7

SHAPER

7.1 INTRODUCTION

The shaper is a reciprocating type of machine tool intended primarily to produce flat surfaces. These surfaces may be horizontal, vertical, or inclined. In general, the shaper can produce any surface composed of straight line elements. Modern shapers can generate contoured surface.

The metal working shaper was developed in the year 1836 by James Nasmyth an, Englishman.

7.2 TYPES OF SHAPERS

Shapers are classified in a number of ways depending upon the general features of design or the purpose for which they are intended. Shapers are classified under the following headings.

1. *According to the type of mechanism used for giving reciprocating motion to the ram :* (a) Crank type (b) Geared type (c) Hydraulic type.
2. *According to the position and travel of ram :* (a) Horizontal type (b) Vertical type (c) Traveling head type.
3. *According to the type of design of the table :* (a) Standard shaper (b) Universal shaper
4. *According to the type of cutting stroke :* (a) Push type (b) Draw type.

Crank shaper : This is the most common type of shaper in which a single point cutting tool is given a reciprocating motion equal to the length of the stroke desired while the work is clamped in position on an adjustable table. In construction, the crank shaper employs a crank mechanism to change circular motion of a large gear called "bull gear" incorporated in the machine to reciprocating motion of the ram. The bullgear receives power either from an individual motor or from an overhead line shaft if it is a belt driven shaper.

Geared type : The reciprocating motion of the ram in some type of shaper is effected by means of a rack and pinion. The rack teeth which are cut directly below the ram mesh with a spur gear. The pinion meshing with the rack is driven by a gear train. The speed and the direction in which the machine will traverse depend on the number of gears in the gear train. This type of shaper is not very widely used

Hydraulic shaper : In a hydraulic shaper, reciprocating movement of the ram is obtained by hydraulic power. Oil under high pressure is pumped into the operating cylinder fitted with a piston. The end of the piston rod is connected to the ram. The high pressure oil first acts on one side of the piston and then on the other causing the piston to reciprocate and the motion is transmitted to the ram. The piston speed is changed by varying the amount of liquid delivered by the pump. One of the most important advantages of this type of shaper is that the cutting speed and force of the ram drive are constant from the very beginning to the end of the cut. It also offers great flexibility of speed and feed control, eliminates shock and permits slip or slowing up of motion when the cutting tool is overloaded, protecting the parts or the tools from breakage. Another advantage is that the machine does not make any noise and operates very quietly.

Horizontal shaper : In a horizontal shaper, the ram holding the tool reciprocates in a horizontal axis. Horizontal shapers are mainly used to produce flat surfaces.

Vertical shaper : In a vertical shaper, the ram holding the tool reciprocates in a vertical axis. In some of the vertical machines provision is made to allow adjustment of the ram to an angle of about 10 degrees from the vertical position. Vertical shapers may be crank driven, rack driven, screw driven or hydraulic power driven. The work table of a vertical shaper can be given cross, longitudinal, and rotary movement. The tool used on a vertical shaper is entirely different from that used on a horizontal shaper. Vertical shapers are very convenient for machining internal surfaces, keyways, slots or grooves. Large internal and external gears may also be machined by indexing arrangement of the rotary table. There are vertical shapers which are specially designed for machining internal keyways. They are then called *keyseaters*

Travelling head shaper : In a traveling head shaper, the ram carrying the tool while it reciprocates moves crosswise to give the required feed. Heavy and unwieldy jobs which are very difficult to hold on the table of a standard shaper and fed past the tool are held static on the basement of the machine while the ram reciprocates and supplies the feeding movements.

Standard or plain shaper : A shaper is termed as standard or plain when the table has only two movements, vertical and horizontal, to give the feed. The table may or may not be supported at the outer end.

Universal shaper : In a universal shaper, in addition to the two movements provided on the table of a standard shaper, the table can be swivelled about an axis parallel to the ram ways, and the upper portion of the table can be tilted about a second horizontal axis perpendicular to the first axis. As the work mounted on the table can be adjusted in different planes, the machine is most suitable for different types of work and is given the name "Universal". A universal shaper is mostly used in tool room work.

Push type shaper : This is the most general type of shaper used in common practice. The metal is removed when the ram moves away from the column, i.e. pushes the work.

Draw type shaper : In a draw shaper, the metal is removed when the ram moves towards the column of the machine, i.e. draws the work towards the machine. The tool is set in a reversed direction to that of a standard shaper. The ram is generally supported by an overhead arm which ensures rigidity and eliminates deflection of the tool. In this shaper the cutting pressure acts towards the column which relieves the crossrail and other bearings from excessive loading and allows to take deep cuts. Vibration in these machines is practically eliminated.

7.3 PRINCIPAL PARTS

Fig.7.1 illustrates different parts of a standard shaper.

Base : The base is the necessary bed or support required for all machine tools. The base may be rigidly bolted to the floor of the shop or on the bench according to the size of the machine. It is so designed that it can take up the entire load of the machine and the forces set up by the cutting tool over the work. It is made of cast iron to resist vibration and take up high compressive load.

Column : The column is a box like casting mounted upon the base. It encloses the ram driving mechanism. Two accurately machined guideways are provided on the top of the column on which the ram reciprocates. The front vertical face of the column which serves as the guideways for the crossrail is also accurately machined. The lid on the left side of the column may be opened for inspection and oiling of the internal mechanism with the column. The other side of the column contains levers, handles, etc. for operating the machine.

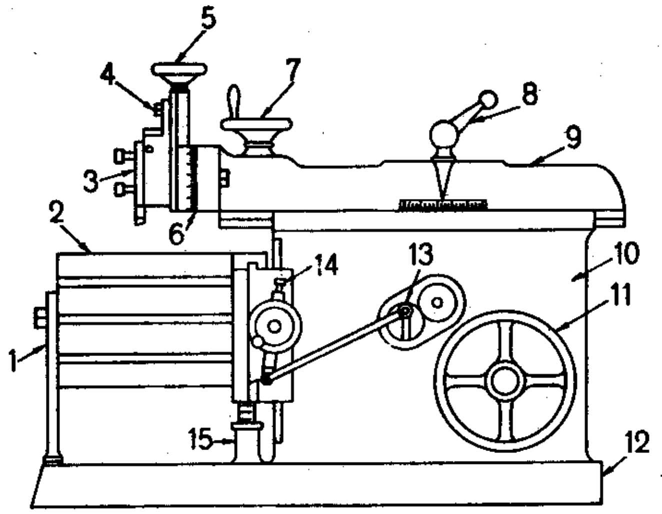


Figure 7.1 Parts of a standard shaper

1. Table support, 2. Table, 3. Clapper box, 4. Apron clamping bolts, 5. Downfeed hand wheel, 6. Swivel base degree graduations, 7. Position of stroke adjustment handwheel, 8. Ram block locking handle, 9. Ram, 10. Column, 11. Driving pulley, 12. Base, 13. Feed disc, 14. Pawl mechanism, 15. Elevating screw.

Crossrail : The crossrail is mounted on the front vertical guideways of the column. It has two parallel guideways on its top in the vertical plane that are perpendicular to the ram axis. The table may be raised or lowered to accommodate different sizes of jobs by rotating an elevating screw which causes the crossrail to slide up and down on the vertical face of the column. A horizontal cross feed screw which is fitted within the crossrail and parallel to the top guideways of the crossrail actuates the table to move in a crosswise direction.

Saddle : The saddle is mounted on the crossrail which holds the table firmly on its top. Crosswise movement of the saddle by rotating the cross feed screw by hand or power causes the table to move sideways.

Table : The table which is bolted to the saddle receives crosswise and vertical movements from the saddle and crossrail. It is a box like casting having T-slots both on the top and sides for clamping the work. In a universal shaper the table may be swivelled on a horizontal axis and the upper part of the table may be tilted up or down. In a heavier type shaper, the front face of the table is clamped with a table support to make it more rigid.

Ram : The ram is the reciprocating member of the shaper. This is semi-cylindrical in form and heavily ribbed inside to make it more rigid. It slides on the accurately machined dovetail guideways on the top of the column and is connected to the reciprocating mechanism contained within the column. It houses a screwed shaft for altering the position of the ram with respect to the work and holds the tool head at the extreme forward end.

Toolhead : The toolhead of a shaper holds the tool rigidly, provides vertical and angular feed movement of the tool and allows the tool to have an automatic relief during its return stroke. The *vertical slide* of the toolhead has a *swivel base* which is held on a circular seat on the ram. The swivel base is graduated in degrees, so that the vertical slide may be set perpendicular to the work surface or at any desired angle. By rotating the *downfeed screw handle*, the vertical slide carrying the tool executes down feed or angular feed movement while machining vertical or angular surface. The amount of feed or depth of cut may be adjusted by a micrometer dial on the top of the downfeed screw. *Apron* consisting of *clapper box, clapper block* and *tool post* is clamped upon the vertical slide by a screw. By releasing the clamping screw, the apron may be swivelled upon the *apron swivel pin* either towards left or towards right with respect to the vertical slide. This arrangement is necessary to provide relief to the tool while making vertical or angular cuts. The two vertical walls on the apron called *clapper box* houses the *clapper block* which is connected to it by means of a *hinge pin*. The tool post is mounted upon the clapper block. On the forward cutting stroke the clapper block fits securely to the clapper box to make a rigid tool support. On the return stroke a slight frictional drag of the tool on the work lifts the block out of the clapper box a sufficient amount preventing the tool cutting edge from dragging and consequent wear. The work surface is also prevented from any damage due to dragging. Fig.7.2 illustrates the tool head of a shaper.

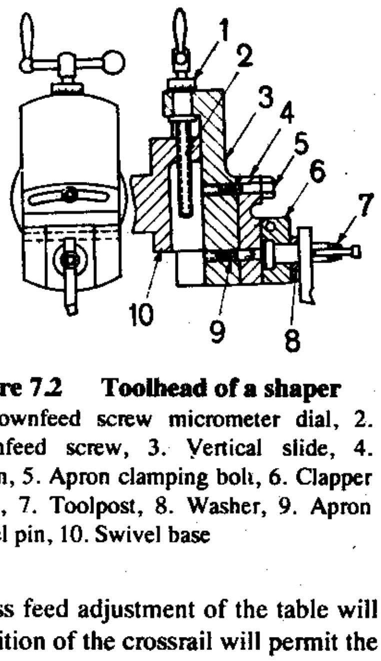


Figure 7.2 Toolhead of a shaper
1. Downfeed screw micrometer dial, 2. Downfeed screw, 3. Vertical slide, 4. Apron, 5. Apron clamping bolt, 6. Clapper block, 7. Toolpost, 8. Washer, 9. Apron swivel pin, 10. Swivel base

7.4 SHAPER SIZE

The size of a shaper is determined by the maximum length of stroke or cut it can make. The usual size ranges from 175 to 900 mm. The length of stroke indicates, in addition to the general size of the machine, the size of a cube that can be held and planed in the shaper. Thus in a 250 mm shaper the length of stroke may be adjusted from 0 to 250 mm, the cross feed adjustment of the table will be 250 mm and the extreme bottom position of the crossrail will permit the table to accommodate a workpiece 250 mm high.

The length of stroke of a shaper merely indicates the overall size of the shaper. Other particulars, such as the type of drive : belt drive or individual motor drive, power input, floor space required, weight of the machine, cutting to return stroke ratio, number and amount of feed, etc. are also sometimes necessary.

7.5 SHAPER MECHANISM

In a shaper, rotary movement of the drive is converted into reciprocating movement by the mechanism contained within the column of the machine. The ram holding the tool gets the reciprocating movement. In a standard shaper metal is removed in the forward cutting stroke, while the return stroke goes idle and no metal is removed during this period. To reduce the total machining time it is necessary to reduce the time taken by the return stroke. Thus the shaper mechanism should be so designed that it can allow the ram holding the tool to move at a comparatively slower speed during the forward cutting stroke, the cutting speed depending upon the type of material and machining condition, whereas during the return stroke it can allow the ram to move at a faster rate to reduce the idle return time. This mechanism is known as *quick return mechanism.* The reciprocating movement of the ram and the quick return mechanism of the machine are usually obtained by any one of the following methods :

1. Crank and slotted link mechanism
2. Whitworth quick return mechanism
3. Hydraulic shaper mechanism

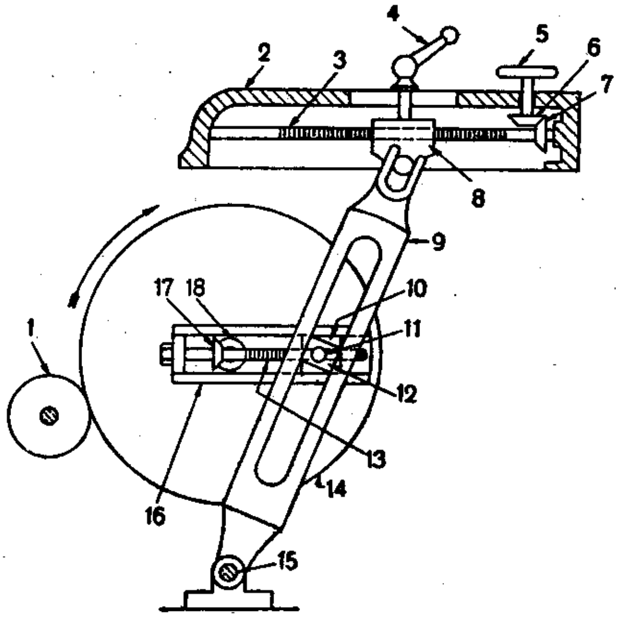


Figure 7.3 Crank and slotted link mechanism
1. Driving pinion, 2. Ram, 3. Screwed shaft, 4. Clamping lever, 5. Handwheel for position of stroke adjustment 6.7. Bevel gears, 8. Ram block, 9. Slotted link or rocker arm, 10. Bull gear sliding block, 11. Crank pin, 12. Rocker arm sliding block, 13. Lead screw. 14. Bull gear, 15. Rocker arm pivot, 16. Bull gear slide, 17,18. Bevel gears.

Crank and slotted link mechanism : The crank and slotted link mechanism is shown in Fig.7.3. The motion or power is transmitted to the bull gear *14* through a pinion *1* which receives its motion from an individual motor or overhead line shaft through speed control mechanism. Speed of the bull gear may be changed by different combination of gearing or by simply shifting the belt on the step cone pulley. Bull gear *14* is a large gear mounted within the column. Bolted to the centre of the bull gear is a radial slide *16* which carries a sliding block *10* into which the crank pin *11* is fitted. Rotation of the bull gear will cause the crank pin *11* to revolve at a uniform speed. Sliding block *12* which is mounted upon the crank pin *11* is fitted within the slotted link *9*. The slotted link *9* which is also known as the rocker arm is pivoted at *15* at its bottom end attached to the frame of the column. The upper end of the rocker arm is forked and connected to the ram block 8 by a pin. As the bull gear rotates causing the crank pin to rotate, the sliding block *12* fastened to the crank pin *11* will rotate on the crank pin circle, and at the same time will move up and down the slot in the slotted link *9* giving it a rocking movement which is communicated to the ram. Thus the rotary motion of the bull gear is converted to reciprocating movement of the ram.

The principle of quick return motion is illustrated in Fig.7.4. When the link is in the position *PM*, the ram will be at the extreme backward position of its stroke, and when it is at *PN*, the extreme forward position of the ram will have been reached. *PM* and *PN* are shown tangent to the crank pin circle. The forward cutting stroke, therefore, takes place when the crank rotates through the angle C_1KC_2 and the return stroke takes place when the crank rotates through the angle C_2LC_1. It is evident that the angle C_1KC_2 made by the forward or cutting stroke is greater than the angle C_2LC_1 described by the return stroke. The angular velocity of the crank pin being constant the return stroke is, therefore, completed within a shorter time for which it is known as quick return motion.

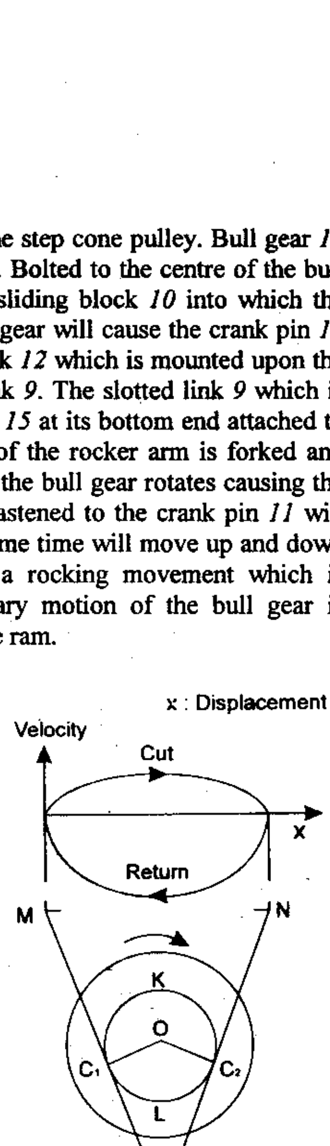


Figure 7.4 Principle of quick return mechanism

The ratio between the cutting time and return time may be determined from the formula :

$$\frac{\text{Cutting time}}{\text{Return time}} = \frac{\widehat{C_1KC_2}}{\widehat{C_2LC_1}} \quad 7.1$$

Cutting time to return time ratio usually varies between 2:1 and the practical limit is 3:2. The only disadvantage lies with this mechanism is that the cutting speed and return speed is not constant throughout the stroke. It is minimum when the rocker arm is at the two extremities and the speed is maximum when the rocker arm is vertical.

Adjusting the length of stroke : Fig.7.3 illustrates how the length of stroke in a crank shaper can be adjusted. The crank pin *11* is fastened to the sliding block *10* which can be adjusted and the radius of its travel may be varied. The block *10* is again mounted upon the radial slide *16* bolted to the centre of the bull gear. The bevel gear *18* placed at the centre of the bull gear may be rotated by a handle causing the bevel gear *17* to rotate. The bevel gear *17* is mounted upon the small lead screw *13* which passes through the sliding block *10*. Thus rotation of the bevel gear *17* will cause the sliding block *10* carrying the crank pin *11* to be brought inwards or outwards with respect to the centre of the bull wheel. Fig.7.5 shows the detail arrangement for altering the position of bull gear sliding block on bull gear for adjusting the length of stroke. The sketch has been drawn without the rocker arm in position. The closer the pin is brought to the centre of the bull wheel, the smaller will be the stroke. Maximum stroke of the ram is obtained when the crank pin is shifted towards the farthest end of the slide. Fig.7.6 (A) and (B) shows the short and long stroke of the ram, effected by altering the position of crank pin.

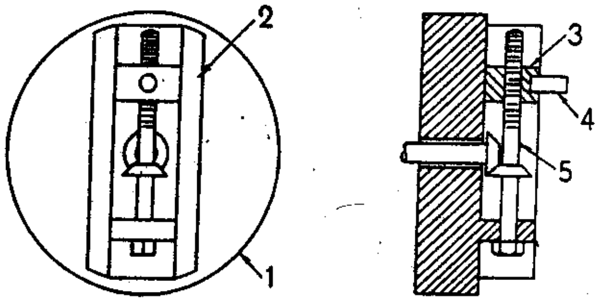


Figure 7.5 Bull gear sliding block mounting arrangement
1. Bullgear, 2. Bullgear slide, 3. Bull gear sliding block, 4. Crank pin, 5. Lead screw

Adjusting the position of stroke : The position of the ram relative to the work can also be adjusted. Referring to the Fig. 7.3, by rotating the hand wheel *5* the screwed shaft *3* fitted in the ram may be made to rotate through two bevel gears *6* and *7*. The ram block *8* which is mounted upon the screwed shaft *3* acts as a nut. When the machine is in operation, the clamping lever *4* is tightened upon the ram body 2 and the ram block, the screwed shaft, and the ram becomes one unit. In order to set the position of stroke, the clamping lever *4* is loosened and by rotating the hand wheel *5* the screwed shaft *3* will rotate within the ram block. The nut remaining fixed in position, rotation of the screwed shaft will cause the ram to move forward or backward with respect to the ram block according to the direction of rotation of the hand wheel *5*. Thus the position of ram may be adjusted with respect to the workpiece. The clamping lever *4* must be tightened after the adjustment has been made.

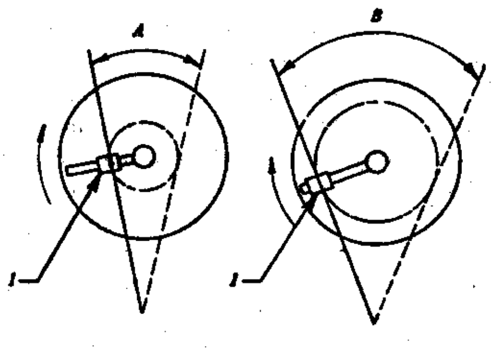


Figure 7.6 Stroke length adjustment
1. Position of crankpin, A. Short stroke length, B. Long stroke length.

Whitworth quick return mechanism : The Whitworth quick return mechanism is shown in Fig.7.7 and a simple line diagram of the mechanism is shown in Fig.7.8. The bull gear is mounted on a large fixed pin *A* upon which it is free to rotate. The crank plate *4* is pivoted eccentrically upon the fixed pin at *5*. Fitted on the face of the bull gear is the crank pin *2* on the top of which is mounted the sliding block 3. Sliding block 3 fits into the slot provided on the crank plate *4*. At the other end of the crank plate *4*, a connecting rod *6* connects the crank plate by a pin *9*

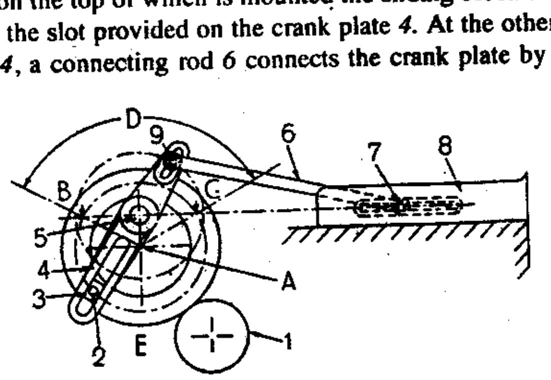


Figure 7.7 Whitworth quick return mechanism
1. Driving pinion, 2. Crank pin, 3. Sliding block, 4. Crank plate, 5. Pivot for crank plate, 6. Connecting rod, 7. Connecting pin for ram, 8. Ram, 9. Pin, A. Fixed pin.

and the ram *8* by a pin *7*. When bull gear will rotate at a constant speed the crank pin *2* with the sliding block *3* will rotate on a crank circle of radius A2 and the sliding block 3 will cause the crank plate to rotate about the point *5* with a variable angular velocity. Pin *9* fitted on the other end of the crank plate *4* will rotate in a circle and the rotary motion of the pin *9* will be converted into reciprocating movement of the ram similar to the crank and connecting rod mechanism. The axis of reciprocating of the ram passes through the pin *5* and is normal to the line *A5*.

When the pin *2* is at the position *C* the ram will be at the extreme backward position but when the pin is at the position *B*, the extreme forward position of the ram will have been reached. When the pin 2 travels from *C* to *B* the crank pin 9 passes through the backward position to the forward position in the cutting stroke, and the return stroke is completed when the pin 2 travels from *B to* C or the pin *9* passes from the forward position to the backward position. As the angular velocity of the crank pin is uniform, the time taken by the crank pin 2 to travel through an arc covering CEB is greater than the time taken to move through an arc covering BDC. Thus a quick return motion is obtained by the mechanism.

The length of stroke of the ram may be changed by shifting the position of pin *9* closer or away from the pivot *5*. The position of stroke may be altered by shifting the position of pin *7* on the ram.

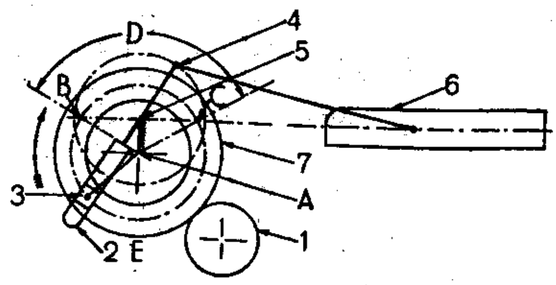


Figure 7.8 Line diagram of quick return mechanism
1. Driving pinion, 2. Crank plate, 3. Sliding block, 4. Crank pin for connecting rod, 5. Pivot for crank plate, 6. Ram, 7. Bull gear, A. Fixed pin.

Hydraulic shaper mechanism : In a hydraulic shaper the ram is moved forward and backward by a piston moving in a cylinder placed under the ram. The machine mainly consists of a constant discharge oil pump *2*, a valve chamber, a cylinder, and a piston *7*. The piston rod 6 is bolted to the ram body. As shown in Fig. 7.9 the oil under high pressure is pumped from the reservoir *1* and is made to pass through the valve chamber to the right side of the oil cylinder *5* exerting pressure on the piston *7*. This causes the ram *4* connected to the piston *7* to perform forward stroke, and any oil present on the left side of the cylinder is discharged to the reservoir through the throttle valve *3*. At the end of extreme forward stroke, the shaper dog *8* hits against the reversing lever *9* causing the valves *12* to alter their positions within the valve chamber. Oil under high pressure is now pumped to the left side of the piston causing the ram to perform return stroke. Oil present on the right side of the piston is now discharged to the reservoir. At the end of the return stroke another shaper dog hits against the reversing lever altering the direction of stroke of the piston and the cycle is thus repeated.

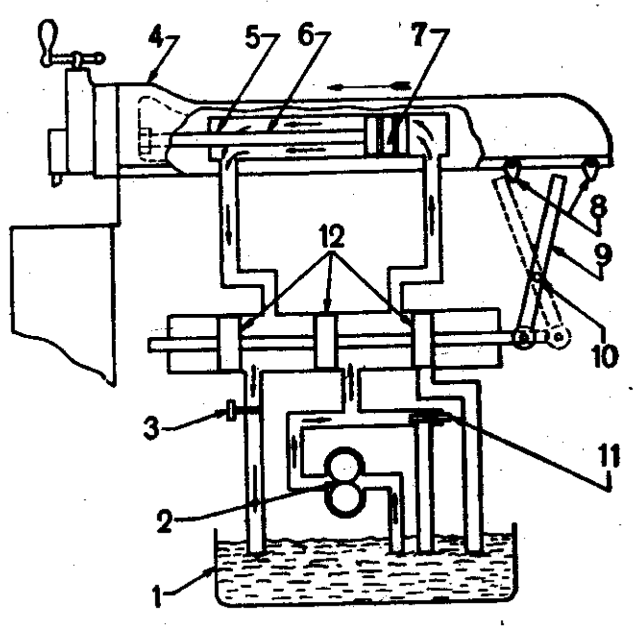


Figure 7.9 Hydraulic shaper mechanism

1. Oil reservoir, 2. Oil pump, 3. Throttle valve, 4. Ram, 5. Cylinder, 6. Piston rod, 7. Piston, 8. Reversing dog, 9. Reversing lever, 10. Reversing lever pivot, 11. Relief valve, 12. Valves.

The quick return motion is effected due to the difference in stroke volume of the cylinder at both ends, the left hand end being smaller due to the presence of the piston rod. As the pump is a constant discharge one, within a fixed period, the same amount of oil will be pumped into the right or to the left hand side of the cylinder. This will mean that the same amount of oil will be packed within a smaller stroke volume causing the oil pressure to rise automatically and increasing the speed during the return stroke.

The length and position of stroke is adjusted by shifting the position of reversing dogs.

The cutting speed may be changed by controlling the throttle valve *3* which regulates the flow of oil. When the throttle valve is partially closed the excess oil flows out through the relief valve *11* to the reservoir maintaining uniform pressure during cutting stroke. A hydraulic shaper is now widely used for having many advantages. Some of them are listed below.

1. The cutting and return speeds are practically constant throughout the stroke. This permits the cutting tool to work uniformly during cutting stroke.
2. The reversal of the ram is obtained quickly without any shock as the oil on the other end of the cylinder provides cushioning effect.
3. Infinite number of cutting speeds may be obtained from zero to the maximum value and the control is easier.
4. With a high rate of return speed, a greater number of cutting strokes may be available within the range of cutting speed.
5. The relief valve ensures safety to the tool and the machine when the machine is overloaded.

Feed mechanism : In a shaper both downfeed and crossfeed movements may be obtained. Unlike a lathe, these feed movements are provided intermittently and during the end of return stroke only. Vertical or bevel surfaces are produced by rotating the downfeed screw of the toolhead by hand. Crossfeed movement is used to machine a flat horizontal surface. This is done by rotating the crossfeed screw either by hand or power. Rotation of the crossfeed screw causes the table mounted upon the saddle to move sideways through a predetermined amount at the end of each return stroke so as to bring the uncut surface of the work in the direct path of the reciprocating tool.

Fig.7.10 illustrates the automatic cross feed mechanism of a shaper. The rotation of the bull gear causes the driving disc *8* to rotate in a particular direction. The driving disc *8* is T-slotted and position of the crank pin *9* attached to the connecting rod may be altered to give different throw of eccentricity. The other end of the connecting rod is attached to the rocking arm by a pin *7*. The rocking arm is fulcrumed at *6*, the centre of the ratchet wheel 5. The ratchet wheel *5* is keyed to the crossfeed screw. The rocking arm houses a spring loaded pawl *4* which is straight on one side and bevel on the other side. As the driving disc rotates, the connecting rod starts reciprocating and the rocking arm rocks on the fulcrum *6*. When the driving disc rotates through half of the revolution in the clockwise direction, top part of the rocking arm moves in the clockwise direction and the pawl *4* being slant on one side slips over the teeth of the ratchet wheel *5* imparting it no movement. As the driving disc rotates through the other half, the top of the rocking arm now moves in the anticlockwise direction and the straight side of the pawl engages with the teeth of the ratchet wheel causing the wheel to move in anticlockwise direction only. As the driving disc is connected to the bull gear the table feed movement is effected when the bull gear or the driving disc rotates through half of the revolution, i.e., during return stroke only. Rotation through other half imparts no feed movement. To reverse the direction of rotation of ratchet wheel and consequently the feed, a knob *1* on the top of the pawl *4* after removing the pin *2* is rotated through 180 degrees.

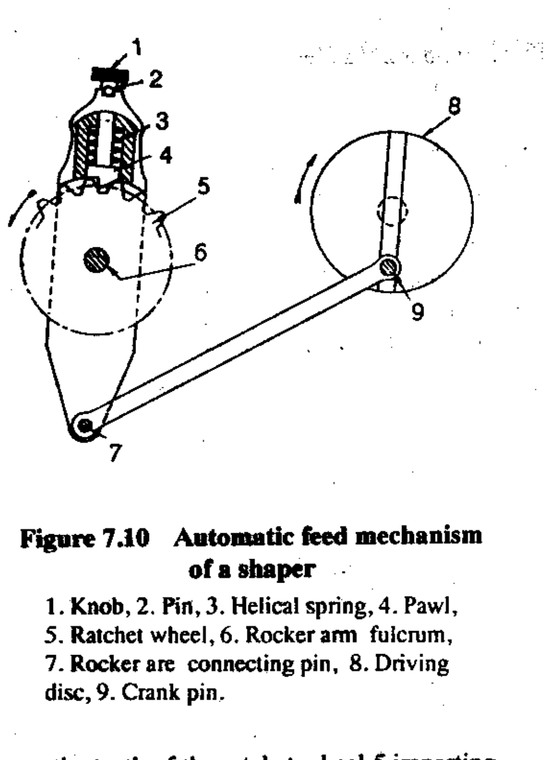


Figure 7.10 Automatic feed mechanism of a shaper

1. Knob, 2. Pin, 3. Helical spring, 4. Pawl, 5. Ratchet wheel, 6. Rocker arm fulcrum, 7. Rocker arc connecting pin, 8. Driving disc, 9. Crank pin.

The amount of feed may be altered by shifting the position of crank pin *9* with respect to the centre. Greater the throw of eccentricity, more will be the rocking movement of the arm and the pawl will pass through three or four teeth on the ratchet wheel at a time imparting greater feed movement.

7.6 WORK HOLDING DEVICES

The top and sides of the table of a shaper have T-slots for clamping the work. The work may be supported on the table by the following methods depending on the nature of the workpiece.

1. Clamped in a vise
2. Clamped on the table
3. Clamped to the angle plate
4. Clamped on a V-block
5. Held between shaper index centre

Shaper vises : Fig.7.11 illustrates a typical shaper vise. A vise is a quick method of holding and locating relatively small and regular shaped workpieces. It consists of a base, table, screw, fixed and movable jaws. The base has a projection or tongue which fits into the slot of the machine table. For properly securing it to the table lugs are provided for clamping the vise by T-bolts. The work is clamped between fixed and movable jaws by rotating the screw. Wherever possible the vise is so placed on the table that the tool while cutting exerts direct pressure upon the jaws. A machine vise may be classified under following headings.

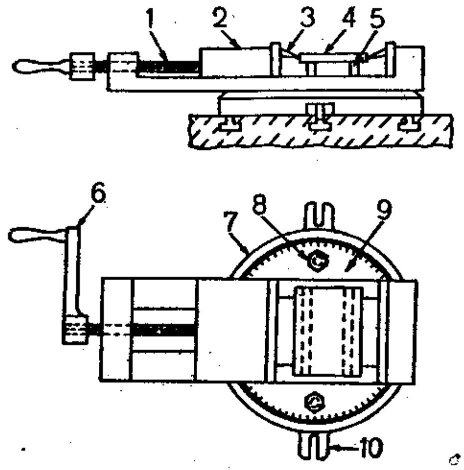


Figure 7.11 Shaper vise
1. Screw, 2. Movable jaw, 3. Hold down, 4. Work, 5. Parallels, 6. Handle, 7. Base, 8. Clamping bolt, 9. Swivelling base, 10. Lug.

1. Plain vise
   (a) Single screw
   (b) Double screw
2. Swivel vise
3. Universal vise

A *plain* vise is the most simple of all the types. The vise may have a single screw or double screws for actuating the movable jaw. The double screws add gripping strength while taking deeper cuts or handling heavier jobs.

In a *swivel vise* the base is graduated in degrees, and the body of the vise may be swivelled at any desired angle on a horizontal plane. The swivelling arrangement is useful in bevelling the end of workpiece.

A *universal vise* may be swivelled like a swivel vise. In addition to that, the body may be tilted in a vertical plane upto 90 degrees from the horizontal. An inclined surface may be machined by a universal vise.

Parallels : Fig.7.11 illustrates the use of parallels. When the height of the job is less than the height of the jaws of the vise, parallels are used to raise and seat the workpiece above the vise jaws and parallel with the vise bottom. Parallels are square or rectangular bars of steel or cast iron, hardened and ground with opposite sides parallel. They are available in various sizes for seating workpieces of different heights and are always used in pairs.

Hold downs : Fig.7.11 illustrates the use of hold downs. Hold downs or grippers are used for holding thin pieces of work in a shaper vise. Hold downs are also used for holding work of smaller height than the vise jaws where suitable parallels are not available. The hold down is a hardened wedge shaped piece with its two working edges tapered at an angle of 5°. Hold downs are placed between two jaws of the vise and the workpiece. When the screw is tightened the typical shape of the hold down exerts downward pressure on the work to hold it tight on the parallels or on the vise table.

Clamping work on the table : When the workpiece is too large to be held in a vise it must be fastened directly on the shaper table. In holding work on the table, clamping bolts should not be unduly tightened to produce distortion of the work. The different methods employed to clamp different types of work on a shaper table are :

1. T-bolts and clamps.
2. Stop pins.
3. Stop pins and toe dogs.
4. Strip and stop pins.

***T-bolts and clamps* :** Fig.7.12 illustrates the use of T-bolts and clamps for holding the work. T-bolts having T-heads are fitted in the T-slots of the table. The length of the threaded portion is sufficiently long in order to accommodate different heights of work. The T-bolts are illustrated in Fig.5.6. The clamps are made of steel having slots at the centre for fitting the bolt. One end of the clamp rests on the side of the work while the other end rests on a fulcrum block. The fulcrum block should be of the same height as the part being clamped. The bolt is placed as near to the work as possible and the nut is then tightened. To hold a large work on the table a series of clamps and T-bolts are used all round the work.

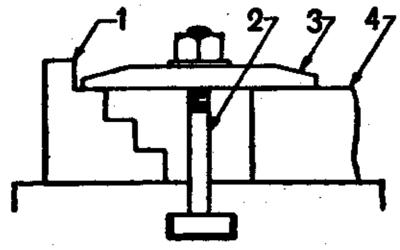


Figure 7.12 Use of T-bolt and clamp
1. Step block, 2. T-bolt, 3. Clamp, 4. Work.

***Stop pins* ·** Fig.7.13 illustrates stop pins. A stop pin is a one-leg screw clamp. As the tool moves forward to perform cutting stroke the work tends to be pushed out of its position under the pressure of the cutting tool. Stop pins are used to prevent the work from coming out of position. The body of the stop pin is fitted in the hole or slot on the table and the screw is tightened till it forces against the work.

***Stop pins and toe dogs* :** Fig.7.14 illustrates the use of stop pins and toe dogs. While holding thin work on the table stop pins in conjunction with toe dogs are used. A toe dog is similar in shape to that of a centre punch or a cold chisel. The head end of a toe dog is drilled slightly so that the end of the stop pin screw may fit into it. Fig.7.15 shows two types of toe dogs. A large number of stop pins and toe

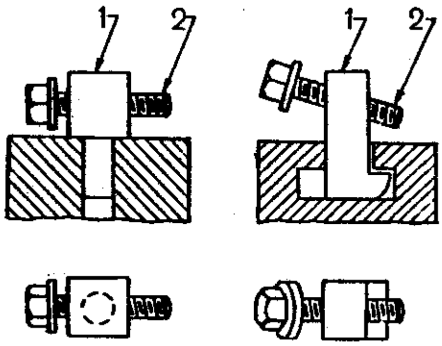


Figure 7.13 Stop pins
1. Body, 2. Screw.

dogs are placed all round the work. When screw of the stop pin is tightened, the work is gripped down on the table.

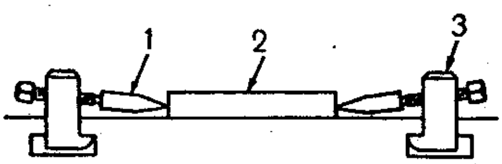


Figure 7.14 Use of stop pin and toe dog
1. Toe dog, 2. Work, 3. Stop pin.

Strip and stop pins : Fig.7.16 illustrates the working of strip and stop pins for holding the work. Work having sufficient thickness is held on the table by strip and stop pins. A strip is a long bar having a tongue with holes for fitting the T-bolts. The strip with bolts is fitted in the T-slot of the table, the tongue of the strip fitting within the slot. The nuts are then tightened so that the strip plate may rest on one side of the work. The stop pin screws are then tightened from the other end of the work so that the work may be clamped between stop pins and strip plate.

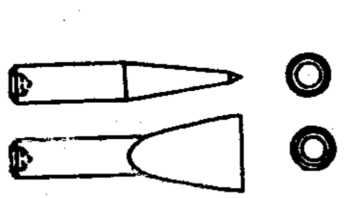
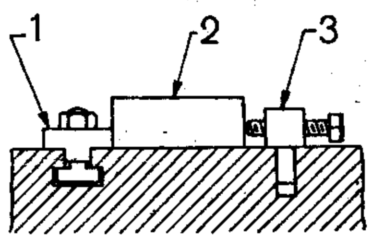


Figure 7.15 Toe dogs



7.16 Use of strip and stop pins
1. Strip, 2. Work, 3. Stop pin.

Angle plate : Fig.5.15 illustrates the use of an angle plate. For holding "L" shaped workpiece, angle plates are used. Angle plates are made of cast iron and is planed on two sides to an angle of exactly 90°. One of the sides is clamped to the table by T-bolts while the other side holds the work by clamps.

V- block : Fig.7.17 illustrates the use of a V-block. For holding round rods V-blocks are used. Work may be supported on two V-blocks at its two ends and is clamped to the table by T-bolts and clamps. The tool may be

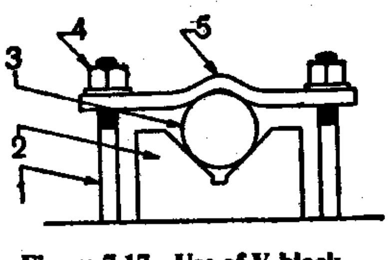


Figure 7.17 Use of V-block
1.T-bolt, 2. V-block, 3. Work, 4. Nut, 5. Clamp.

made to reciprocate between the two clamps for cutting grooves or key ways. V-blocks are made of cast iron or steel and are accurately machined.

Shaper centers : Fig.7.18 illustrates a shaper center. This is a special attachment used for cutting equally spaced grooves or splines on the periphery of a round work. In special cases, it may be used for cutting gears. A shaper centre consists of a headstock and a tailstock, and the work is mounted between two centres. Mounted upon the headstock spindle is the worm gear *4* which meshes with the worm. The handle *2* is connected with the worm shaft. Rotation of the handle *2* causes the worm gear *4* to rotate and the motion is transmitted to the work through a catch plate and carrier. After cutting a slot or groove on the top of the work, it may be turned to a predetermined amount by an index plate *3* and index pin *1*. The indexplate is mounted on the worm gear shaft. The index plate has a series of holes around its circumference and is locked in any desired position by engaging the index pin in the corresponding hole. Index plates are provided with various number of holes.

7.7 SHAPER OPERATIONS

A shaper is a versatile machine tool primarily designed to generate a flat surface by a single point cutting tool. But it may also be used to perform many other operations. The different operations which a sharper can perform are as follows :

1. Machining horizontal surface.
2. Machining vertical surface.

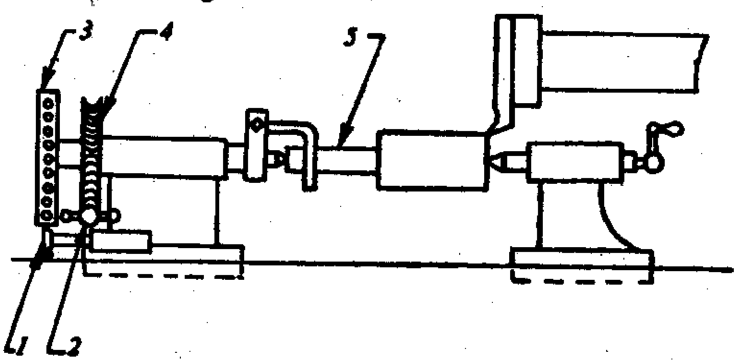


Figure 7.18 Use of shaper centre
1. Index pin, 2. Worm handle, 3. Index plate, 4. Worm gear, 5. Work.

3. Machining angular surface.
4. Cutting slots, grooves, and keyways.
5. Machining irregular surface.
6. Machining splines or cutting gears.

Machining horizontal surface : Fig.7.19 illustrates machining horizontal surface on a workpiece. A shaper is mostly used to machine a flat, true surface on a workpiece held in a vise or other holding devices. After the work is properly held on the table, a planing tool is set in the tool post with minimum overhang. The table is raised till there is a clearance of 25 to 30 mm between the tool and the workpiece. The length and position of stroke are then adjusted. The length of stroke should be nearly 20 mm longer than the work and the position of stroke is so adjusted that the tool begins to move from a distance of 12 to 15 mm before the beginning of the cut and continues to move 5 to 8 mm after the end of the cut. Proper cutting speed and feed is then adjusted. Short strokes should be given with high speed while long strokes with slow speed. Both roughing and finishing cuts are performed to complete the job. For roughing cut speed is decreased but feed and depth of cut is increased. Depth of cut is adjusted by rotating the down feed screw of the toolhead. The amount of depth of cut is adjusted by a micrometer dial. The depth of cut for roughing work usually ranges from 1.5 to 3 mm, while for finishing work it ranges from 0.075 to 0.200 mm. Feed is adjusted about one half the width of the cutting edge of the tool so that each cut will overlap the last cut giving a smooth surface finish.

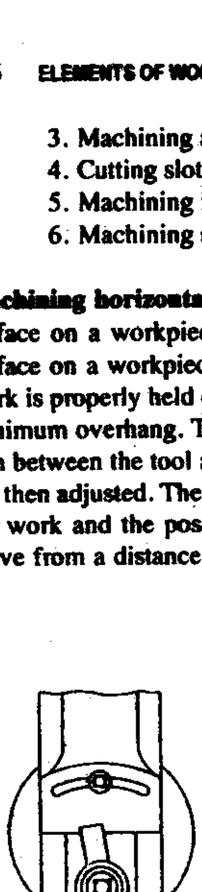


Figure 7.19 Machining horizontal surface

Machining vertical surface : Fig7.20 illustrates machining vertical surface on a workpiece. A vertical cut is made while machining the end of a workpiece, squaring up a block or cutting shoulder. The work is mounted in the vise or directly on the table and the surface to be machined is carefully aligned with the axis of the ram. A side cutting tool is set on the tool post and the position and length of stroke is adjusted. The vertical slide is set exactly at zero position and the apron is swivelled in a direction away from the surface being cut. This is necessary to enable the tool to move upwards and away from the work during return stroke. This prevents the side of the tool from dragging on the planed vertical surface during return stroke. The downfeed is given by rotating the down feed screw by hand. The feed is about 0.25 mm given at the end of each return stroke. Both roughing and finishing cuts are performed to complete the job.

Machining angular surface: Fig.7.21 illustrates machining of an angular surface on a workpiece. An

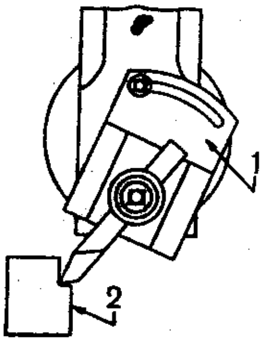


Figure 7.20 Machining vertical surface
1. Apron, 2. Work.

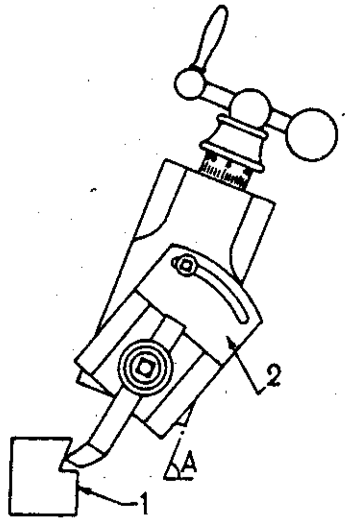


Figure 7.21 Machining angular surface
1. Work, 2. Apron, A, Swivelling angle of the vertical slide.

angular cut is made at any angle other than a right angle to the horizontal or to the vertical plane. The work is set on the table and the vertical slide of the toolhead is swivelled to the required angle either towards left or towards right from the vertical position. The apron is then further swivelled away from the work so that the tool will clear the work during return stroke. The downfeed is given by rotating the downfeed screw. Angular surface can also be machined in a universal shaper or by using a universal vise without swivelling the toolhead.

Cutting slots and keyways : With suitable tools a shaper can very conveniently machine slots or grooves on a work or cut external keyways on shafts and internal keyways on pulleys or gears. For cutting slots or keyways a square nose tool similar to a parting tool is selected. Fig.7.22 illustrates cutting of external keyways and Fig.7.23 shows cutting of internal keyways in a shaper. External keyways are cut on a shaft by first drilling a hole at the blind end of the keyway. The diameter of the holes should be 0.5 to 0.8 mm oversize than the width of the keyway and the depth should be about 1.5 mm larger than the depth of the keyway. This is necessary to leave a clearance on the tool at the end of the stroke. The length and position of stroke is carefully adjusted so that the stroke will terminate exactly at the clearance hole. The speed is reduced while cutting a keyway. Internal keyways are cut by holding the tool on a special tool holder so that the tool post will not hit against the work at the end of the stroke. The clapper block is locked in the clapper box to prevent the tool from lifting during return stroke. Lubrication is necessary on the work to prevent the cutting edge of the tool from wear due to dragging.

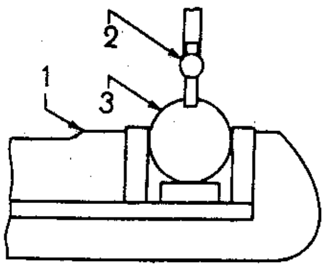


Figure 7.22 Cutting external keyway
1. Vise, 2. Tool, 3. Work.

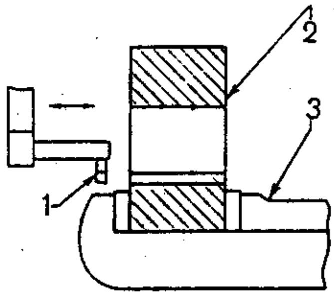


Figure 7.23 Cutting internal keyway
1. Tool bit, 2. Work., 3. Vise

Machining irregular surface : A shaper can also produce a contoured surface, i.e. a convex or concave surface or a combination of any of the above surfaces. To produce a small contoured surface a forming tool is used. If the curve is sufficiently large, power-crossfeed in conjunction with manual downfeed is so adjusted that the tool will trace the required contour. If the contour has too many ups and downs both the feeds are operated by hand. A round nose tool is selected for machining irregular surfaces. For a shallow cut the apron may be set vertical but if the curve is quite sharp, the apron is swivelled towards right or left away from the surface to be cut. Fig.7.24 shows machining of a concave surface using a round nose tool.

Machining splines or cutting gears : By using an index centre, illustrated in Fig.7.18, a gear or equally spaced spline may be cut.

The work is mounted between two centres and a spline is cut similar to the cutting of a keyway. After the first spline is cut, the work is rotated through a predetermined amount by using the index plate and index pin. The periphery of a gear blank is divided, and equally spaced grooves are cut by using an index plate having proper hole circles. While cutting gear a formed tool is used.

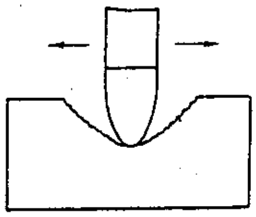


Figure 7.24 Machining irregular surface

7.8 SHAPER TOOLS

The cutting tool used in a shaper is a single point cutting tool having rake, clearance and other tool angles similar to a lathe tool. It differs from a lathe tool in tool angles. Shaper tools are much more rigid and heavier to withstand shock experienced by the cutting tool at the commencement of each cutting stroke. In a lathe tool the effective angle of rake and clearance may be varied by raising or lowering the point of the tool in relation to the centre of the work, but in a shaper the tool angles cannot be changed as the tool is always clamped perpendicular to the surface of the work. When it becomes necessary to change the tool angles it can only be done by grinding. In a lathe tool sufficient amount of side clearance angle must be provided as the tool is continually fed sideways tracing a helical path, but in a shaper tool as the feed is given at the end of cutting stroke, a very small clearance angle is necessary to give relief to the side cutting edge. In a shaper tool the amount of side clearance angle is only 2° to 3° and the front clearance angle is 4° for cast iron and steel. Small clearance angle adds strength to the cutting edge. As the tool removes metal mostly from its side cutting edge, side rake of 10° is usually provided with little or no front rake. The side rake angle to be provided is dependent upon the kind of metal being cut, the hardness of the tool material, type of cut: roughing or finishing, and other factors which influence the rake angle. A shaper can also use a right hand or left hand tool. The left hand tool is more common because it permits the operator to see the cut better than the right hand tool. High speed steel is the most common material for a shaper tool but shock resistant cemented carbide tipped tool is also used where harder material is to be machined. As in a lathe, tool holders are also used to hold the tool bits. Some of the most common cutting tools are :

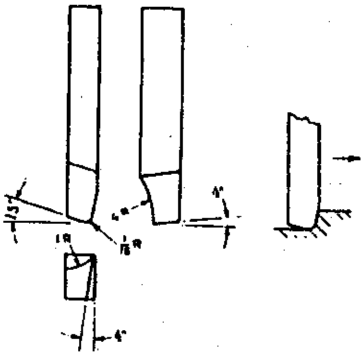


Figure 7.25 A left hand roughing tool for planing

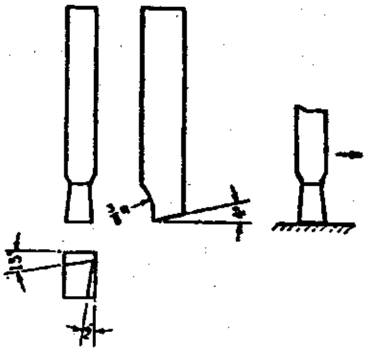


Figure 7.26 A left hand finishing tool for planing

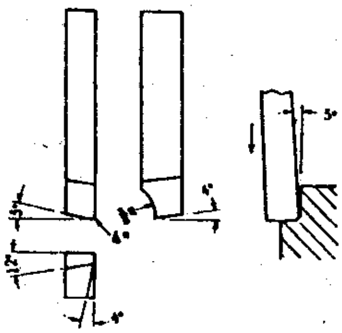


Figure 7.27 A left hand side roughing tool

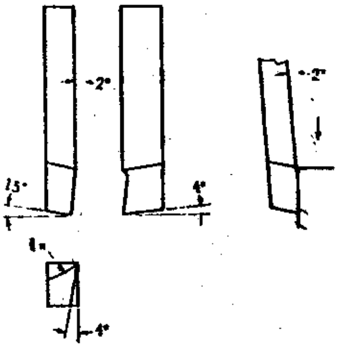


Figure 7.28 A left hand side finishing tool

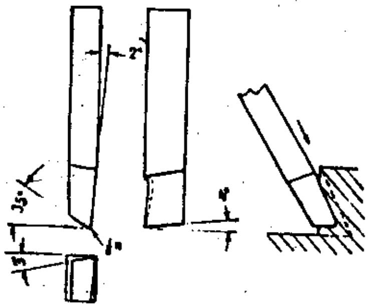


Figure 7.29 A left hand dovetail cutting tool for roughing

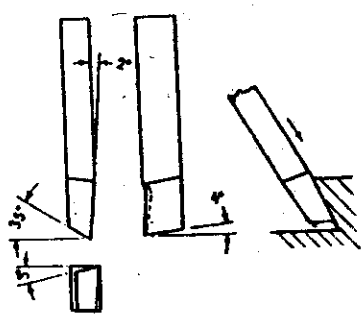


Figure 7.30 A left hand dovetail cutting tool for finishing

1. A left hand roughing tool for planing (Fig.7.25)
2. A left hand finishing tool for planing (Fig.7.26)
3. A left hand side facing tool for vertical shaping and for shaping sharp corner (roughing) (Fig.7.27)
4. A left hand side facing tool (finishing) (Fig.7.28)
5. A left hand dovetail cutting tool (roughing) (Fig.7.29)
6. A left hand dovetail cutting tool (finishing) (Fig.7.30)
7. A parting or slotting tool. (Fig.7.31.)

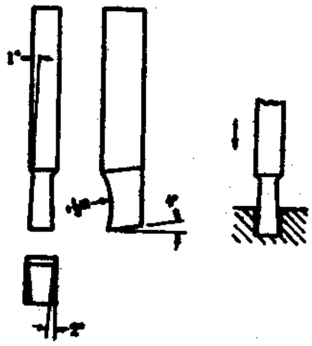


Figure 7.31 A parting or sloting tool

7.9 CUTTING SPEED, FEED AND DEPTH OF CUT

Cutting speed : In a shaper, the cutting speed is the rate at which the metal is removed by the cutting tool. This is expressed in metre per minute. In a lathe as the cutting action is continuous the cutting speed is expressed by the peripheral speed of the work. But in a shaper the cutting action is intermittent. In a shaper the cutting speed is considered only during the forward cutting stroke.

Cutting speed calculations : The cutting speed in a shaper is expressed by the formula :

$$\text{Cutting speed} = \frac{\text{length of the cutting stroke}}{\text{time required by the cutting stroke}}$$

In practice, to calculate the cutting speed, it is difficult to measure exactly the time taken during the forward cutting stroke. The ratio between the return time to cutting time and the number of double strokes per minute or r.p.m. of the bull wheel should be known. The cutting speed may be obtained from the equation (7.2).

Let, L = the length of cutting stroke in mm.

m = the ratio between return time to cutting time.

n = the number of double strokes of the ram per minute or r.p.m. of the bull wheel

V = the cutting speed expressed in m/min.

From the equation No. (7.2),

$$\text{Time taken by the cutting stroke, min} = \frac{\text{length of cutting stroke in mm}}{\text{cutting speed in m/min}}$$

$$= \frac{L}{1{,}000 \times v} \quad \text{and,} \quad m = \frac{\text{return stroke time}}{\text{cutting stroke time}}$$

or return stroke time = m x cutting stroke time $= \dfrac{m \times L}{1{,}000 \times v}$

$$\text{Time taken to complete one double stroke} = \frac{L}{1{,}000 \times v} + \frac{m \times L}{1{,}000 \times v}$$

$$= \frac{L}{1{,}000 \times v}(1+m) \qquad 7.3$$

Number of double strokes per minute

or r.p.m. of the bull wheel $= \dfrac{1}{\dfrac{L(1+m)}{1000 \times v}}$

$$n = \frac{1000 \times v}{L(1+m)} \quad \text{and,} \quad v = \frac{nL(1+m)}{1{,}000} \qquad 7.4$$

The cutting speed so calculated is the average cutting speed as it has been assumed that the cutting stroke is completed at a uniform speed. But, in reality, in a crank driven shaper cutting speed and return speed is not uniform.

The factors which govern the amount of cutting speed are same as the discussed in Art. 2.17.

Example 7.1 : In a shaper work, the length of stroke is 200 mm, number of double strokes per minute is 30 and the ratio of return time to cutting time is 2 : 3. Find the cutting speed.

$$\text{Cutting speed} = \frac{nL(1+m)}{1{,}000} = \frac{30 \times 200\left(1+\frac{2}{3}\right)}{1{,}000}$$

$$= \frac{30 \times 200 \times 5}{1{,}000 \times 3} = \mathbf{10\ m/min.}$$

Feed : Feed (s) is the relative movement of the tool or work in a direction perpendicular to the axis of reciprocation of the ram per double stroke and is expressed in mm. The feed is always given at the end of return stroke when the tool is not cutting the metal. The selection of feed is dependent upon the kind of metal, type of job, etc.

Depth of cut : Depth of cut (t) is the thickness of metal that is removed in one cut. It is the perpendicular distance measured between machined surface and non-machined surface of the workpiece.

7.10 MACHINING TIME

If the length of cutting stroke, breadth of the job, feed and cutting speed are known, the time required to complete the job may be calculated as :

Let,

L = the length of the stroke in mm.
B = the breadth of the work in mm.
s = the feed expressed in mm/double stroke.
m = the ratio return time to cutting time.
v = the cutting speed in m/min.

Then from equation (7.3),

$$\text{Time taken to complete one double stroke} = \frac{L}{1{,}000 \times v}(1+m)$$

$$\text{Total number of double strokes required to complete the job} = \frac{B}{s}$$

$$\therefore \quad \text{Total time taken to complete the cut} = \frac{L \times B(1+m)}{1{,}000 \times v \times s}$$

Example 7.2 : Find the time required for taking a complete cut on a plate 600 × 900 mm, if the cutting speed is 9 m/min. The return time to cutting time ratio is 1:4 and the feed is 3 mm. The clearance at each end is 75 mm.

In a shaper a stroke length of more than 900 mm is not ordinarily available so the work is placed on the table to take a cut of 600 mm plus the clearances.

$$\text{Total length of stroke} = 600 + 75 + 75 = 750 \text{ mm.}$$

$$\text{Cutting time} = \frac{750 \times 60}{1{,}000 \times 9} = 5 \text{ sec.}$$

$$\frac{\text{Return stroke time}}{\text{Cutting stroke time}} = \frac{1}{4}$$

$\therefore$ Return time = $5\times\frac{1}{4}=\frac{5}{4}$ sec.

Total time for one complete double stroke = $5+\frac{5}{4}=\frac{25}{4}$ sec.

Total number of double strokes necessary to complete the cut

$$=\frac{900}{3}=300$$

$\therefore$ Total time required to complete the cut $=\frac{25\times300}{4\times60}=\frac{125}{4}=$ **31.25 min.**

TABLE 7.1 AVERAGE VALUE OF CUTTING SPEED AND FEED

Material	*High carbon steel*		*High speed steel tool*		*Cemented carbide*	
	V m/min	S mm	V m/min	S mm	V m/min	S mm
Cast iron	9	1.5	18	2	30	0.125–0.5
Mild steel	12	1.25	24	1.5	45	0.125–0.5
Brass	30	1	48	1.25	60	0.25–0.35

REVIEW QUESTIONS

1. Classify and list shapers.
2. What are the advantages of hydraulic shaper over crank shaper ? Discuss.
3. Name different parts of a shaper. Describe them in brief pinpointing their functions.
4. How the size of a shaper is specified ? Discuss.
5. Describe the principle of quick return mechanism as used in shapers.
6. How you can adjust the length of stroke in a shaper ? Explain.
7. Describe Whitworth quick return mechanism, used in shapers in brief.
8. Name and describe the various work holding devices in shapers.
9. What types of operation can be performed in a shaper efficiently Describe them in brief.
10. Which way a shaper tool differs from that of a lathe tool ? Discuss.
11. In a shaper work the length of stroke is 300 mm, number of double strokes per minute is 40 and the ratio of return time to cutting time is 1 : 2. Find the cutting speed. (18 m/min)
12. Define speed, feed and depth of cut in a shaper.