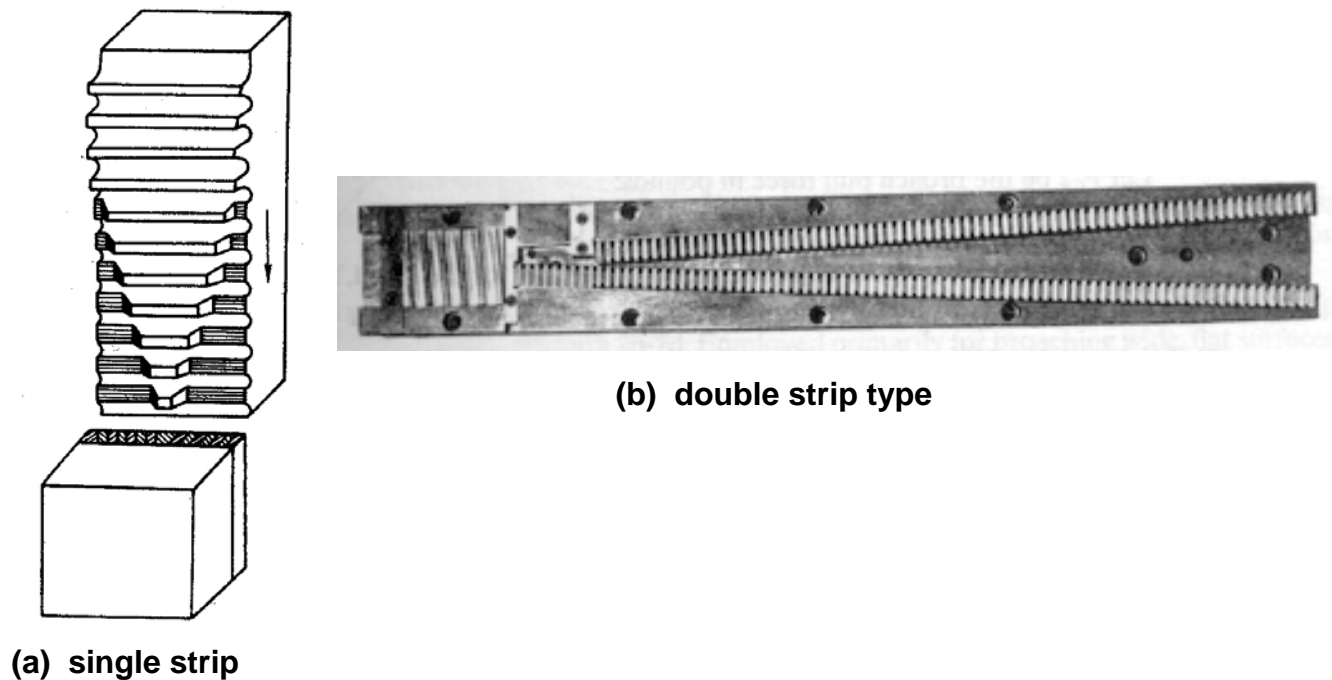


Fig. 4.10.12 Progressive – cut type broaches; (a) single bar and (b) double bar type

□ **Solid, Sectional and module type broaches**

Broaches are mostly made in single pieces specially those used for pull type internal broaching. But some broaches called sectional broaches, are made by assembling several sections or cutter-pieces in series for convenience in manufacturing and resharpening and also for having little flexibility required by production in batches having interbatch slight job variation. External broaches are often made by combining a number of modules or segments for ease of manufacturing and handling. Fig. 4.10.13 typically shows solid, sectional and segmented (module) type broaches.

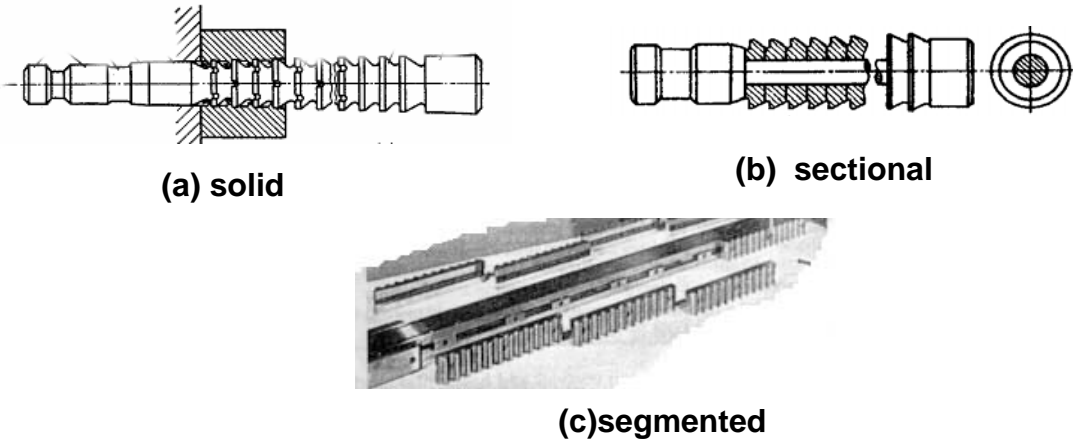


Fig. 4.10.13 (a) Solid, (b) Sectional and (c) Segmented broaches.

□ **Profile sharpened and form relieved type broaches**

Like milling cutters, broaches can also be classified as

- **Profile sharpened type broaches;**

Such cutters have teeth of simple geometry with same rake and clearance angles all over the cutting edge. These broaches are generally designed and used for machining flat surface(s) or circular holes.

- **Form relieved type broaches**

These broaches, being used for non-uniform profiles like gear teeth etc., have teeth where the cutting edge geometry is more complex and varies point – to – point along the cutting edges. Here the job profile becomes the replica of the tool form. Such broaches are sharpened and resharpener by grinding at their rake faces unlike the profile sharpened broaches which are ground at the flank surfaces.

(iv) Broaching Machines

The unique characteristics of broaching operation are

- For producing any surface, the form of the tool (broach) always provides the Generatrix and the cutting motion (of the broach relative to the job surface) provides the Directrix.
- So far as tool – work motions, broaching needs only one motion and that is the cutting motion (velocity) preferably being imparted to the broach.

Hence design, construction and operation of broaching machines, requiring only one such linear motion, are very simple. Only alignments, rigidity and reduction of friction and wear of slides and guides are to be additionally considered for higher productivity, accuracy and surface finish.

Broaching machines are generally specified by

- Type; horizontal, vertical etc.
- Maximum stroke length
- Maximum working force (pull or push)
- Maximum cutting velocity possible
- Power
- Foot print

Most of the broaching machines have hydraulic drive for the cutting motion. Electro-mechanical drives are also used preferably for high speed of work but light cuts.

There are different types of broaching machines which are broadly classified

- According to purpose of use
 - △ general purpose
 - △ single purpose
 - △ special purpose
- According to nature of work
 - △ internal broaching
 - △ external (surface) broaching
- According to configuration
 - △ horizontal
 - △ vertical
- According to number of slides or stations
 - △ single station type
 - △ multiple station type
 - △ indexing type
- According to tool / work motion
 - △ intermittent (one job at a time) type
 - △ continuous type

Some of the broaching machines of common use have been discussed here.

o **Horizontal broaching machine**

Horizontal broaching machines, typically shown in Fig. 4.10.14, are the most versatile in application and performance and hence are most widely employed for various types of production. These are used for internal broaching but external broaching work are also possible. The horizontal broaching machines are usually hydraulically driven and occupies large floor space.

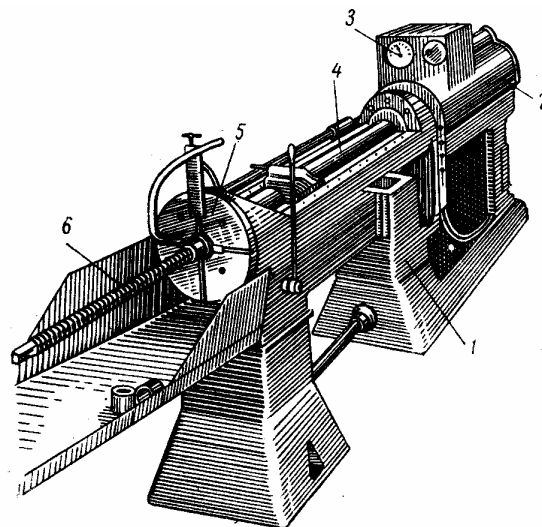


Fig. 4.10.14 Horizontal broaching machine.

o **Vertical broaching machine**

Vertical broaching machines, typically shown in Fig. 4.10.15,

- Δ occupies less floor space
- Δ are more rigid as the ram is supported by base
- Δ mostly used for external or surface broaching though internal broaching is also possible and occasionally done.

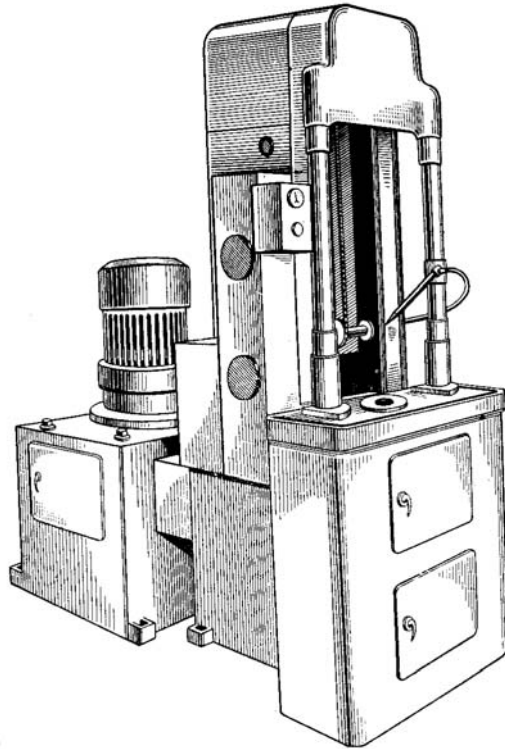


Fig. 4.10.15 Vertical broaching machine.

o **High production broaching machines**

Broaching operation and broaching machines are as such high productive but its speed of production is further enhanced by;

- Δ incorporating automation in tool – job mounting and releasing
- Δ increasing number of workstations or slides for simultaneous multiple production
- Δ quick changing the broach by turret indexing
- Δ continuity of working

Fig. 4.10.16 schematically shows the principle and methods of continuous broaching, which is used for fast production of large number of pieces by surface broaching.

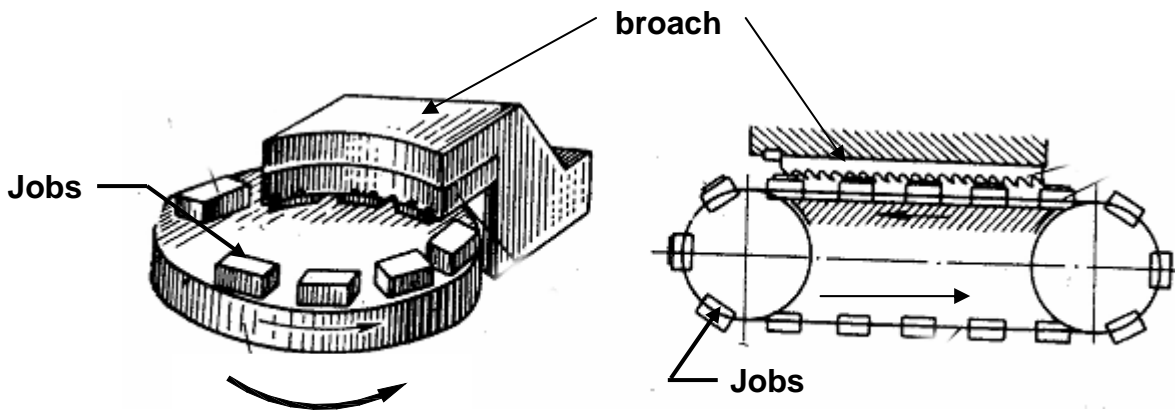


Fig. 4.10.16 Continuous broaching.

(v) ADVANTAGES AND LIMITATIONS OF BROACHING

□ Major advantages

- Very high production rate (much higher than milling, planing, boring etc.)
- High dimensional and form accuracy and surface finish of the product
- Roughing and finishing in single stroke of the same cutter
- Needs only one motion (cutting), so design, construction, operation and control are simpler
- Extremely suitable and economic for mass production

□ Limitations

- Only through holes and surfaces can be machined
- Usable only for light cuts, i.e. low chip load and unhard materials
- Cutting speed cannot be high
- Defects or damages in the broach (cutting edges) severely affect product quality
- Design, manufacture and restoration of the broaches are difficult and expensive
- Separate broach has to be procured and used whenever size, shape and geometry of the job changes
- Economic only when the production volume is large.