Module
4
General purpose machine tools

Lesson 20

Construction, working principle and applications of shaping, planing and slotting machines.

Instructional objectives

At the end of this lesson, the students will be able to;

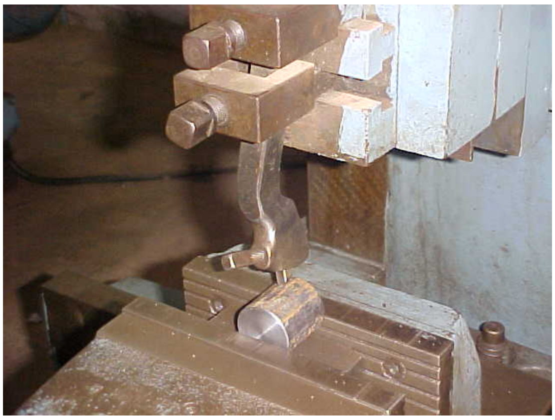
(i) Demonstrate the configurations and functions of shaping machine, planing machine and slotting machine
(ii) Illustrate the kinematic systems and explain the working principles of shaping machine, planing machine and slotting machine
(iii) Show and describe the various machining applications of shaping, planing and slotting machines.

(i) Configurations and basic functions of

- **Shaping machines**
- **Planing machines**
- **Slotting machines**

- **Shaping machine**

A photographic view of general configuration of shaping machine is shown in Fig. 4.4.1. The main functions of shaping machines are to produce flat surfaces in different planes. Fig. 4.4.2 shows the basic principle of generation of flat surface by shaping machine. The cutting motion provided by the linear forward motion of the reciprocating tool and the intermittent feed motion provided by the slow transverse motion of the job along with the bed result in producing a flat surface by gradual removal of excess material layer by layer in the form of chips. The vertical infeed is given either by descending the tool holder or raising the bed or both. Straight grooves of various curved sections are also made in shaping machines by using specific form tools. The single point straight or form tool is clamped in the vertical slide which is mounted at the front face of the reciprocating ram whereas the workpiece is directly or indirectly through a vice is mounted on the bed.



Cutting tool in action

Fig. 4.4.1 *Photographic view of a shaping machine*

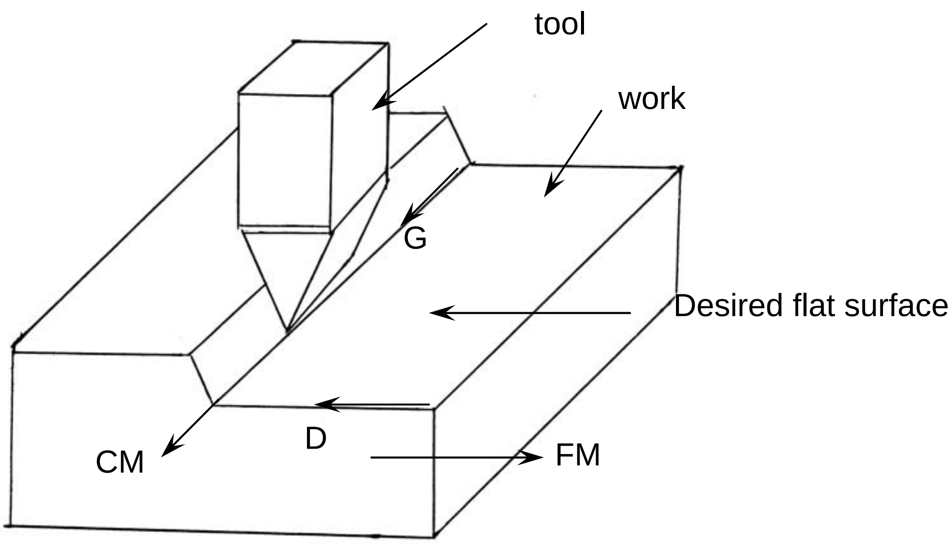


Fig. 4.4.2 *Principle of producing flat surface in shaping machine*

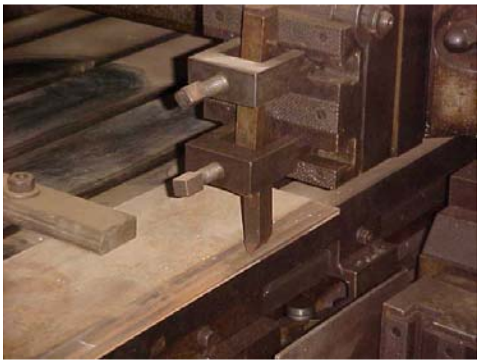
- **Planing machine**

The photographic view in Fig. 4.4.3 typically shows the general configuration of planing machine. Like shaping machines, planing machines are also basically used for producing flat surfaces in different planes. However, the major differences between planing machines from shaping machines are :

  - Though in principle both shaping and planing machines produce flat surface in the same way by the combined actions of the Generatrix and Directrix but in planing machine, instead of the tool, the workpiece reciprocates giving the fast cutting motion and instead of the job, the tool(s) is given the slow feed motion(s).
  - Compared to shaping machines, planing machines are much larger and more rugged and generally used for large jobs with longer stroke length and heavy cuts. In planing machine, the workpiece is mounted on the reciprocating table and the tool is mounted on the horizontal rail which, again, can move vertically up and down along the vertical rails.
  - Planing machines are more productive (than shaping machines) for longer and faster stroke, heavy cuts (high feed and depth of cut) possible and simultaneous use of a number of tools.

As in shaping machines, in planing machines also;

- ∆ The length and position of stroke can be adjusted
- ∆ Only single point tools are used
- ∆ The quick return persists
- ∆ Form tools are often used for machining grooves of curved section
- ∆ Both shaping and planing machines can also produce large curved surfaces by using suitable attachments.

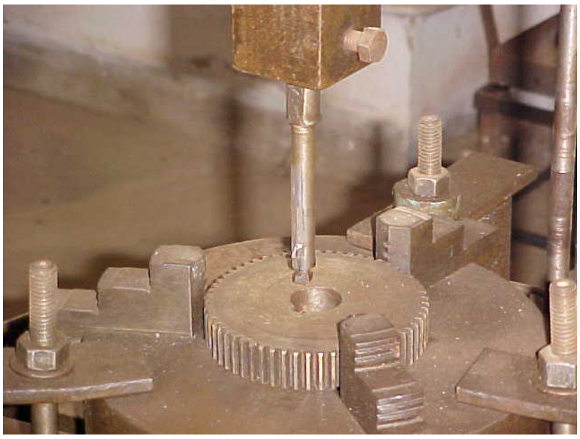


Cutting tool in action

Fig. 4.4.3 *Photographic view of a planing machine*

- **Slotting machine**

Slotting machines can simply be considered as vertical shaping machine where the single point (straight or formed) reciprocates vertically (but without quick return effect) and the workpiece, being mounted on the table, is given slow longitudinal and / or rotary feed as can be seen in Fig. 4.4.4. In this machine also the length and position of stroke can be adjusted. Only light cuts are taken due to lack of rigidity of the tool holding ram for cantilever mode of action. Unlike shaping and planing machines, slotting machines are generally used to machine internal surfaces (flat, formed grooves and cylindrical).
Shaping machines and slotting machines, for their low productivity, are generally used, instead of general production, for piece production required for repair and maintenance. Like shaping and slotting machines, planing machines, as such are also becoming obsolete and getting replaced by plano-millers where instead of single point tools a large number of large size and high speed milling cutters are used.



Cutting tool in action

Fig. 4.4.4 *Photographic view of a slotting machine*

(ii) Kinematic system and working principles of

- **Shaping machine**
- **Planing machine**
- **Slotting machine**

- **Shaping machine**

The usual kinematic system provided in shaping machine for transmitting power and motion from the motor to the tool and job at desired speeds and feeds is schematically shown in Fig. 4.4.5.

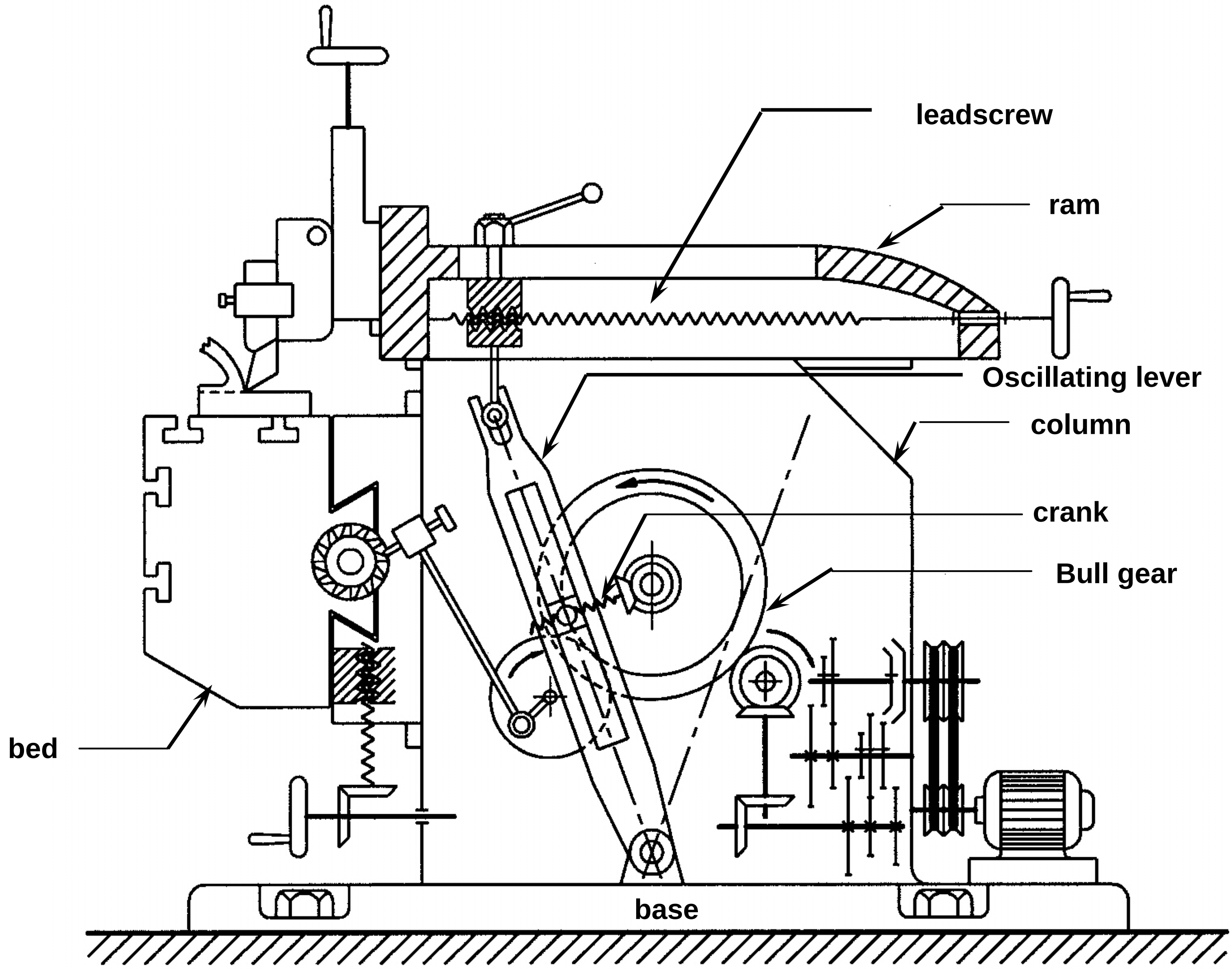


***Fig. 4.4.5** Kinematic diagram of a shaping machine.*

The central large bull gear receives its rotation from the motor through the belt-pulley, clutch, speed gear box and then the pinion. The rotation of the crank causes oscillation of the link and thereby reciprocation of the ram and hence the tool in straight path. Cutting velocity which needs to be varied depending upon the tool-work materials, depends upon

- The stroke length, S mm
- Number of strokes per min., N_s and
- The Quick return ratio, QRR (ratio of the durations of the forward stroke and the return stroke)

As, $$V_C = \frac{sxN_s}{1000}\left(1 + \frac{1}{QRR}\right) m/\text{min} \qquad (4.5.1)$$

To reduce idle time, return stroke is made faster and hence QRR > 1.0 (4.5.2)

Since $$QRR = \frac{2L + s}{2L - s} \qquad (4.5.3)$$

where, L = length (fixed) of the oscillating lever
and s = stroke length

The benefit of quick return decreases when S becomes less.

The changes in length of stroke and position of the stroke required for different machining are accomplished respectively by

- Δ Adjusting the crank length by rotating the bevel gear mounted coaxially with the bull gear
- Δ Shifting the nut by rotating the leadscrew as shown in Fig. 4.4.5.

The value of N_s is varied by operating the speed gear box.

The main (horizontal) feed motion of the work table is provided at different rate by using the ratchet – paul systen as shown in Fig. 4.4.5. The vertical feed or change in height of the tool tip from the bed can be obtained either by lowering the tool or raising the bed by rotating the respective wheel as indicated in Fig. 4.4.5.

- **Planing machine**

The simple kinematic system of the planing machine enables transmission and transformation of rotation of the main motor into reciprocating motion of the large work table and the slow transverse feed motions (horizontal and vertical) of the tools. The reciprocation of the table, which imparts cutting motion to the job, is attained by rack-pinion mechanism. The rack is fitted with the table at its bottom surface and the pinion is fitted on the output shaft of the speed gear box which not only enables change in the number of stroke per minute but also quick return of the table.

The blocks holding the cutting tools are moved horizontally along the rail by screw-nut system and the rail is again moved up and down by another screw-nut pair as indicated in Fig. 4.4.3.

- **Slotting machine**

The schematic view of slotting machine is typically shown in Fig. 4.4.6

The vertical slide holding the cutting tool is reciprocated by a crank and connecting rod mechanism, so here quick return effect is absent. The job, to be machined, is mounted directly or in a vice on the work table. Like shaping machine, in slotting machine also the fast cutting motion is imparted to the tool and the feed motions to the job. In slotting machine, in addition to the

longitudinal and cross feeds, a rotary feed motion is also provided in the work table.
The intermittent rotation of the feed rod is derived from the driving shaft with the help of a four bar linkage as shown in the kinematic diagram.
It is also indicated in Fig. 4.4.6 how the intermittent rotation of the feed rod is transmitted to the leadsrews for the two linear feeds and to the worm – worm wheel for rotating the work table. The working speed, i.e., number of strokes per minute, N_s may be changed, if necessary by changing the belt-pulley ratio or using an additional “speed gear box”, whereas, the feed values are changed mainly by changing the amount of angular rotation of the feed rod per stroke of the tool. This is done by adjusting the amount of angle of oscillation of the paul as shown in Fig. 4.4.6. The directions of the feeds are reversed simply by rotating the tapered paul by 180^o as done in shaping machines.

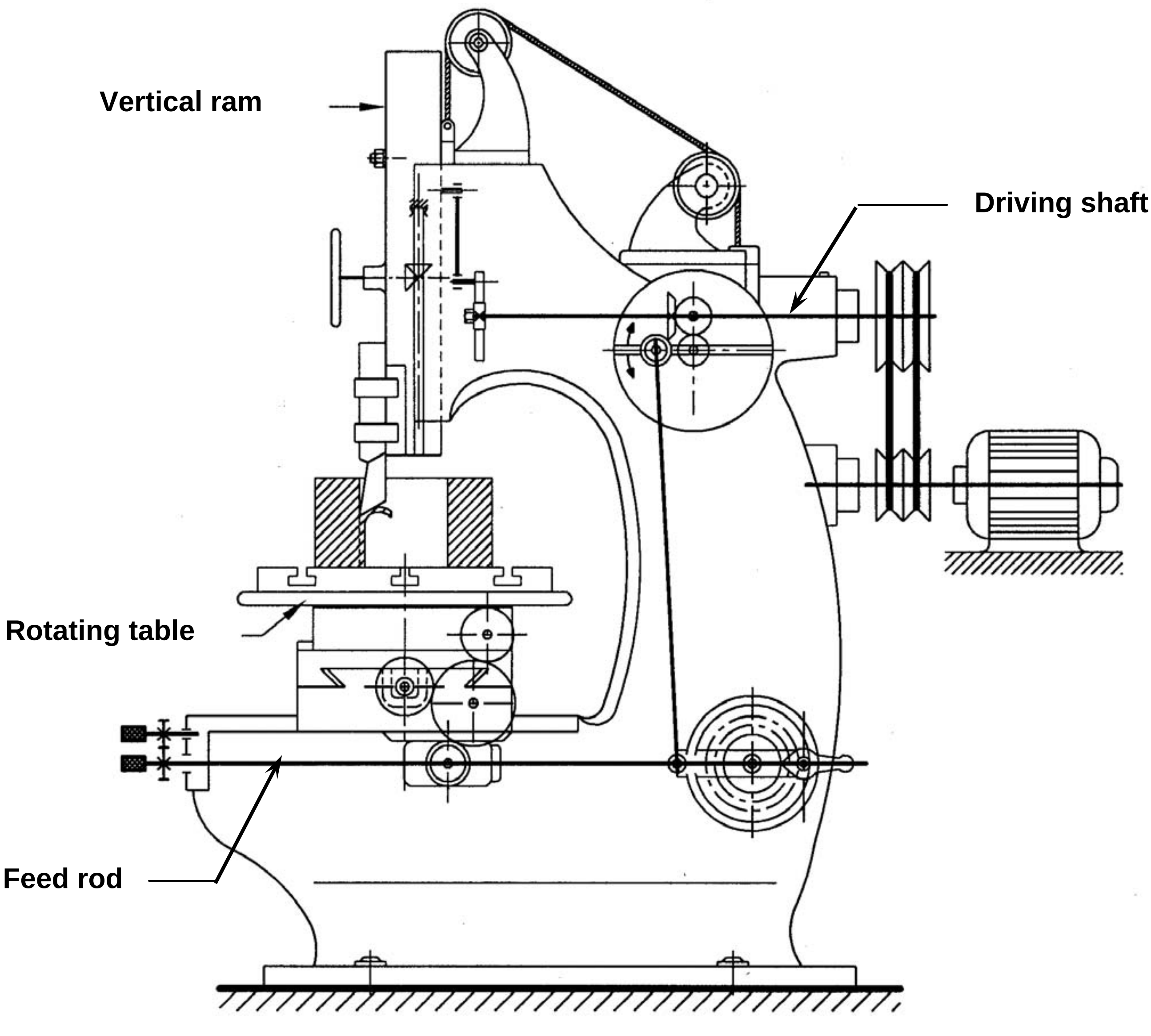


Fig. 4.4.6 *Kinematic system of a slotting machine.*

(iii) Various applications of

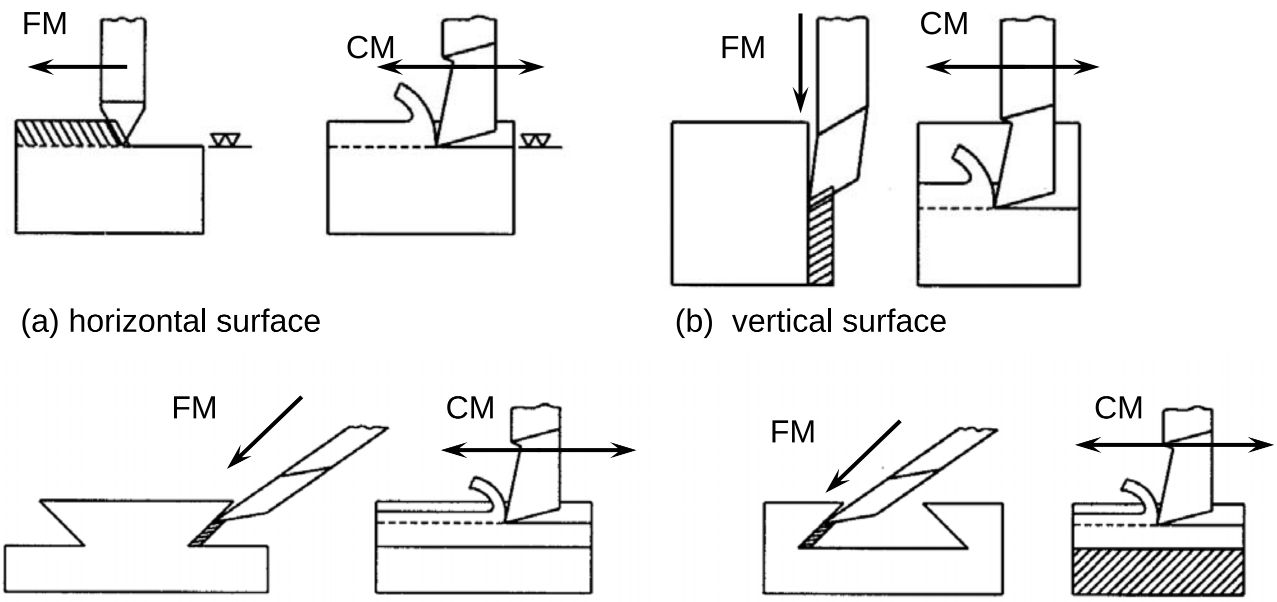
- **Shaping machine**
- **Planing machines**
- **Slotting machines**

- **Shaping machines**

It is already mentioned that shaping machines are neither productive nor versatile.

However, its limited applications include :

Δ Machining flat surfaces in different planes. Fig. 4.4.7 shows how flat surfaces are produced in shaping machines by single point cutting tools in (a) horizontal, (b) vertical and (c) inclined planes.



(a) horizontal surface

(b) vertical surface

(c) inclined surfaces (dovetail slides and guides)

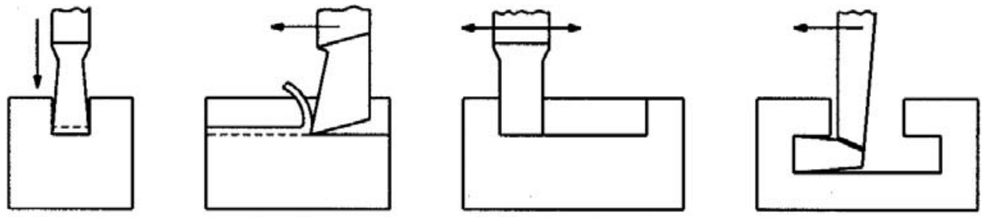
***Fig. 4.4.7** Machining of flat surfaces in shaping machines*

Δ Making features like slots, steps etc. which are also bounded by flat surfaces. Fig. 4.4.8 visualises the methods of machining (a) slot, (b) pocket (c) T-slot and (d) Vee-block in shaping machine by single point tools.

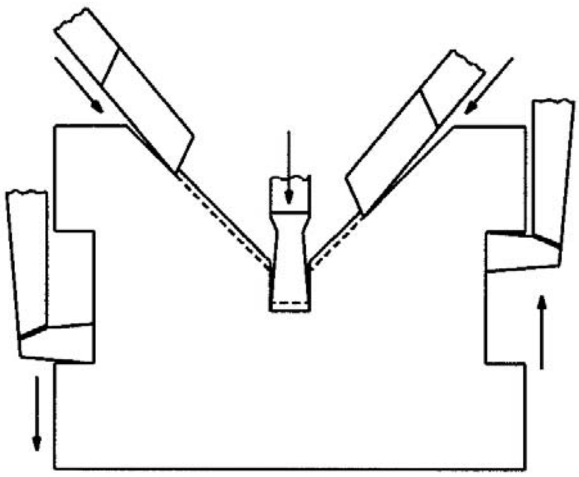
Δ Forming grooves bounded by short width curved surfaces by using single point but form tools. Fig. 4.4.9 typically shows how (a) oil grooves and (b) straight tooth of spur gears can be made in shaping machine

Δ Some other machining applications of shaping machines are cutting external keyway and splines, smooth slitting or parting, cutting teeth of rack for repair etc. using simple or form type single point cutting tools.

Some unusual work can also be done, if needed, by developing and using special attachments.

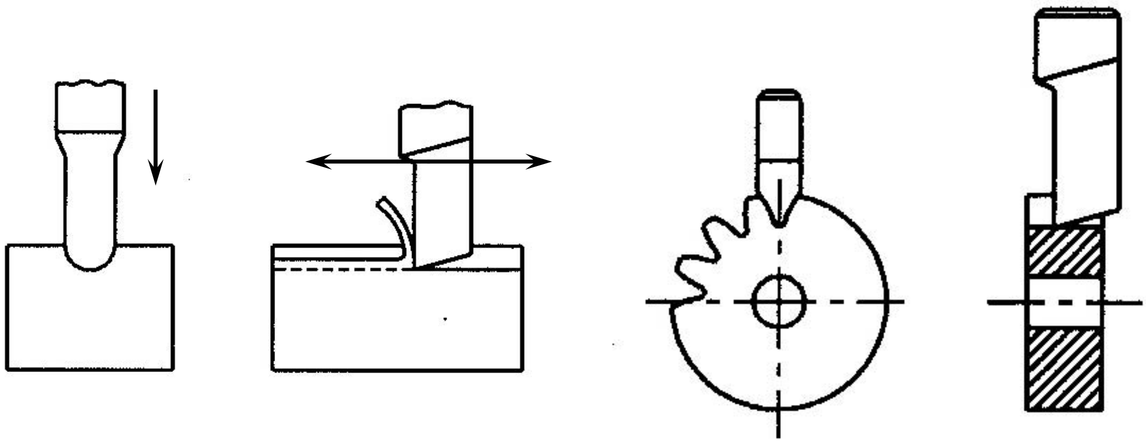


(a) slotting (b) pocketing (c) T-slot cutting



(d) Vee-block

Fig. 4.4.8 *Machining (a) slot, (b) pocket (c) T-slot and (d) Vee block in shaping machine*



(a) grooving (b) straight tooth cutting for spur gears

Fig. 4.4.9 *Making grooves and gear teeth cutting in shaping machine by form tools*.

However, due to very low productivity, less versatility and poor process capability, shaping machines are not employed for lot and even batch production. Such low cost primitive machine tools may be reasonably used only for little or few machining work on one or few pieces required for repair and maintenance work in small machine shops.

- **Planing machines**

The basic principles of machining by relative tool-work motions are quite similar in shaping machine and planing machine. The fast straight path cutting motion is provided by reciprocation of the tool or job and the slow, intermittent transverse feed motions are imparted to the job or tool. In respect of machining applications also these two machine tools are very close. All the operations done in shaping machine can be done in planing machine. But large size and stroke length and higher rigidity enable the planing machines do more heavy duty work on large jobs and their long surfaces. Simultaneous use of number of tools further enhances the production capacity of planing machines.
The usual and possible machining applications of planing machines are

- ∆ The common machining work shown in Fig. 4.4.7, Fig. 4.4.8 and Fig. 4.4.9 which are also done in shaping machines
- ∆ Machining the salient features like the principal surfaces and guideways of beds and tables of various machines like lathes, milling machines, grinding machines and planing machines itself, broaching machines etc. are the common applications of planing machine as indicated in Fig. 4.4.10 where the several parallel surfaces of typical machine bed and guideway are surfaced by a number of single point HSS or carbide tools. Besides that the long parallel T-slots, Vee and inverted Vee type guideways are also machined in planing machines.

- Besides the general machining work, some other critical work like helical grooving on large rods, long and wide 2-D curved surfaces, repetitive oil grooves etc. can also be made, if needed, by using suitable special attachments.

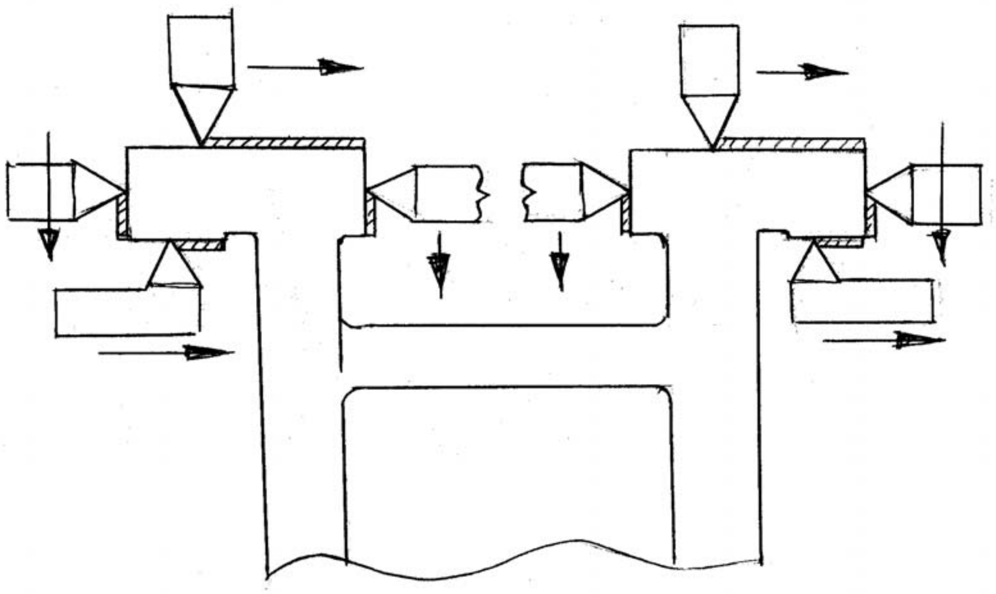


Fig. 4.4.10 *Machining of a machine bed in planing machine*

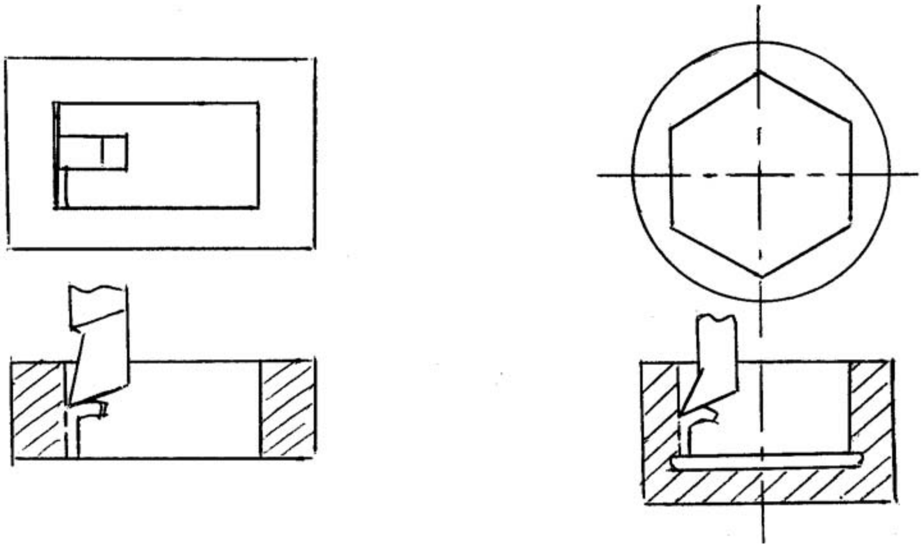
- **Slotting machine**

Slotting machines are very similar to shaping machines in respect of machining principle, tool-work motions and general applications. However, relative to shaping machine, slotting machines are characterised by :

- Vertical tool reciprocation with down stroke acting
- Longer stroke length
- Less strong and rigid
- An additional rotary feed motion of the work table
- Used mostly for machining internal surfaces.

The usual and possible machining applications of slotting machines are :

- Internal flat surfaces
- Enlargement and / or finishing non-circular holes bounded by a number of flat surfaces as shown in Fig. 4.4.11 (a)
- Blind geometrical holes like hexagonal socket as shown in Fig. 4.4.11 (b)
- Internal grooves and slots of rectangular and curved sections.
- Internal keyways and splines, straight tooth of internal spur gears, internal curved surface of circular section, internal oil grooves etc. which are not possible in shaping machines.



(a) through rectangular hole (b) hexagonal socket

Fig. 4.4.11 *Typical machining application of slotting machine.*

However, it has to be borne in mind that productivity and process capability of slotting machines are very poor and hence used mostly for piece production required by maintenance and repair in small industries. Scope of use of slotting machine for production has been further reduced by more and regular use of broaching machines.

Exercise

Identify the correct answer from the given four options.

1. Reciprocation of the cutting tool in shaping machines is accomplished by
   a. Rack pinion mechanism
   b. Crank and connecting rod mechanism
   c. Cam and cam follower mechanism
   d. Oscillating lever mechanism
2. Internal keyway in gears can be cut in
   a. Shaping machine
   b. Planing machine
   c. Slotting machine
   d. None of the above
3. The job reciprocates in
   a. Shaping machine
   b. Planing machine
   c. slotting machine
   d. All of the above
4. The T-slots in the table of planing machines are cut in
   a. Shaping machine
   b. Planing machine
   c. Slotting machine
   d. None of the above
5. Flat surface can be produced in
   a. Shaping machine only
   b. Planing machine only
   c. Slotting machine only
   d. All of the above
6. Large number of cutting tools can be simultaneously used in
   a. Shaping machine
   b. Planing machine
   c. Slotting machine
   d. None of the above

7. Heavy cuts can be given during machining in
    a. Shaping machine
    b. Planing machine
    c. Slotting machine
    d. None of the above
8. Slotting machines are used to cut internal gear teeth for
    a. Batch production
    b. Lot production
    c. Mass production
    d. None of the above
9. The work-table can rotate in
    a. Shaping machine
    b. Planing machine
    c. Slotting machine
    d. None of the above

10. Length of the stroke can be varied in
    a. Shaping machine
    b. Planing machine
    c. Slotting machine
    d. All of the above

Answers

Q.No	Answers
1	d
2	c
3	b
4	b
5	d
6	b
7	b
8	a
9	c
10	b