# CUTTING AND SHAPING MACHINE USING SCOTCH YOKE MECHANISM

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**Abstract**

"Multi Operational Mechanical Machine "This work was mainly carried out for manufacturing and fabrication industries. The machine 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 to the main drive shaft, is directly connected, and then it is used for different operations. Several operations have been performed by a single-drive system. The main focus of the work is to reduce power usage and increase the productivity of reduced floor space. Portability is an important quality in any machine in today's world; every field of science and engineering has portability as one of its most important advancements. Therefore, the machine we have designed satisfies this principle with respect to the manufacturing industry.

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## 1. Introduction

A cutting and shaping machine using a scotch yoke mechanism has a fine-toothed hacksaw for cutting the metals with high-speed operations and a shaper to take a slot on another side of the machine. There are hand saws and power hacksaws. The hacksaws are adjustable and can hold several 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 using push or pull the cutting teeth. Suppose a workpiece 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.

**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 thickness of the 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 that 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.

**Shaper machine:**

It is a type of special machine mostly performing in a linear direction for metal removal operations. A single-point cutting tool that 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 the help of a ram that moves above a stationary workpiece instead of the entire workpiece moving beneath the cutter. The ram travels back and forth by a crank inside the column.

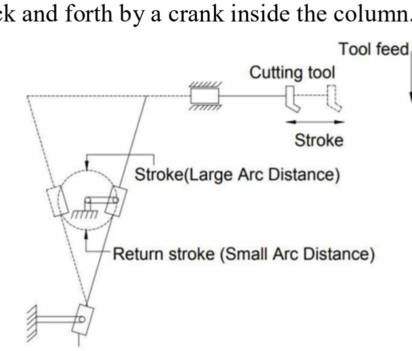


**Fig.1 Shaping Operation**

**B.1. Linkage of Shaper**

The cutting stroke takes more time than the return stroke using mechanisms. Due to the result of the quick return mechanism, a more powerful cutting takes in forward stroke, and tool rubbing action is eliminated by return stroke. In the shaper machine, the workpiece is in idle condition, the cutting tools only move on the workpiece. The tool is mounted on a reciprocating ram. Sometimes the motion of the table is controlled manually, but typically it can be automated, it is known as a feed mechanism. The mechanism has been operated by a lead screw. At the end of the ram is the tool post and clapper box. The function of the tool post is to clamp the tool at a different angle. The tool slide enables the feeding of the tool downwards to make the cut deepen. The versatile nature of a machine gives a path for 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 and internal splines and gear teeth.

**A. 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 to a sliding yoke using a slot that engages the pin on the rotating part of the yoke.

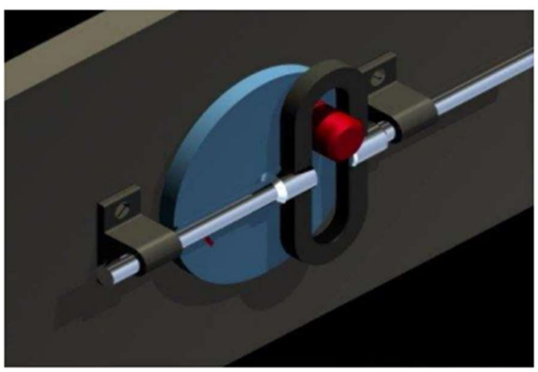

**Fig.2 Scotch Yoke Mechanism**

## 2. Literature Survey

The Scotch Yoke mechanism is a simple and effective mechanical system that converts rotary motion into reciprocating motion using a slotted yoke and a crank which was developed by Joao O Rendeiro [1]. Traditionally used in engines, pumps, and compressors due to its ability to produce a smooth reciprocating motion, its applications have broadened over time. Various researchers and designers have explored this mechanism for multipurpose operations such as cutting, shaping, slotting, and even pressing in small-scale workshops and industries is suggested by Clayton M. Christensen [2]. One of the key advantages of the Scotch Yoke system is its compactness and ability to generate higher force with less input, which makes it highly suitable for fabricating multifunctional devices.

The literature highlights the integration of this mechanism into machines that aim to perform more than one operation—commonly seen in setups that combine drilling and shaping or cutting and grinding functionalities in a single frame. Studies have shown that this design significantly reduces the need for multiple machines, saving space and cost, while also enhancing productivity in small or medium-sized enterprises (SMEs) [3]. The fabrication process typically involves assembling components such as the yoke, crank, slider, shaft, and working tools onto a base frame, with careful attention to alignment and motion transmission efficiency [4].

Research also emphasizes material selection for durability, ease of fabrication, and maintenance considerations. Moreover, modifications like electric motor drives, speed control mechanisms, and tool change adaptability have been implemented to make the system more versatile. Comparative studies with other motion-conversion mechanisms like slider-crank systems reveal that the Scotch Yoke offers smoother motion and greater efficiency in particular configurations, although it may be limited by wear in high-load conditions [5].

Additionally, the mechanism provides a symmetric and continuous stroke motion, which is particularly advantageous for shaping operations where consistent reciprocating motion enhances the surface finish and dimensional accuracy of the workpiece [6]. Researchers have explored the feasibility of implementing the Scotch yoke in both vertical and horizontal shaping configurations, demonstrating that its adaptability allows for diverse machine orientations without sacrificing performance. A number of experimental studies have investigated the effect of varying crank radii and yoke slot dimensions on output force and speed, finding that optimal sizing can significantly improve cutting efficiency and tool life [7].

## 3. Methodology

The methodology for designing and fabricating a cutting and shaping machine using the Scotch yoke mechanism involves a systematic approach that integrates conceptual design, material selection, component fabrication, assembly, and performance testing, all tailored to utilize the advantages of the Scotch Yoke mechanism for multiple mechanical operations. The process begins with an in-depth understanding of the Scotch Yoke mechanism, which converts rotary motion into linear reciprocating motion through a slotted yoke connected to a crank driven by a rotating shaft. This motion is harnessed to drive various tools such as cutters, slotters, grinders, or drill bits.

## 4. Related Work

The related work covers a range of studies, design innovations, and experimental projects where the mechanism has been explored for compact, cost-effective solutions in manufacturing and mechanical operations. Numerous research papers and academic projects have investigated the application of the Scotch Yoke mechanism to perform smooth linear motion with fewer components compared to traditional slider-crank mechanisms.

Several researchers have documented the performance advantages of Scotch Yoke machines, citing improved efficiency, lower maintenance, and space-saving benefits compared to using separate machines for each task. Some studies also present CAD and FEA analysis of the yoke and crank components to ensure structural integrity and durability under load.

Overall, the body of related work forms a strong foundation for continued innovation, suggesting that cutting and shaping machines using scotch yoke mechanisms are not only feasible but also highly effective for educational, experimental, and small industrial uses.

## 5. Proposed System

- Adjustable vice or clamping mechanism to hold the workpiece securely during cutting or shaping.
- Ability to vary the crank radius or yoke position to change stroke length according to material size and operation type.
- Simple lever or switch mechanism to alternate between cutting and shaping functions as needed.
- Generally single-phase electric motor (typically 0.5 HP–1 HP) acts as the primary drive, providing rotary motion to the crank.
- Ideal for small workshops, educational labs, and light manufacturing units for working on materials like mild steel, aluminium, or plastic.
- Functionality reduces equipment needs, Compact and cost-effective design.

## 6. Experimental Procedure

- **Material Selection and Component Preparation**

The first step involves selecting suitable materials for various machine parts. Mild steel is generally used for the frame due to its strength and ease of fabrication, while components like the yoke, crank, and slider may also be made from mild steel or cast iron for better durability. Cutting tools are selected based on the type of material to be machined, typically high-speed steel (HSS) or carbide tools for shaping and cutting operations. Once the materials are chosen, fabrication of the frame, crankshaft, yoke, tool holder, and base is carried out using standard machining processes like turning, milling, welding, and grinding.

- **Assembly of the Scotch Yoke Mechanism**

After preparing the individual components, the assembly of the Scotch Yoke mechanism is done. The crank is attached to the output shaft of an electric motor using a key or coupling. The slotted yoke is connected to the crank pin in such a way that as the crank rotates, it slides the yoke back and forth, converting rotary motion into linear motion. The tool holder or ram is fixed to the moving end of the yoke. Bearings and guide rods are fitted to ensure smooth reciprocating motion and reduce friction.

- **Mounting the Tools and Workpiece**

Next, the cutting and shaping tools are mounted onto the tool holder. The workpiece is clamped firmly in position using a vice or fixture attached to the machine bed. The alignment of the tool and workpiece is checked to ensure accurate cutting or shaping. Depending on the design, interchangeable tool mounting may be available to switch easily between cutting and shaping operations.

- **Initial Trial Run and Motion Testing**

Before starting the actual experiment, an initial trial run is conducted. The electric motor is powered on, and the movement of the crank, yoke, and ram is observed. This helps in identifying any misalignment, excessive vibration, or obstruction in the motion path. Lubrication is applied to moving parts to reduce wear and ensure smooth operation. Adjustments to the stroke length or speed can be made, if necessary, depending on the material and desired finish.

- **Performing the Cutting and Shaping Operations**

Once the machine is confirmed to be running smoothly, actual cutting and shaping trials are carried out. For cutting, the tool is pressed against the workpiece in each stroke to remove material. In shaping, the tool performs a linear forward stroke to cut and a return stroke without cutting. Multiple passes may be made by adjusting the feed after each stroke. Observations regarding tool movement, material removal rate, surface finish, and accuracy are recorded.

- **Observation and Data Collection**

During the operation, data is collected on parameters such as stroke length, cutting time, surface finish, dimensional accuracy, and tool wear. The behavior of the machine under different loads and materials can also be studied. Any vibration, misalignment, or unusual noise is noted for possible design improvements.

- **Post-Operation Analysis**

After completing the experiment, the finished workpiece is inspected for quality and precision. The wear and condition of the tool are also evaluated. The performance of the machine is analyzed based on factors such as smoothness of operation, ease of switching between functions, and quality of the output. Any improvements required in the mechanical setup, stroke mechanism, or tool holding system are identified for future modifications.

## 7. Construction and Working Principle

**Components and Descriptions:**

- AC Motor (230V,50Hz,1500 RPM)
- Belt (Material: Leather) (1200mm Length)
- Driver Pulley (Material: MS) (40mm Dia)
- Driven Pulley (Material: MS) (300mm Dia)
- Disc (Material: MS) (130mm Dia)
- Connecting Shaft (Material: MS) (25mm Dia, 75mm Length)
- Blade Movable Distance (90mm)

**Construction:**

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

**Basic Construction and operating principle:**

**Fig.3 AC Motor Used in the Project**

Another important element in the mechanism is an AC induction motor with a cover known as a stator and a rotor that rotates inside with an air gap between both. In reality, all systems of prime movers use 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 fields of the electromagnets generates torque. As a result, the motor rotates in the direction of the resultant torque.

**Load Characteristic:**

The load system is stable when torque is developed. It is equal to the compulsory load torque. The motor will operate 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 selection for a given load.

**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.

**Fig.4 Hacksaw Blade**

**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 workpiece is used to remove the material from the workpiece.

**Fig.5 Shaper**

Types of tools:

- Straight tool (for general purpose)
- Crank tool (for better access and clearance)
- Round nose tool (for added functionality)

**Pulley**

A pulley is a mechanical component consisting of a wheel with a grooved rim around its circumference, designed to support the movement and change the direction of a taut rope, belt, or cable. It is typically mounted on a shaft and rotates as the rope or belt moves over it. Pulleys are used to transmit mechanical power or motion and are a fundamental element in belt drive systems, where they help in transferring rotational motion from one shaft to another. By using pulleys of different diameters, it is possible to achieve changes in speed and torque between the driving and driven shafts. Pulleys are commonly made from materials such as cast iron, steel, or aluminium, and they are widely used in various mechanical and industrial applications, including lifting systems, conveyors, engines, and machine tools. Their simplicity, efficiency, and versatility make them an essential part of mechanical power transmission systems.

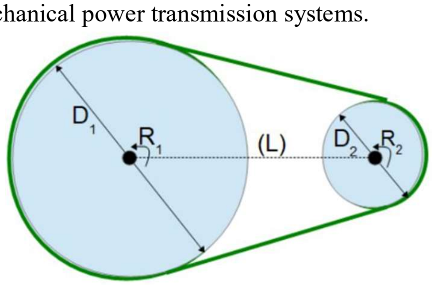


**Fig.6 Drive Pulley and Driven Pulley**

**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 a high bending moment.

**Fig.7 Frame**

**Principle of Model:**

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

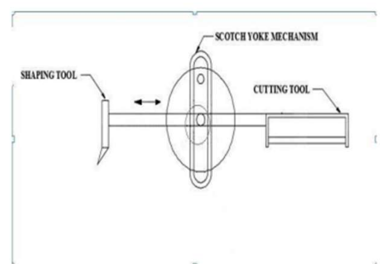


**Fig.8 2D Layout of the Machine**

**Working Principle:**

To operate the machine, energy is required. The value of the power supply is 230v AC. The rotation of the crank and the sliding of the pin inside the yoke also move 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 move in the reverse direction. On completion of a full rotation by the crank, the yoke will move back to its original position. The yoke moves across a length equivalent to double the crank for a complete rotation.

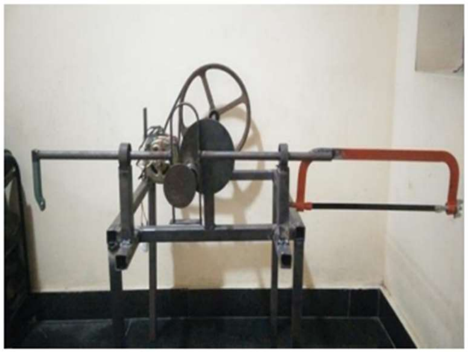

**Fig.9 Prototype**

## 8. Applications

- **Flat Surface Generation:**

Ideal for producing flat surfaces on metal, plastic, or wood workpieces in workshops or training centres.

- **Keyway Cutting:**

Can be used to cut internal or external keyways in shafts and hubs by modifying the tool and work holding.

- **Groove and Slot Cutting:**

With a grooving tool, the machine can make straight slots, grooves, or recesses in components for assembly or fitting purposes.

- **Prototype Fabrication:**

Suitable for small-batch or prototype manufacturing where large CNC machines are not economical.

- **Small Component Machining:**

Effective for machining small to medium-sized mechanical parts in small-scale industries or repair workshops.

- **Cutting Non-Metallic Materials:**

Can be adapted for cutting plastic, acrylic, PVC, and other non-metallic materials with the right tool.

## 9. Conclusion

We have presented the development of a multi-mechanical machine in various modes by which it can actively be adopted. We have explained the various parts and components of a multi-mechanical machine using a scotch yoke mechanism. Special categories of additional and variety of tools can be implemented on multi-mechanical machines. The requirement for the invention of a multi-mechanical 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 the rate of production and skill of the worker.

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