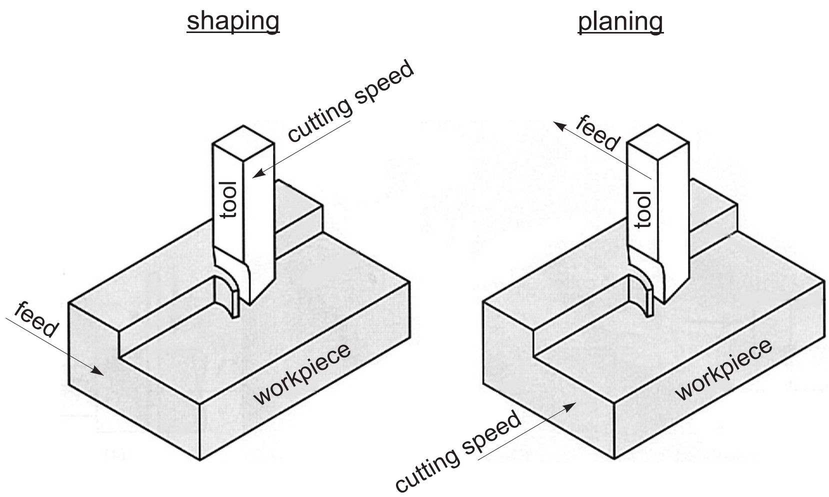
6.4 PLANING, SHAPING AND BROACHING

This section covers several machining operations that are used to machine straight and open external or internal surfaces:

- *Planing* and *shaping*: these operations are used to machine straight open mainly external surfaces with a single-point cutting tool;
- *Broaching* is used to machine straight and open basically internal surface of complex cross-section shapes by means of a special tool called a *broach*.

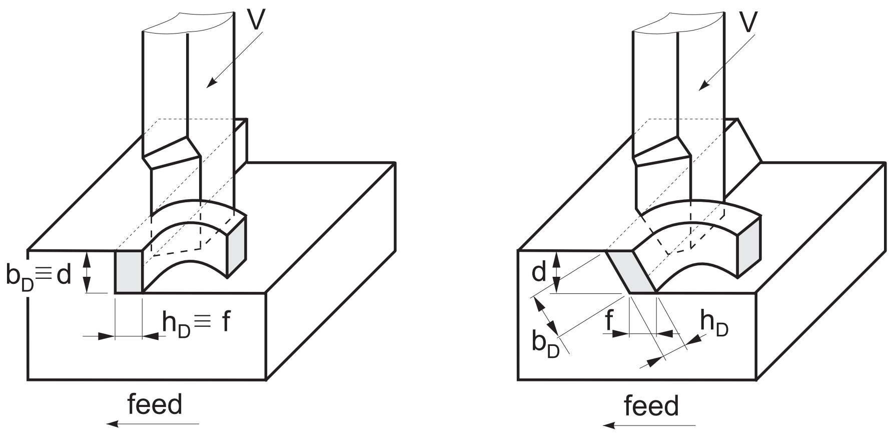
PLANING AND SHAPING

Planing and *shaping* are similar operations, which differ in the kinematics of the process. Planing is a machining operation in which the primary cutting motion is performed by the workpiece and feed motion is imparted to the cutting tool. In shaping, the primary motion is performed by the tool, and feed by the workpiece:



Kinematics of shaping and planing.

The *cutting conditions* in planing and shaping are illustrated in the figure. Only the shaping operation is portrayed but the cutting conditions are essentially the same and for planing:



Cutting conditions in orthogonal (*Left*) and oblique (*Right*) shaping.

Cutting velocity V in planing is linear and constant along the cutting path.

In shaping, the picture is more complicated. The cutting tool is held in the tool post mounted in the ram, which reciprocates over the work with a forward stroke, cutting at velocity V and a quick return stroke at higher velocity. The cutting velocity is therefore not constant along the cutting path. It increases from zero to maximum in the beginning of the stroke and gradually decreases to zero at the end of the stroke. The cutting speed V is assumed to be twice the average forwarded ram velocity.

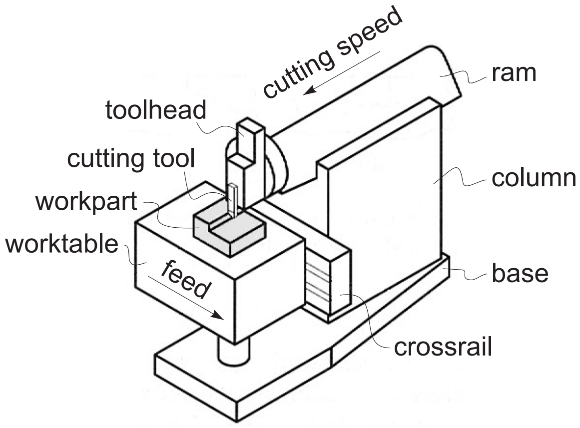
Feed f in planing and shaping is in mm per stroke and is at right angles to the cutting direction.

Depth of cut d is defined as usual as the distance between the work and machined surfaces.

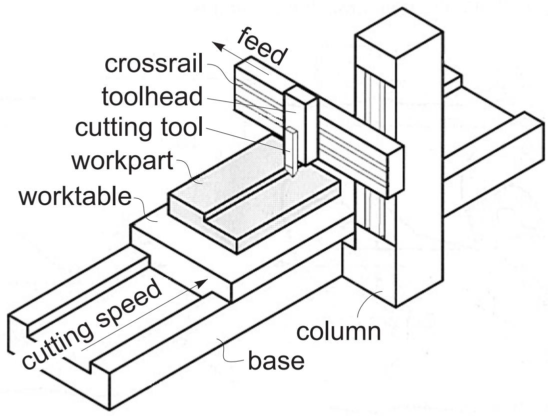
Machine tools for shaping and planing

Shapers

Shaping is performed on a machine tool called a *shaper*. The major components of a shaper are the *ram*, which has the *toolpost* with cutting tool mounted on its face, and a *worktable*, which holds the part and accomplishes the feed motion.



Components of a shaper



Components of an open-side planer.

Planers

The machine tool for planing is a *planer*. Cutting speed is achieved by a reciprocating worktable that moves the part past the single-point cutting tool. Construction and motion capability of a planer permit much larger parts to be machined than on a shaper. Planers can be classified as either open side planers or double-column planers.

The *open side planer*, also known as a *single-column planer* has a single column supporting the crossrail on which a toolhead is mounted. The configuration of the open side planer permits very wide workparts to be machined.

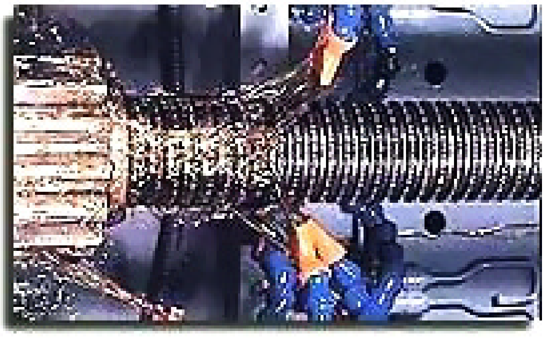
A *double-column planer* has two columns, one on either side of the bed and worktable. The columns support the crossrail on which one or more toolheads are mounted. The two columns provide a more rigid structure for the operation but limit the width of the work that can be handled.

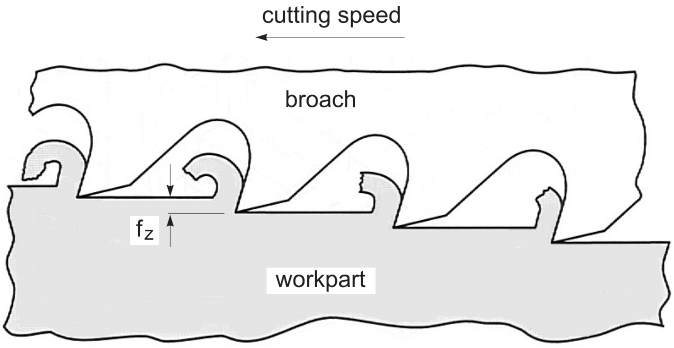
Cutting tools for shaping and planing

Cutting tool for shaping or planing is essentially the same single-point cutting tool that is used in turning. The only difference is that the cutting tool for planing and shaping must be more rigid to withstand the higher impact cutting forces. The clearance angle must be bigger to avoid plunging of the cutting tool into the machined surface during the quick return of the ram over the workpiece.

Broaching

Broaching is a machining operation that involves the use of a multiple-tooth cutting tool moved linearly relative to the workpiece in the direction of the tool axis:





The broaching operation.

The cutting tool is called a *broach*, and the machine tool is called a *broaching machine*. 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 include 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.

Productivity improvement to ten times or even more is not uncommon, as the metal removal rate by broaching is vastly greater. Roughing, semi finishing and finishing of the component is done just in one pass by broaching, and this pass is generally accomplished in seconds.

Broaching can be used for machining of various integrate shapes which can not be otherwise machined with other operations. Some of the typical examples of shapes produced by internal broaching are:

Various shapes produced by internal broaching operation.

Cutting conditions in broaching

The *cutting speed* motion is accomplished by the linear travel of the broach past the work surface.

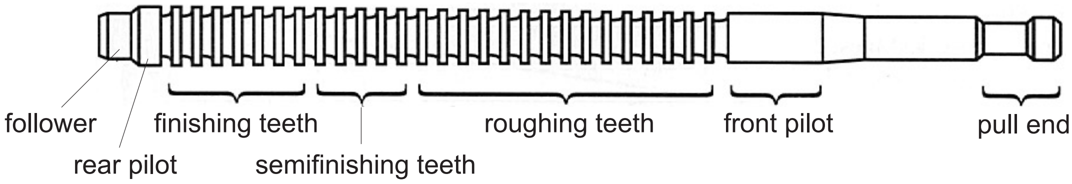
Feed in broaching is unique among machining operations, since is accomplished by the increased step between successive teeth on the broach. This step is actually the *feed per tooth*, f_z. The feed per tooth is not a constant for all the teeth. The total material removed in a single pass of the broach or the *total feed* f is the cumulative result of all the steps in the tool. Since not all of the broach teeth are engaged simultaneously in cutting but only a part of them, the term *active cumulative feed* can be introduced, defined as the sum of all the steps only of the active teeth.

Depth of cut in broaching is defined as the length of the active cutting edge. In internal broaching, which is the most common type of broaching, the entire length of a single broach tooth is engaged in cutting and the depth of cut is actually the tooth circumference.

From the definitions of feed and depth of cut it follows that the total area of cut and respectively the cutting force in broaching will be substantial.

Cutting tools for broaching

The terminology of the broach is shown in the figure:

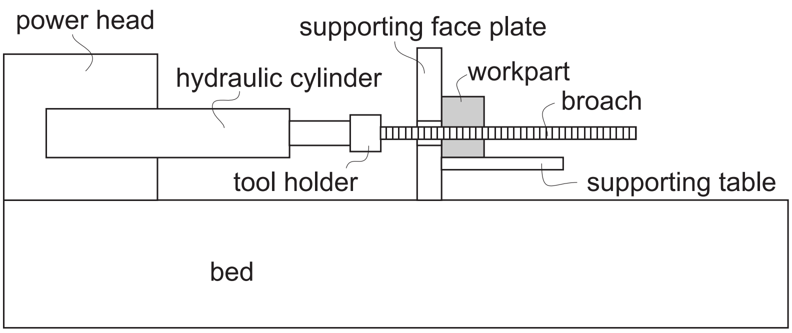


Typical broach for internal broaching.

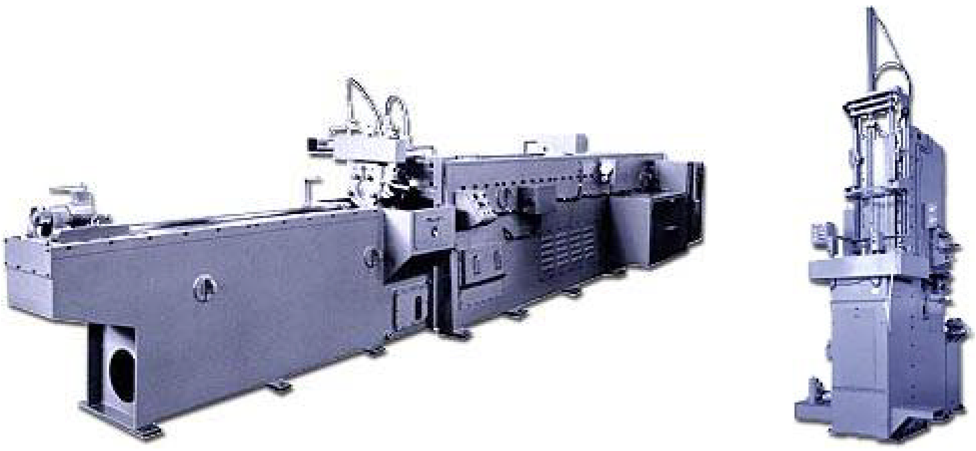
Most broaches are made of high-speed steel, although broaches with carbide inserts either brazed or mechanically attached are also available.

Broaching machines

There is no relative feed motion that is carried out by either the tool or the work. It makes the kinematics of the broaching machine quite simple.



Major components of a broaching machine.



Horizontal (*Left*) and vertical (*Right*) broaching machine.

The basic function of a broaching machine is to provide a precise linear motion of the tool past a stationary work position. There are two principal modifications of the broaching machines, *horizontal*, and *vertical*. The former are suitable for broaching of relatively long and small diameter holes, while the later are used for short lengths and large diameters.