# 9

# SLOTTING MACHINES

## 9.1 INTRODUCTION

The slotting machine falls under the category of reciprocating type of machine tool similar to a shaper or a planer. It operates almost on the same principle as that of a shaper. The major difference between a slotter and shaper is that in a slotter the ram holding the tool reciprocates in a vertical axis, whereas in a shaper the ram holding the tool reciprocates in a horizontal axis. A vertical shaper and a slotter are almost similar to each other as regards to their construction, operation, and use. The only difference being, in the case of a vertical shaper, the ram holding the tool may also reciprocate at an angle to the horizontal table in addition to the vertical stroke. The ram can be swivelled not more than 5° to the vertical. The slotter is used for cutting grooves, keyways and slots of various shapes, for making regular and irregular surfaces both internal and external, for handling large and awkward workpieces, for cutting internal or external gears and many other operations which cannot be conveniently machined in any other machine tool described before. The slotting machine was developed by Brunel in the year 1800 much earlier than a shaper was invented.

## 9.2 TYPES OF SLOTTING MACHINE

There are mainly two classes of slotter :

1. Puncher slotter 2. Precision slotter

**Puncher slotter :** The puncher slotter is a heavy, rigid machine designed for removal of large amount of metal from large forging or castings. The length of a puncher slotter is sufficiently large. It may be as long as 1800 to 2000 mm. The puncher slotter ram is usually driven by a spiral pinion meshing with the rack teeth cut on the underside of the ram. The pinion is driven by a variable speed reversible electric motor similar to that of a planer. The feed is also controlled by electrical gears.

**Precision slotter** : The precision slotter is a lighter machine and is operated at high speeds. The machine is designed to take light cuts giving accurate finish. Using special jigs, the machine can handle a number of identical works on a production basis. The precision machines are also used for general purpose work and are usually fitted with Whitworth quick return mechanism.

## 9.3 SLOTTER SIZE

The size of a slotter like that of a shaper is specified by the maximum length of stroke of the ram, expressed in mm. The size of a general purpose or precision slotter usually ranges from 80 to 900 mm. To specify a slotter correctly the diameter of the table in mm, amount of cross and longitudinal travel of the table expressed in mm, number of speeds and feeds available, h.p. of the motor, floor space required, etc. should also be stated.

## 9.4 SLOTTING MACHINE PARTS

Fig.9.1 illustrates a slotting machine. The different parts of a slotting machine are :

1. Base.
2. Column.
3. Saddle.
4. Cross-slide.
5. Rotating table.
6. Ram and toolhead assembly.
7. Ram drive mechanism.
8. Feed mechanism.

**Base or bed** : The base is rigidly built to take up all the cutting forces and entire load of the machine. The top of the bed is accurately finished to provide guideways on which the saddle is mounted. The guideways are perpendicular to the column face.

**Column** : The column is the vertical member which is cast integral with the base and houses driving mechanism of the ram and feeding mechanism. The front vertical face of the column is accurately finished for providing ways on which the ram reciprocates.

**Saddle** : The saddle is mounted upon the guideways and may be moved toward or away from the column either by power or manual control to supply longitudinal feed to the work. The top face of the saddle is accurately finished to provide guideways for the cross-slide. These guideways are perpendicular to the guideways on the base.

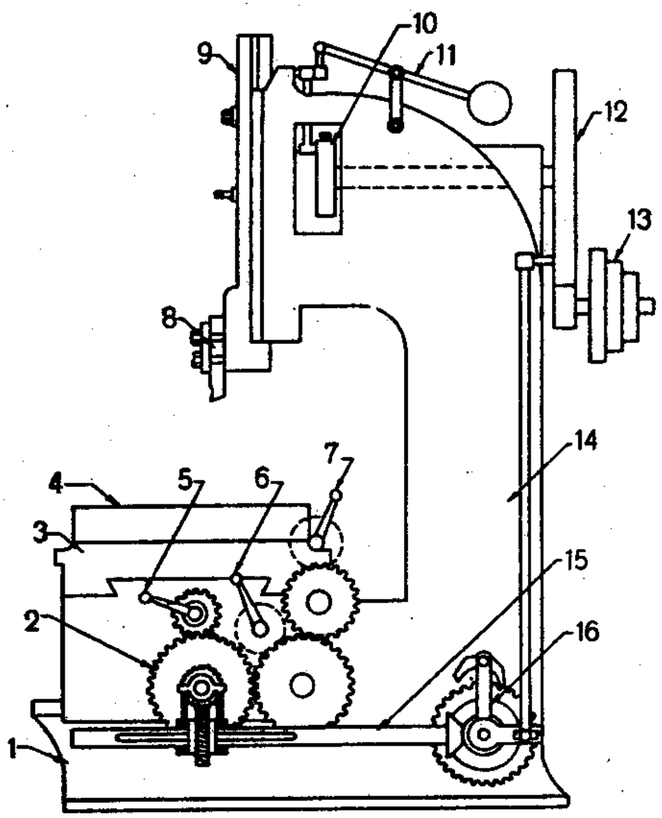


**Figure 9.1 Slotting machine**

1. Base, 2. Feed gear, 3. Cross-slide, 4. Table, 5. Crossfeed handle, 6. Longitudinal feed handle, 7. Circular feed handle, 8. Tool, 9. Ram, 10. Crank disc, 11. Lever for conterbalance weight, 12. Bull gear, 13. Cone pulley, 14. Column, 15. Feed sh^a^ 16. Pawl actuating crank.

**Cross-slide** : The cross-slide is mounted upon the guideways of the saddle and may be moved parallel to the face of the column. The movement of the slide may be controlled either by hand or power to supply crossfeed.

**Rotary table** : The rotary table is a circular table which is mounted on the top of the cross-slide. The table may be rotated by rotating a worm which meshes with a worm gear connected to the underside of the table. The rotation of the table may be effected either by hand or power. In some machines the table is graduated in degrees that enables the table to be rotated for indexing or dividing the periphery of a job in equal number of parts. T-slots are cut on the top face of the table for holding the work by different clamping devices. The rotary table enables a circular or contoured surface to be generated on the workpiece.

**Ram and toolhead assembly** : The ram is the reciprocating member of the machine mounted on the guideways of the column. It supports the tool at its bottom end on a toolhead. A slot is cut on the body of the ram for changing the position of stroke. In some machines, special type of toolholders are provided to relieve the tool during its return stroke.

**Ram drive mechanism** : A slotter removes metal during downward cutting stroke only whereas during upward return stroke no metal is removed. To reduce the idle return time, quick return mechanism is incorporated in the machine. The usual types of ram drive mechanisms are :

1. Whitworth quick return mechanism.
2. Variable speed reversible motor drive mechanism.
3. Hydraulic drive mechanism.

**Whitworth quick return mechanism** : The Whitworth quick return mechanism is most widely used in a medium sized slotting machine for driving the ram. The mechanism which has been explained in Art. 7.5 is slightly modified in the case of a slotter. As shown in Fig.9.2, the bullgear *7* located at the back of the machine receives its motion from the pinion *11* which is driven by an electric motor. The gear *7* is mounted on a fixed pin or hub *9* attached to the machine frame. The driving plate *8* is mounted on the shaft *6* which passes through the fixed hub *9*. The shaft *6* is placed eccentrically with respect to the bullgear centre. A crank pin is mounted on the face of the bullgear which holds a slide block *10*. The slide block *10* is fitted within a radial slot provided at the innerside of the driving plate *8*. As the bullgear rotates, the crank pin and the slide block *10* rotate in a circular path, but owing to the eccentricity of the bullgear and the driving plate *8*, the slide block *10* rotates and slides within the slot of the driving plate imparting it and the shaft *6* rotary movement. The rotation of the driving plate *8* is transmitted to the disc *5* which is attached to the end of the shaft *6*. A radial T-slot is cut on the face of the disc *5*. The position of the pin fitted within the T-slot may be altered with respect to the center of the disc *5* and then clamped at one end of the connecting rod. The other end of the connecting rod is attached to the ram *1* by a clamping bolt *2*. The rotation of the disc *5* is converted into reciprocating movement of the ram by the connecting rod and the pin eccentrically mounted on the disc *5*.

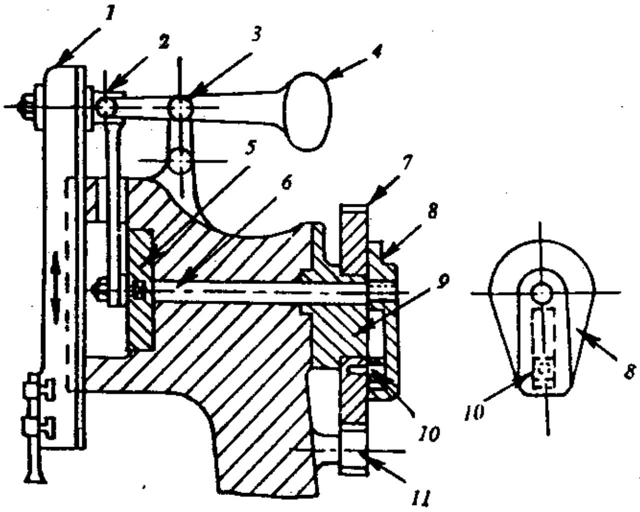


**Figure 9.2 Whitworth quick return mechanism**

1. Ram, 2. Connecting rod clamping bolt, 3. Pivot, 4. Counter balance weight, 5. Crank disc, 6. Driving shaft, 7. Bull gear, 8. Driving plate, 9. Fixed hub, 10. Crankpin with slide block, 11. Driving pinion.

The principle of quick return mechanism can be understood from the line diagram shown in Fig. 9.3. A and B are the fixed centers of the bull gear 7 and the driving plate 8 as shown in the Fig.9.2. The crank pin and the slide block 4 rotate in a circular path at a constant speed, rotating the plate 8 about B. This causes the driving disc 5 attached to the shaft 6 to rotate. The pin 3 on the disc rotates in a circular path about the fixed point B. The length of the ram is equal to twice the throw of eccentricity, which is equal to 2x3B. From the diagram 9.3 it is clear that when the block 4 is in the position C, the ram is at the maximum upward position of the stroke and when it is at D, the maximum downward position of the ram has been reached. Thus if the bullgear rotates in anti clockwise direction, when the block 4 rotates through an angle CAD, the downward cutting stroke is performed, whereas when the block rotates through an angle DAC, the return stroke completed. As the block 4 rotates at a constant speed the rotation of the crank pin through an angle CAD during the cutting stroke takes longer time than rotation through an angle DAC during the return stroke. Thus the quick return motion is obtained. The cutting time and return time is related by the formula :

$$\frac{\text{Cutting time}}{\text{Return time}} = \frac{\widehat{CAD}}{\widehat{DAC}}$$

The length of stroke of the ram can be varied by altering the position of pin 3 with respect to the center B, i.e. the center of the disc 5. Further the position of the pin 3 with respect to the disc center, greater will be the throw of eccentricity and longer will be the stroke length.

The position of stroke of the ram be adjusted by releasing the nut 2 and then by altering the position of the connecting rod clamping bolt within the slot provided on the body of the ram. After setting the position, the nut is tightened again.

As the ram moves in a vertical axis, the weight of the ram is counterbalanced by a weight 4 attached to the back of the ram and is pivoted at a point 3. This results even and jerk free movement of the ram in cutting and return stroke.

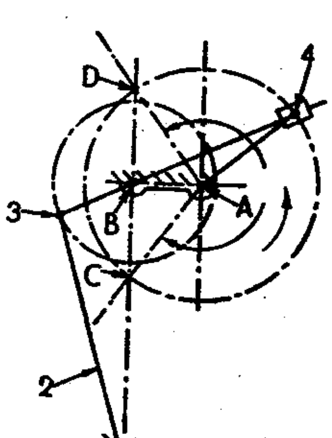


**Figure 9.3 Line diagram of Whitworth quick return mechanism**

1. Ram, 2. Connecting rod, 3. Crankpin on disc "5", 4. Slide block and crankpin on driving plate, A. Bull gear centre B. Driving plate centre

**Electrical and hydraulic drive :** Large machines are driven by variable voltage reversible motor. The drive is similar to that described in Art.7. 5.

The hydraulic drive is adapted in machines used in precision or tool-room work. In a hydraulic drive, the vibration is minimized resulting improved surface finish.

**Feed mechanism :** In a slotter, the feed is given by the table. A slotting machine table may have three types of feed movements :

1. Longitudinal 2. Cross 3. Circular

If the table is fed perpendicular to the column toward or away from its face, the feed movement is termed as longitudinal.

If the table is fed parallel to the face of the column the feed movement is termed as cross.

If the table is rotated on a vertical axis, the feed movement is termed as circular.

Like a shaper or a planer, the feed movement of a slotter is intermittent and supplied at the beginning of the cutting stroke. The feed movement may by supplied either by hand or power. The hand feed is supplied by rotating the individual feed screws.

The power feed mechanism is shown in Fig.9.4. A cam groove *1* is cut on the face of the bull gear in which a roller *2* slides. As the bull gear rotates, the roller attached to a lever *3* follows the contour of the cam groove and moves up and down only during a very small part of revolution of the bull gear. The cam groove may be so cut that the movement of the lever *3* will take place only at the beginning of the cutting stroke. Fig.9.5 shows the cam groove cut on a bull gear. The rocking movement of the lever *3* is transmitted to the ratchet and pawl mechanism 6 and *8*, so that the ratchet 8 will move in one direction only during this short period of time. The ratchet wheel

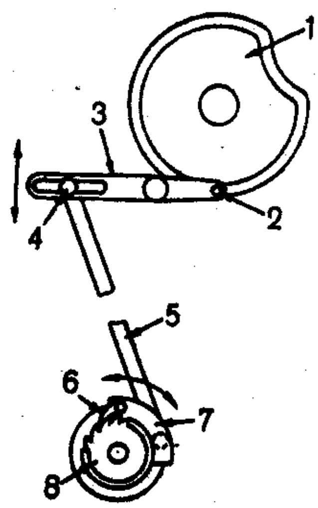


**Figure 9.4 Power feed mechanism**
1. Cam groove on bull gear, 2. Roller, 3. Lever, 4. Feed adjustment pin, 5. Connecting rod, 6. Pawl, 7. Pawl lever, 8. Ratchet wheel.

is mounted on a feed shaft which may be engaged with cross, longitudinal or rotary feed screws individually or together to impart power feed movement to the table.

## 9.5 WORK HOLDING DEVICES

The work is held on a slotter table by a vise, T-bolts and clamps or by special fixtures. T-bolts and clamps are used for holding most of the work on the table. Before clamping, pieces are placed below the work so as to allow the tool to complete the cut without touching the table. Fixtures are used for holding repetitive work.

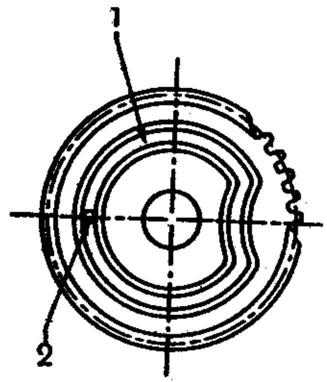

**Figure 9.5 Cam groove on bull gear**
1. Cam groove, 2. Roller.

## 9.6 SLOTTER OPERATIONS

The operations performed in a slotter are :

1. Machining flat surface.
2. Machining cylindrical surface.
3. Machining irregular surface and cam machining.
4. Machining slots, keyways and grooves.

**Machining flat surfaces** : The external and internal flat surfaces may be generated on a workpiece easily in a slotting machine. The work to be machined is supported on parallel strips so that the tool will have clearance with the table when it is at the extreme downward position of the stroke. The work is then clamped properly on the table and the position and the length of stroke is adjusted. A clearance of 20 to 25 mm is left before the beginning of cutting stroke, so that the feeding movement may take place during this ideal part of the stroke. The table is clamped to prevent any longitudinal or rotary travel and the cut is started from one end of the work. The crossfeed is supplied at the beginning of each cutting stroke and the work is completed by using a roughing and a finishing tool. While machining an internal surface, a hole is drilled in the work piece through which the slotting tool may pass during the first cutting stroke. A second surface parallel to the first machined surface can be completed without disturbing the setting by simply rotating the table through 180° and adjusting the position of the saddle. A surface perpendicular to the first machined surface may be completed by rotating the table by 90° and adjusting the position of the saddle and crosslide.

**Machining circular surfaces :** The external and internal surface of a cylinder can also be machined in a slotting machine. The work is placed centrally on the rotary table and packing pieces and clamps are to hold the work securely on the table. The tool is set radially on the work and necessary adjustments of the machine and the tool are made. The saddle is clamped in its position and the machine is started. While machining, the feeding is done by the rotary table feed screw which rotates the table through a small arc at the beginning of each cutting stroke.

**Machining irregular surfaces or cams :** The work is set on the table and necessary adjustments of the tool and the machine are made as detailed in other operations. By combining cross, longitudinal and rotary feed movements of the table any contoured surface can be machined on a workpiece.

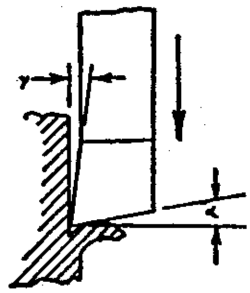


**Figure 9.6 Slotter tool angles**
α. Top rake angle, γ. Front clearance angle.

**Machining grooves or keyways :**
Internal and external grooves are cut very conveniently on a slotting machine. A slotter is specially intended for cutting internal grooves which are difficult to produce in other machines. External or internal gear teeth can also be machined in a slotter by cutting equally spaced grooves on the periphery of the work. The indexing or dividing the periphery of the work is done by the graduations on the rotary table.

## 9.7 SLOTTER TOOLS

A slotting machine tool differs widely from a shaper or a planer tool as the tool in a slotter removes metal during its vertical cutting stroke. This changed cutting condition presents a lot of difference in the tool shape. In a lathe, shaper or a planer tool the cutting pressure acts perpendicular to the tool length, whereas in a slotter the pressure acts along the length of the tool. The rake and the clearance angle of a slotter tool apparently look different from a lathe or a shaper tool as these angles are determined with respect to a vertical plane rather than the horizontal. Fig.9.6 illustrates a typical slotter tool with tool angles. Slotter tools are provided with top rake, front clearance and side clearance, but no side rake is given. The nose of the tool projects slightly beyond the shank to provide clearance. The amount of rake angle given is similar to that of a shaper tool.

The slotter tools are robust in cross-section and are usually of forged type; of course, bit type tools fitted in heavy duty tool holders are also used. Fig.9.7 illustrates different slotter tools used in different operations. Keyway cutting tools are thinner at the cutting edges. Round nose tools are used for machining circular or contoured surfaces. Square nosed tools are used for machining flat surfaces.

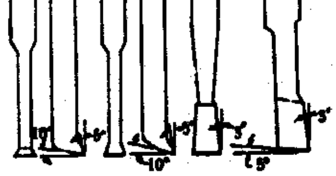

**Figure 9.7 Slotter tools**

## 9.8 CUTTING SPEED, FEED AND DEPTH OF CUT

Similar to a shaper, the *cutting speed* of a slotter is defined by the rate with which the metal is removed during downward cutting stroke and is expressed in meters per minute.

***Feed*** is the movement of the work per double stroke expressed in mm.

***Depth of cut*** is the perpendicular distance measured between the machined surface and unmachined surface expressed in mm.

## REVIEW QUESTIONS

1. Describe various types of slotters in brief. How a slotter is specified ?
2. Describe the main parts of a slotting machine. Describe at least three of them.
3. Write about the various ram drive mechanisms of a slotter.
4. Describe with a line diagram of Whitworth quick return mechanism, used in slotter.
5. Describe various slotting tools and slotter operations.
6. Describe various feed movement in a slotting machine ?
7. Describe in brief how you can machine circular surfaces in a slotting machine.