

# Fabrication and usage of multipurpose mechanical machine using scotch yoke mechanism

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**Abstract.** “Multi Operational Mechanical Machine “This work was mainly carried for manufacturing and fabrication industries. The machine which is used to produce the product with high accuracy and quality and produce the goods in an economical manner. It makes the inventory cost less. The multipurpose machine has performed different operations simultaneously with high possibility. The scotch yoke mechanism which is attached with the main drive shaft directly attached then it is used for different operation. Number of operations has been performed by a single drive system. The main focus of the work is to reduce power usage and increase the productivity reduced floor space. Portability is an important quality in any machine in today’s world; every field of science and engineering has got portability as one of its most important advancements. Therefore, the machine we have designed satisfies this principle with respect to the manufacturing industry.

## 1. Introduction

In a multipurpose machine has a fine-toothed hacksaw for cutting the metals with high speed of operations. There are hand saws and power hacksaws. The hacksaws are adjustable and can hold a number of blades within a specified limit under tension. The blade is mounted on the frame with either the teeth facing towards or away from a point on the frame, finally cutting action takes place either by means of push or pull the cutting teeth. Suppose a work piece requires many operations to be done at the same time but the tools are situated in various locations in the plant layout, a multi operational machine can be devised that does the job effectively and efficiently.

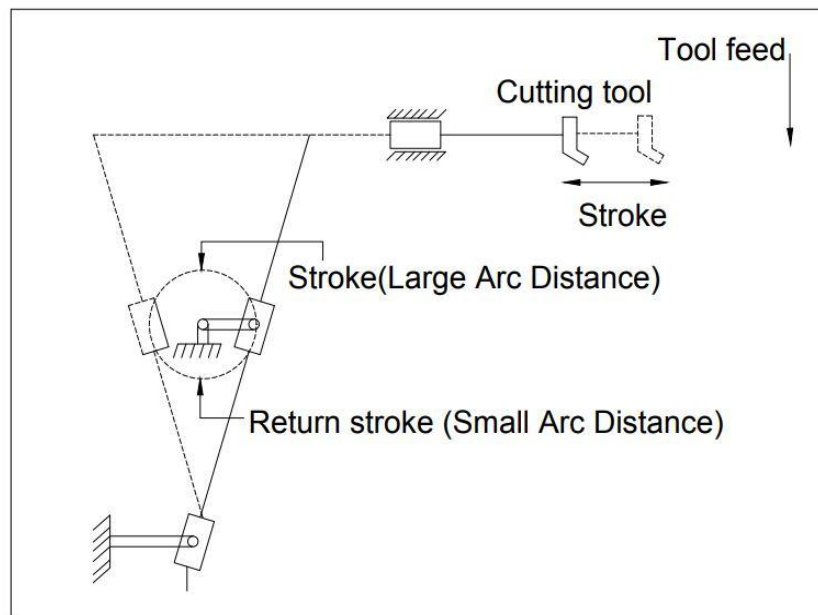
### A. Blades

The standard hacksaw usually has blades in standardized lengths such as 254mm or 304.8mm .Small hacksaws are 150mm in length. The pitch of the teeth varies between successive distances per inch (tpi). The selection of the blade is based on the thick ness of materials to be cut. Specifications of a Hacksaw blade: The 12 inch or 300 mm length is the most common blade. Hacksaw blades are mounted in the saw frame. The kerf has been formed by the blades is wider than the blade thickness due to the position of the teeth. It is more often than 0.030 and 0.063 inches. Sometimes it is between 0.75 and 1.6 mm depending upon the pitch and size of the teeth.



## B. Shaper machine

It is a type of special machine mostly performing in a linear direction for metal removal operations. A single point cutting tool which is connected with a ram. The cutting operation made by the shaper is comparable to a traditional lathe machine, apart from the fact that it is linear and not helical. A shaper is similar to a slighter small planer machine and has the cutter traversing with help of ram that moves above a stationary work piece instead of the entire work piece moving beneath the cutter. The ram has travels back and forth by a crank inside the column.



**Figure 1.** Shaping Operation

### B.1. Linkage of Shaper

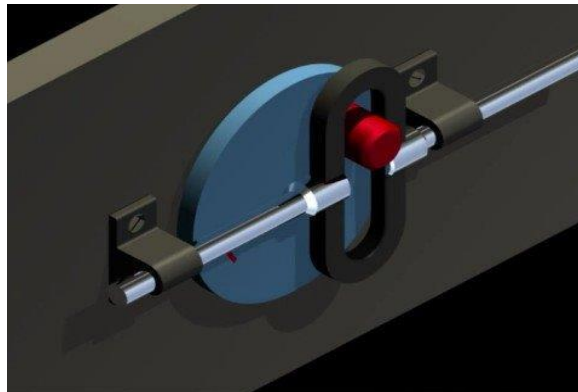
The cutting stroke takes more time than the return stroke by means of mechanisms. Due to the result of quick return mechanism a more powerful cutting takes in forward stroke and tool rubbing action eliminated by return stroke. In the shaper machine the work piece is in idle condition, the cutting tools only moves on the work piece. The tool is mounted on a reciprocating ram. Sometimes the motion of the table has controlled by manually, but typically it can be automated, it is known as feed mechanism. The mechanism has been operated by lead screw. At end of the ram has the tool post and clapper box. The function of the tool post is to clamp the tool at a different angles. The tool-slide enables the feeding of the tool downwards to make the cut deepen. The versatile nature of a machine gives a path to the operator to cut the gear teeth, splines, keyways etc. Due to linkage geometry, the return stroke is faster and hence this is known widely as the quick return mechanism. This is possible via a Whitworth link or slotted link.

### B.2. Uses

Shafts have keyways that can be machined without being subjected to any complex machining setup like broaching. This also includes external, internal splines and gear teeth.

## C. Scotch Yoke Mechanism

It is a type of mechanism used to change the rotational motion of a slider to linear motion. The assembly has a piston which is the reciprocating part. It can be directly attached with sliding yoke using a slot that engage the pin on the rotating part of the yoke.



**Figure 2.** Scotch Yoke Mechanism

### C.1.Construction

Iron bars are employed to make the scotch yoke mechanism. Since the crank is of a certain length, same material is used to build yoke and crank. Twice the length of crank should be minimum length of yoke. The pin is used to join the yoke and crank. Both the sides of the yoke are welded to iron bars in order to obtain the required motion. In the construction of the mechanism the steel bar is connected with display board by the help of clamps. The crank is joined at the end of the motor.

### C.2.Working Principle

To operate the machine, energy is required. The value of power supply is 230v AC. The rotation of the crank and the sliding of the pin inside the yoke and also moves the yoke forward. The rotation of the crank in a clockwise direction results in the yoke getting displaced in a forward direction. The maximum quantum of displacement will be equal to the length of the crank. As soon as the crank completes the rotation of the yoke will come back to its initial position. At the next rotation, the yoke will moves in the reverse direction. On completion of a full rotation by the crank, the yoke will moves back to its original position. The yoke moves across a length are equivalent to double the crank for a complete rotation. To change the crank length, displacement of yoke only need be changed.

## 2. Principle of Model

### Machine Using Scotch Yoke Mechanism

This project employs the Scotch yoke mechanism in multi mechanical machine which enables it to perform cutting as well as shaping at the same time thereby improving the productivity. This machine performs cutting and shaping of material simultaneously with its scotch yoke mechanism, to increase production rate twice then that of conventional machine. This mechanism is used to translate the reciprocating motion from a rotary motion.

## 3. Components

**Table 1.** Components and Descriptions

COMPONENT	MATERIAL	DIMENSION
AC Motor	-	230V, 50Hz, 1500 RPM
Belt Drive	Leather	1000 mm length
Driver pulley	Mild Steel	37mm diameter

Driven pulley	Mild Steel	280mm diameter
Disc	Mild Steel	130mm diameter
Connecting Shaft	Mild Steel	15mm diameter, 60mm length
Frame	Cast Iron	-
Blade Movable Distance	-	90mm

#### 4. Basic Construction and operating principle



**Figure 3.** AC Motor as in Project

The another important elements in the mechanism is AC induction motor with a cover known as stator and a rotor that rotate inside with an air gap between both. In reality, in all systems of prime movers uses magnetic field rotation principles to spin their rotors. A 3-phase AC induction motor is the only type where the rotating magnetic field is created naturally in the stator due to the influence of the power supply. Whereas a single-phase motor depends on other electrical components to produce a rotating magnetic field. Therefore, one set of electromagnets is formed in the stator due to the AC supply connected to the stator windings. This alternating nature of supply voltage induces an electromagnetic force in the rotor according to Lenz's law. This generates another set of electromagnets. Interaction between the magnetic field of the electromagnets generates torque. As a result, the motor rotates in the direction of the resultant torque.

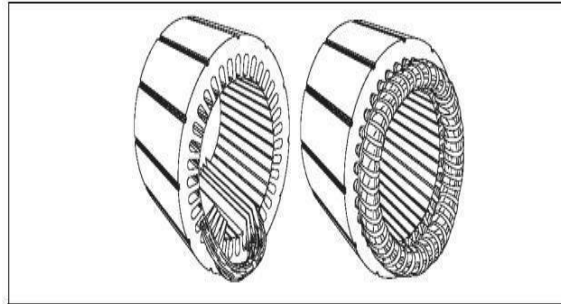
**Table 2.** AC Motor Details

Voltage	230 V
Frequency	50 HZ, 1 PH PSC
Ampere	2.5 A
Power	0.25 HP
Watt	180W
RPM	1500RPM

##### A.1.Stator

The stator is composed of many thin covers of Cast Iron or Aluminum. Then clamped together and punched to appearance as a hollow cylinder containing slots. Then the Coils of insulated wires are

then fixed into these slots. The Electromagnet on the applications of the AC supply is formed by the group of coils, together with the core which it surrounds. The stator winding which was having number of poles of an AC induction motor. The stator windings are then connected directly to the power source. On the applications of the AC supply, a rotating magnetic field is created due to the internal links of the stator winding.



**Figure 4.** A Typical Stator

### **A.2.Rotor**

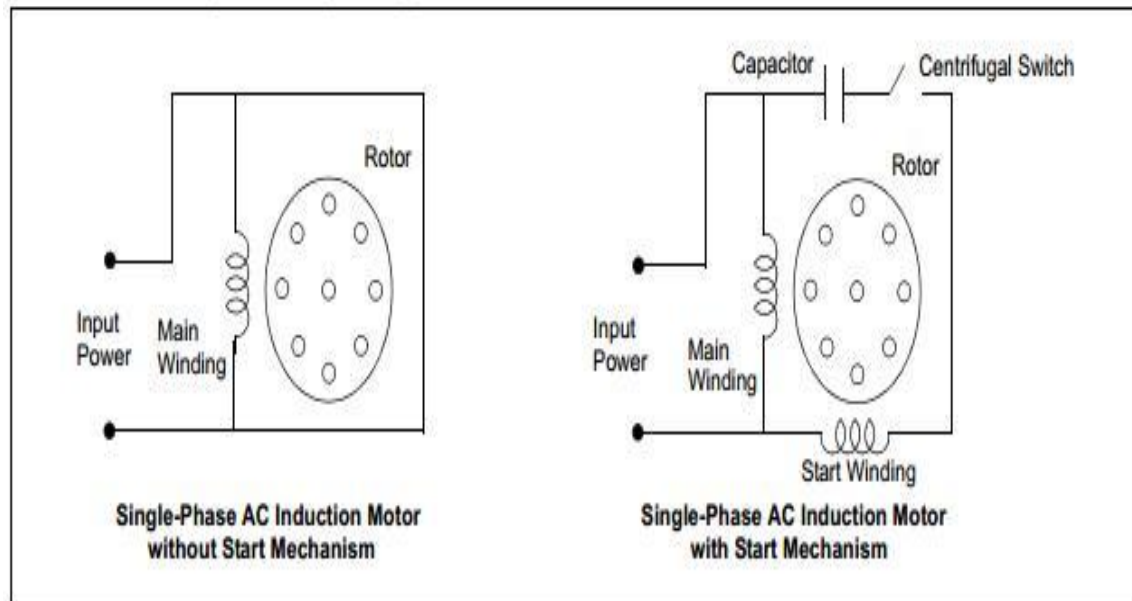
No of layers of steel sheets are arranged one by one to form the rotors with evenly spaced bars. It is made of copper or aluminium, along the outside edge. In the squirrel cage rotor, the evenly spaced bars are connected electrically and mechanically at the ends by the use of rings. The rotor consists of laminated sheets of cylindrical core with axially located parallel slots to carry the conductors. Each slot contains a copper or aluminium alloy bars. With help of the end rings the bars of the rotors are permanently short circuited at both ends. The slots of the rotors are not parallel to the shaft. To control the running noise of the motor a skew is provided. This can be achieved by reducing magnetic hum, decreasing slot harmonics and reducing locking of rotor. The rotor teeth locked with stator teeth because of direct magnetic attraction. Locking happens only the stator and rotor having the same number of teeth. The shaft is fixed into the rotor bearings.

### **A.3.Types of Induction Motors**

Induction motors are classified based on the number of stator windings. The categories are: Single phase and Three-phase induction motor

#### **A.3.1.Single-Phase Induction Motor.**

The rotor is the squirrel cage type. The single-phase induction motor is not self-starting. The main winding carries a n AC current when single phase power supply is coupled to motor. A pulsating magnetic field is produced and rotor is energized. But, required torque is not generated and only vibrates. To prevent this wastage, a starting mechanism is required. This is done using an additional stator coil winding. The start winding has a number of series of switches. When a power is given, current in the main winding lets the voltage due to main winding impedance. Interaction between magnetic fields generated by the main winding and the use of the starting mechanisms.



**Figure 5.** AC Induction Motor With and Without A Start Mechanism

#### A.4.Starting Characteristic

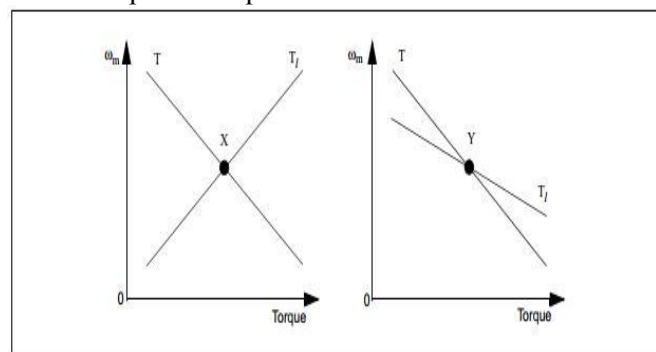
Induction motors illustrate a very high current known as the “Locked Rotor Current” if connected to the full supply voltage at rest. It also produces the torque which is known as the “Locked Rotor Torque”. The Locked Rotor Torque and Current are the functions of the terminal voltages of the motor design. When the motor accelerates, both the torque and current changes with rotor speed if the voltage is constant. The initial current of the motor, with a fixed voltage will drop gradually. The reason being the motor’s speed falls only when it has reached 80% of full speed. This locked rotor current has a range that starts from 500% and ends at 1400% of the full load currents. Whereas, heavy duty motors have a range of 550% to 750% of full load current.

#### A.5.Load Characteristic

The load system is stable when torque developed. It is equal to compulsory load torque. The motor will operates in a constant state at a fixed speed. How the motor responds to disturbance exhibits an idea of the motor’s stability. This serves as a great deal of motor’s selection for a given load.

#### A.6.Running Characteristic

The motor if gets speed once means, the level of the slip is going to be less. The speed determined by the number of the stator poles. The slip of the squirrel motor is 5%.



**Figure 6.** Torque-Speed Curve – Same Motor with Two Different Loads

The design of the motor will define the full load slip. The speed ranges for four pole induction motors 1420 to 1480 rpm at 50 Hz, while the synchronous speed is 1500 rpm at 50 Hz. There are two current components for the induction motor namely magnetizing and working current. The magnetizing current is not dependent on the load, is only dependent on design of the stator and the voltage. The magnetizing current of the induction motor can vary from as low as 20% at full load current and for two poles machine. For eight pole machine it is 60%. The working current is directly proportional to the load.

## B. Hacksaw Blade

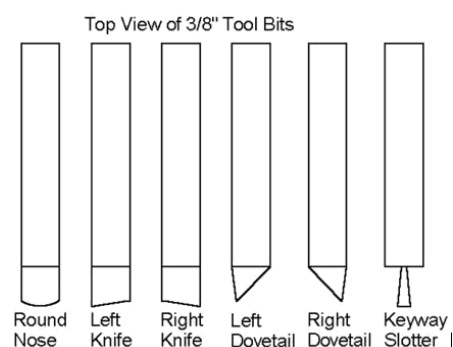
A hacksaw is full of a fine-toothed blade under tension in a frame, used for cutting metal. Hand-held hacksaws consist of a metal frame with a handle, and pins for attaching a narrow disposable blade. The blade is put under tension via a screw.



**Figure 7.** A Hack Saw

### B.1. Technical Aspects and Design

The machine design consists of various elements. The important one is blades which are available with some standard sizes. The selection of the blade is based on the size of the work piece is going to be cut. To put more care to use the blades. To select the Bi-metal blades minimize this risk.



**Figure 8.** Types of Shapers

## C. Shaper Tool

A single point cutting tool is used in special machines like a shaper machine. The type of relative motion between the tool and the work piece is used to remove the material from the work piece.





**Figure 9.** Shaper tool used

#### **D. Belt Drive**

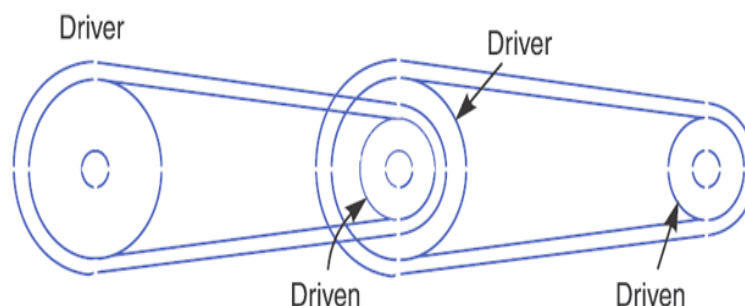


**Figure 10.** Belt Drive used

The flexible machine elements are the main components of the fabrication. These are used for a most of the power transmission applications, some of applications are conveyor systems, coal transport and mineral ores over a large distance. Generally used in power transmission in engines.

##### **D.1. Typical Belt Drives**

There are two types namely, a crossed and open belt drives in all types of drives, a belt is wrapped around a pulley. The smaller pulley is the driving pulley. This transmits motion to the belt and the motion of the belt gives a power transmission to another driven pulley. In an open belt drive system the rotation of both the pulleys is in the same direction, for crossed belt drive system, opposite direction of rotation is observed. So the percentage of slips is controlled in crossed belt drives.



**Figure 11.** Belt drive



**Figure 12.** Scotch Yoke Mechanism used**Table 3.** Specifications of Scotch Yoke Mechanism

Disc	M.S
Diameter	130mm
Blade Movable Distance	90mm

**E. Shaft****Table 4.** Specifications of Connecting Shaft

Material	M.S
Diameter	15mm
Length	600mm

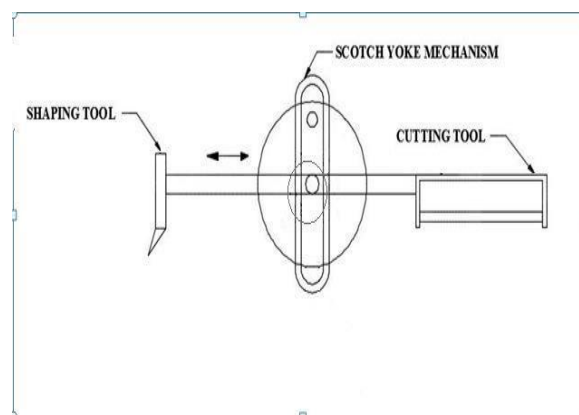
**Figure 13:** Connecting Shaft used**F. Frame**

Our machine, which needs to be supported as its base, requires a frame. Here, we have fixed our setup on a frame made up of Cast Iron, since it is hard and does not bend as much as mild steel due to load. It has high bending Moment.

**Figure 14.** Frame as in Project**Table 5.** Specifications of Frame

DIMENSION	SIZE
Length	500mm
Breadth	500mm
Height	470mm

## 5. Specifications

**Figure 15.** 2D Layout of the Machine**Table 6.** Specifications of design

Tube Length	85.5
Tube Diameter	2.5
Slider Height	13
Slider Width	5
Rectangular Frame Length	68.5
Rectangular Frame Height	36
Disc Diameter	14
Table Diameter	7.5

Supporting Link Length	18
Supporting Link Height	13

## 6. Operation

Design and fabrication of the “Multi function machine” the power supply is given to the main shaft of the prime movers initially. A pair of bevel gears has been mounted along the axis of the shaft through the pinion shaft. Drive is given to drill shaft through belt- stepped pulley arrangement. Grinding centre is also driven using bevel gear arrangement. Angular velocity of main shaft and scotch yoke mechanism is same since they are on the same shaft.

## 7. Advantages

It gives a high torque output with small cylinder size and few moving parts that enable smoother operation. There is no necessity for piston skirt in Combustion engines since side loading due to sine of connecting rod is nil. Also scuffing is eliminated.

## 8. Applications

It is used in IC engines namely Bourke and SyTech engine also in valve actuator mechanisms in high pressure applications. It was used in crude shapers.

## 9. Results

Comparison of displacement and acceleration for a Scotch yoke compared with a crank and slider



**Figure 16.** Prototype

In a general idea of the issues concerning different aspects of multipurpose machine using scotch yoke mechanism is provided. It focuses on the principle of scotch yoke mechanism, performance of tools and parameters, performance measure which can be run simultaneously and fabrication having been done for the multipurpose machine.

## 10. Design Procedure

Diameter of Crank = 0.21m.

Length of slotted bar = 0.185 m.

Length of connecting rod = 0.45m.

Cutting Force:

Assume, Power = 736 Watts; Speed = 200 RPM

$P = 2\pi NT/60 = 35.159 \text{ Nm}$

Torque = Force X Radius of crank

$$F = 296.75 \text{ N}$$

Design of Shaft:

$$\text{Diameter of the shaft} = 15 \text{ mm}$$

$$\text{Permissible shear stress for mild steel} = 34 \text{ N/mm}^2$$

$$T_1 = \pi/16 \cdot (f_s) \cdot d^3 \cdot 35.159$$

$$= \pi/16 \cdot (f_s) \cdot 0.033 \cdot F_s$$

$$= 6635338.5 \text{ N/m}^2 \cdot F_s$$

$$= 6.635 \text{ N/mm}^2 < F_s \text{ (permissible)} = 34 \text{ N/mm}^2.$$

Therefore design is safe.

Let 'X' is the length of the cutting stroke  $X = OD + DE - AC - OA$

r – Radius of the Crank

L – Length of the link AB.

$$\text{Angle AOB} = \theta$$

$$\text{Angle ACB} = \phi$$

In triangle ABC,  $\cos \phi = AC/L$   $AC = L \cdot \cos \phi$

$\cos \theta$  In Triangle OAB,  $\cos \theta = OA/r$   $OA = r \cdot \cos \theta$

$$\cos \theta \text{ Sine } \phi = h/L$$

$$\text{Sine } \theta = h/r$$

$$\cos \phi = \sqrt{1 - \text{Sine}^2 \theta}$$

$$= \sqrt{1 - (r^2 \text{Sine}^2 \theta / L^2)}$$

$$n = L / r = \text{connecting rod length/Crank radius}$$

$$\cos \phi = [1 - (\text{Sine}^2 \theta / n^2)]^{1/2}$$

If  $n \gg 1$ , by binomial expansion  $\cos \phi = 1 - (\text{Sine}^2 \theta / 2n^2)$

$$X = r + L - L [1 - (\text{Sine}^2 \theta / 2n^2)] - r \cos \theta$$

$$X = r (1 - \cos \theta) + L [1 - 1 + (\text{Sine}^2 \theta) / 4n^2]$$

$$X = r (1 - \cos \theta) + r^2 / 4L (1 - \cos 2\theta)$$

$$\text{Velocity: } V = dX/dt = \omega r (\sin \theta) + r/4L (2 \sin 2\theta)$$

$$\text{Acceleration: } a = d^2X/dt^2 = \omega^2 r (\cos \theta + r/L (\cos 2\theta))$$

Assume, Radius of the crank,  $r = 105 \text{ mm}$

Length of the CR = 450 mm

$$\text{At } \phi = 0, \theta = 0 \quad X = 450 + 105 = 555 \text{ mm}$$

$$\text{At } \phi = 0, \theta = 180^\circ \quad X = 450 + 105 + 0 - 100 \cos 180 = 555 \text{ mm}$$

$$\text{The length of the cutting stroke} = 555 - 450 = 105 \text{ mm} = 10.5 \text{ cm}$$

Cutting speed,

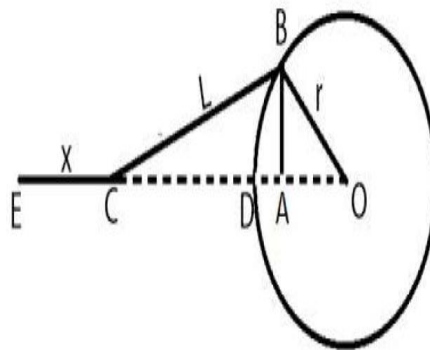
$$v = N L (1+m) / 1000 \text{ m/min}$$

N = the number of double strokes or cycles of the ram per min (take  $N = 100$ )

L = Length of the ram stroke in mm

m = return stroke time/cutting stroke time,

$$m = 1 \quad v = 0.021 \text{ m/min}$$



**Figure 17.** Free body diagram of scotch yoke mechanism

## 11. Conclusion

We have presented the development of multipurpose machine in various modes by which it can actively be adopted. We have explained the various parts and components of multipurpose machine using scotch yoke mechanism. Special categories of additional and verity of tools that can be implemented on multipurpose machines. The requirement for the invention of a multipurpose machine is significant in the delay it takes in using hand tools to carry out jobs. Moreover, the cost of a lathe machine is too high for an average user. These machines will aid in reducing costs, increasing rate of production and skill of the worker.

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