

Design and Fabrication Of Pneumatic Rubber Pipe Cutting Machine.

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1. Abstract

The manufacturing industry demands efficiency in production while maintaining the desired quality of the products. In this era of Industry 4.0 efficient methods are developed for mass production in least possible time while maintaining quality and keeping Ergonomic aspects under consideration to reduce work-related fatigue, automation plays an important role in it. Manually operated cutting machines often yield inconsistent and low output. The objective of this project is to design and fabricate a pneumatically operated rubber pipe cutting (PRPC) machine which can utilise multiple circular cutting tools to cut multiple workpieces in a single cycle and thus increase the efficiency of the production. The PRPC machine is powered using an electric motor and a worm gearbox is used to transfer the power from the motor to the rotating mandrel/spindle. Multiple circular cutting tools are mounted on mild steel(M.S.) guideway and positioned below the mandrel/spindle and can be calibrated in terms of length required and are operated using a pneumatic cylinder. This arrangement of circular cutting tools helps to increase production rate in the least possible time. The first operation of the new machine resulted in decreasing production time for a batch of 800 units from 12 hours to 5 hours.

Keywords: Pneumatic systems, Pipe cutting machine, Aspects in Ergonomics, Ergonomic Design, Rubber pipe cutting machine, Pneumatic Cutting machine

2. INTRODUCTION

Cutting is one of the significant manufacturing processes in the industries, it is a simple yet efficient process that utilizes mechanical, thermal energies to carry out the operation Nilkanth et al (2017) . Cutting operation is carried out by giving greater force to a single point or multipoint cutting tool against the workpiece. The machine formerly used was a manual pipe cutting machine that required two operators and yielded low and inconsistent output. The existing machine consisted of a manually operated single-point cutting tool, an electrical motor of 2hp, and 1440 rpm connected to the pipe mounting mandrel using a belt drive, this machine required modifications due to reduced run time of the machine. Lakhe et al (2018) performed analysis and fabrication of an automated pipe cutting machine which can be pneumatically operated. The authors performed Static Structural and Modal Analysis on a CAD model of the pneumatically operated machine which concluded that the deformation of the cutting blade mostly depends upon the frequency. Nilkanth et al (2017) fabricated a pneumatically operated pipe cutting machine that feeds, clamps and cuts the workpiece. The machine shows use of control valves, relay circuits and two pneumatic cylinders and has applications in small metal cutting industries. Bipinchandra et al (2016) designed and fabricated a pneumatically operated pipe cutting machine, the resulting machine can perform cutting operations with high cutting speed and increases efficiency of production. Frederick et al (2016) assembled a pneumatically controlled hacksaw cutting machine. The machine exhibits a circuit with directional control valves and IC timing circuit to control linear motion of the hacksaw blade. C. Phan (2020) fabricated a concrete pipe cutting machine to achieve custom cutting dimensions required in industry. The machine shows use of a PID controller for positioning of the workpiece to achieve accurate cutting dimensions. Kailasingh (2014) fabricated a pneumatically operated pipe/rod cutting machine. The machine mechanism can feed, clamp and

cut the workpiece and has applications in drilling and small scale industries. The literature exhibits various mechanisms with pneumatic cylinder to cut pipes/rods of different materials but yield only one workpiece per cycle. It can be further improved by using multiple cutting tools to cut workpiece in a single cycle. The modified machine uses a pneumatic cylinder to control the circular cutting tools mounted on a M.S. guide way for cutting. The power transmission consists of an electric motor connected to mandrel/spindle via a worm gearbox. Multiple circular cutting tools can be mounted on the M.S guideway with a linear scale to calibrate lengths of the tools. This arrangement can simultaneously cut multiple workpieces of varying lengths with high production rate.

3. Problem Statement

The existing rubber pipe cutting machine available at Belmont rubber Industry Pvt ltd, Faridabad, India, is a totally manually operated machine. The manual rubber pipe cutting machine required two operators, the role of one operator was to position the rubber pipe on the mandrel of the machine and the other operator controlled the manual single-point cutting tool. The machine yielded one piece of pipe per cycle before readjusting the pipe on the mandrel. The mandrel is powered by a 2hp electric motor which is connected to the mandrel using a belt drive. The electric motor had a fixed rpm at 1444, which is not suitable for every specification of the rubber pipe cuttings required. After gathering information and discussing with the industry, the problems encountered were the overall run time of the machine was reduced but the demand for the product was the same, thus the efficiency of the machine is to be increased and the shortage of operators due to global pandemic demands for a mechanism through which only one operator can operate the machine with ease and efficiency.

4. Proposed Design

The proposed design is to modify the mechanism of the existing manually operated machine pipe cutting machine. The manually operated single-point cutting tool will be replaced by multiple circular cutting tools mounted on a M.S. guideway, the operator can utilize the cutting tools with the help of a pneumatic cylinder which will be powered by a foot pedal/push button. The 2hp electric motor will be replaced by a 1.5hp electric motor which will be connected to the mandrel mechanism using a gearbox with a flange. The modified cutting tool mechanism results in cutting multiple rubber pipe pieces at a time, due to the pneumatic cylinder with foot pedal or a push button mechanism only one operator is required to operate the machine. The belt drive was replaced by the gearbox, this helps operators to change the rotation speed of the mandrel and easily cut rubber pipes of required specification and sizes.

5. Methodology :

This project consists of multiple (3/4) circular cutting tools mounted on a horizontal M.S. guide way which can be moved in vertical direction using a pneumatic cylinder. The M.S. guide way has a steel measuring scale on it which aids the operator to calibrate the length of the circular cutting tools to achieve varying cutting dimensions simultaneously. The mandrel/spindle used contains an air inlet for easy mounting and removal of the workpiece and grooves to guide the circular cutting tools after cutting is complete . The rubber pipe is mounted on the mandrel and power is given to the motor which powers the worm gear box and the shaft connected to gearbox rotates the mandrel/spindle. The pneumatic cylinder is operated using a foot pedal/push button which elevates the M.S. guideway and circular cutting tools towards the rotating workpiece. The cutting tools cut the workpiece by coming in contact with it and rotating in opposite direction. The cutting tools cut the workpiece and move into grooves provided in the mandrel for guidance. The pneumatic cylinder is given reverse stroke and circular cutting tools with M.S. guideway come back to initial position. The air inlet in mandrel is given and the workpieces are removed.

After finalising the design of the PRPC machine new components were introduced .

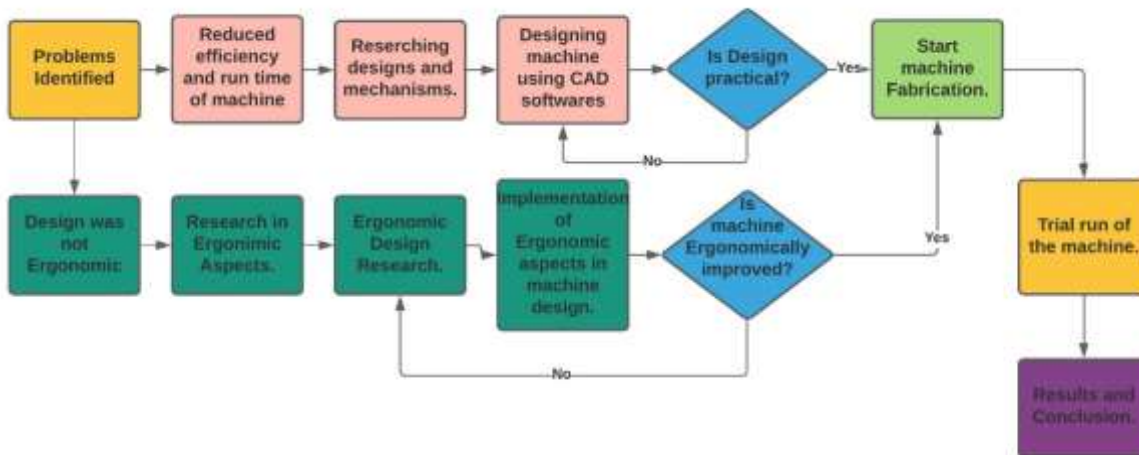


Fig 1: Research Methodology Flow Chart

6. Components Description:

1) Pneumatic cylinder

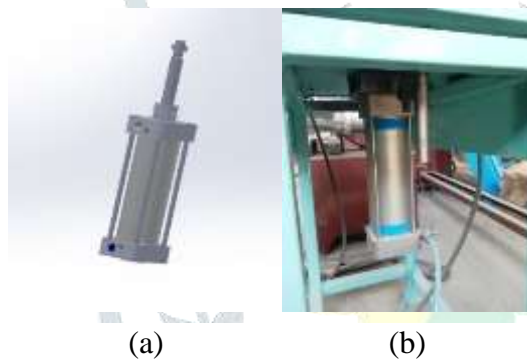


Fig 2: Pneumatic Cylinder (a) CAD model, (b) Actual pneumatic cylinder.

Pneumatic Cylinder is a mechanical device which utilises pressure energy from compressed air to achieve mechanical work. The piston in the pneumatic cylinder moves to and fro in a linear motion to perform mechanical work. In this machine pneumatic cylinders are used to move the circular cutters in upward direction to perform cutting operation. Pneumatic cylinders have less risk because it utilises atmospheric air and it can be used in variety of work conditions.

2) Electric motor

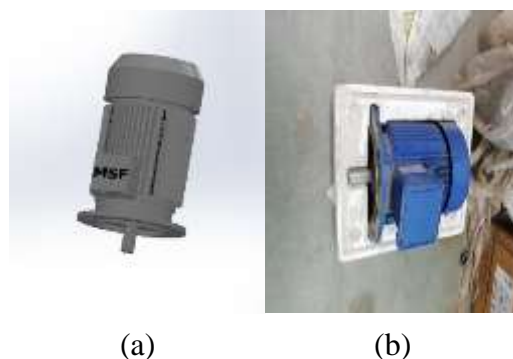


Fig 3: Electric Motor (a) CAD model, (b) Actual motor

Electric motor is an electrical device which uses electrical energy to perform mechanical work. The motor used in this machine is a 1.5hp electric motor which replaced the previous 2hp motor. The electric motor is connected to the worm gear box which in turn rotates the mandrel using power from electric motor.

3) Worm Gear Box

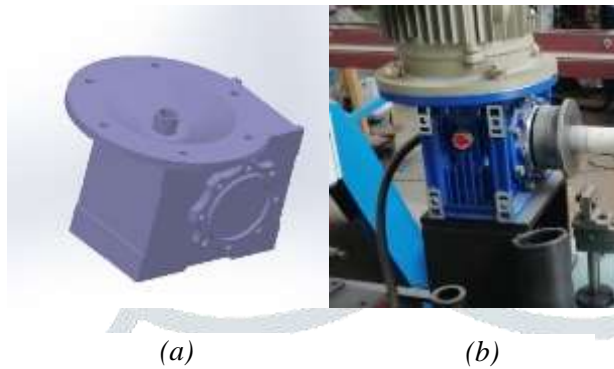


Fig 4: Worm Gear box (a) CAD model, (b) Actual gearbox

The gear box used in this machine is AL063 80B5 worm gearbox which is positioned between electric motor and mandrel/spindle. This gearbox contains flange coupling and shaft for power transfer from electric motor to mandrel.

4) Mandrel/Spindle

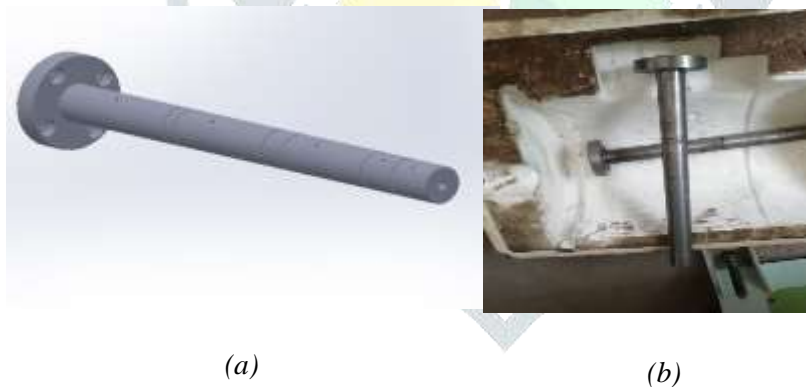


Fig 5: Mandrel/Spindle (a) CAD model, (b) Actual mandrel

The mandrel/spindle used in this machine has a diameter of 45 mm and it is used to mount the rubber pipe for cutting operation. The mandrel rotates by utilising power supplied by the electric motor through the worm gear box. The mandrel has grooves cut at specific distances to accommodate and guide the circular cutting tools for cutting operation.

5) Circular cutters

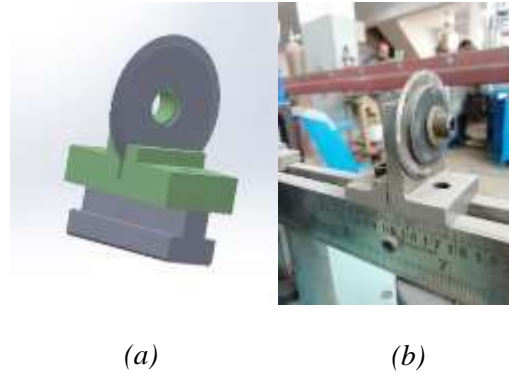


Fig 6: Circular cutter (a) CAD model, (b) Actual circular cutter.

The circular cutters used in the machine replaced the manually operated single point cutting tool. The circular cutters are mounted on a M.S. guideway powered by the pneumatic cylinder and are positioned below the mandrel. The circular cutters cut the rubber pipe by rotating in opposite direction of the mandrel and move into grooves on the mandrel which are provided for guidance to avoid damage after cutting the workpiece.

7. Ergonomic Aspects.

Ergonomics is that scientific study of the link between human and work culture. It discovers and implements information concerning human behaviour, safety, comfort, limitations and alternative characteristics to the planning of tools, machines, systems, tasks, jobs and use expeditiously human power. When featured with productivity issues, engineers may come up with better machines, personnel management may hire trained humans however ergonomics comes up with higher interaction between user and machine. For ergonomics, the human is a vital part of the system and should be totally integrated into it in the least planning stages. Human requirements are thus system's requirements, instead of secondary thought.

7.1 Layout study –

A) Maximum space covered by arm –

The maximum space is that space which will be reached by extending the arms from the shoulders and while not moving them. This space is most solely in terms of maintaining body posture; by leaning forward or sideways a larger reach is created. For adults (50th percentile) the most areas for non-automatic controls are:

- Males: 60-70 cm
- Females: 55-65 cm

B) Normal space for arm –

The normal space is that space which will be reached handily with a sweep of the forearm, the higher arm hanging in a very natural position at the facet. For adults (50th percentile) the traditional areas for non-automatic controls are: -

- Males: 40-50 cm

- Females: 35-45 cm

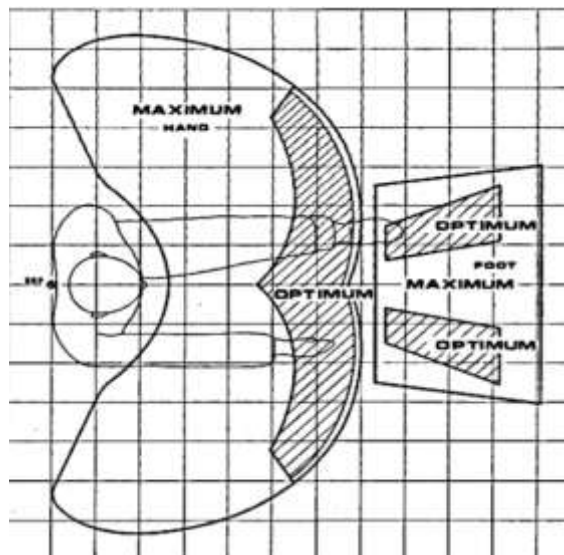


Fig 7: Hand and leg range. Muhundhan (2013)

C) Maximum space for legs –Most space is reached by extending legs at forty five degree angles and can cover most distance with none pain. . For adults (50th percentile) the most areas for non-automatic controls are: -

- Males: 55-58 cm
- Females: 50-52cm

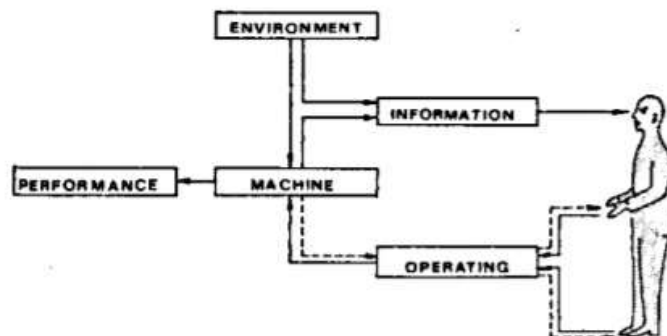


Fig 8: Ergonomics required in upright position. Zander, J. (1972).

7.2 Aspects of Ergonomics–

There are 5 aspects of ergonomics:

- Safety
- Comfort
- Ease of use
- Productivity/ performance
- Aesthetic

Manufacturing trade is associate trade that amend raw materials, components, or alternative components into a final product that is consistent with company’s standards. Within the production floor all the activities

within the producing trade, the staff have totally different job specifications with one another. Some work consists of human-machine interaction is revealed by the activity between staff and pipe cutting machine, shaping machine, fastening machine, shaper and others. The manufacturing industry can expand its capacity to serve a wider range of higher-quality goods as a result of consumer demand or encouragement.. In general, consistent with the rise of company targets, it additionally would like improvement from the side of labour performance. The eight aspects of ergonomics, which include the consumption of nutrition for workers (energy), muscle strength, body posture, environment, time conditions, social conditions, data conditions, and human machine interaction, must be identified to get an overview of the proposed improvement supported human performance. Susihono et al (2018).

Optimizing the security, health, comfort and potency of the staff within the operating setting is the aim of ergonomics. The productivity of staff primarily relies on the ergonomically designed digital computer. Analysis and improvement of digital computers and layout is finished by the uncountable analysis. Correct engineering in digital computers offers a decent interaction between the employee and dealing setting. If the digital computer isn't designed with considering the measurement information, then the potency of the digital computer gets weakened. Ergonomics is additionally referred to as Human factors, comfort style and purposeful style may be a methodology of coming up with the product and system to administer a high interaction between the individuals and also the operating setting. Ergonomics is defined by the association because it is concerned with the study of human interactions and also the choice parts of a system and also the profession that applies theory, principles, information and ways to style to optimize human eudaimonia and overall system performance.

In order to figure expeditiously and to manufacture sensible quality product and to extend productivity, the geographic point needs to be designed by considering ergonomics principles Muhundhan (2013) .In the current state of affairs, makers realised that rather than investment a uncountable cash to material, man, machine, method, providing an ergonomically work point is value saving. Shinde et al (2012) . So ergonomically designed workstation in industries with correct standard structure provides several edges, e.g. inflated motivation and satisfaction of worker, higher performance, and process quality.

The goal of ergonomics is to optimise the human-machine-environment system by adapting operating conditions to a person's physical, psychophysical, and physiological nature, while taking into account specific differences that exist between humans in terms of job relevance and geographic location. By James H. Stramler (1993) ergonomics is outlined because the field that is concerned in doing analysis concerning human psychological, biological, social, as well as the physical characteristics, preserving the information gained from the study, and dealing with the data in relation to the preparation, operation, or use of products or systems for optimising human health, efficiency, protection, and habitability.

7.3 Implementation of Ergonomics in Workstation

- By providing the ergonomics concerns in coming up with the digital computer, following are the benefits
- Productivity gets increased by providing a snug geographic point to staff, thereby creating the roles easier.
- Product quality is improved thanks to fewer errors within the ergonomically designed geographic point.
- System disorders get reduced.
- Absence by the staff are reduced thanks to the lower injury rates featured throughout their workday.
- Ergonomics creates a more robust safety culture.
- Staff comfort inflated.
- Staff fatigue reduced.

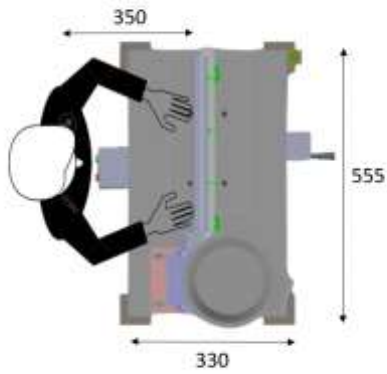


Fig 9: Ergonomics Illustration with machine (Top View) Dimensions in mm

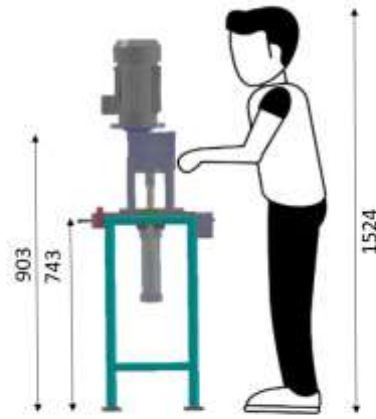


Fig 10: Ergonomics Illustration with machine (Front View) Dimensions in mm

8. CAD Model of the machine

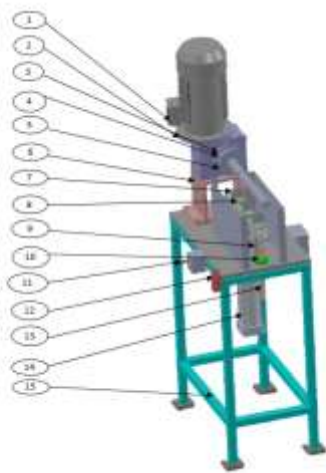


Fig 11: Isometric view

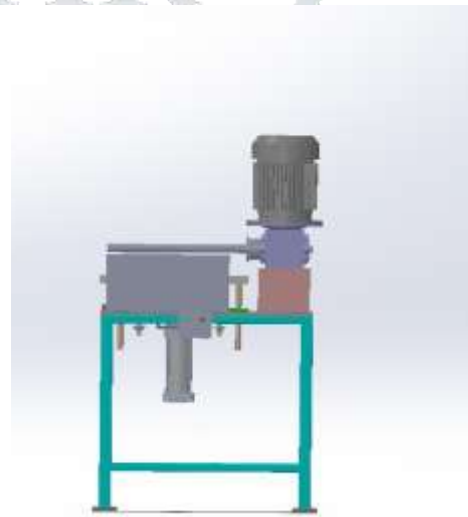


Fig 12: Side View

Table 1. Components as shown in fig 11

1) Electric motor.	6) Gearbox support	11) Pneumatic on/off valve.
2) Worm Gearbox.	7) Circular cutter (1)	12) Pneumatic pushbutton.
3) Connecting shaft.	8) Circular cutter (2)	13) M.S. guideway support.
4) Workpiece remover.	9) M.S. guideway	14) Pneumatic cylinder.
5) Mandrel/Spindle	10) Stopper	15) M.S. Bed.

9. Working Principle

Power supply and air supply is provided to the mandrel/spindle. When power supply is provided to the electrical motor, it transfers power to the worm gear box which in turn rotates the shaft and the mandrel. The air supply is provided using a compressor through holes in the mandrel which facilitates easy mounting of rubber pipe on the mandrel. Then feed is given to the pneumatic cylinder which provides a vertical stroke to the M.S guideway on which three circular cutters are mounted. The circular cutters start rotating in the opposite direction of the mandrel and cut the pipe through slight penetration. The circular cutting tools cut the rubber pipe and move into the grooves provided in the mandrel for guidance. Three pieces of pipe are cut simultaneously, then reverse stroke is given to the pneumatic cylinders which brings the channel and circular cutters back to the initial position.

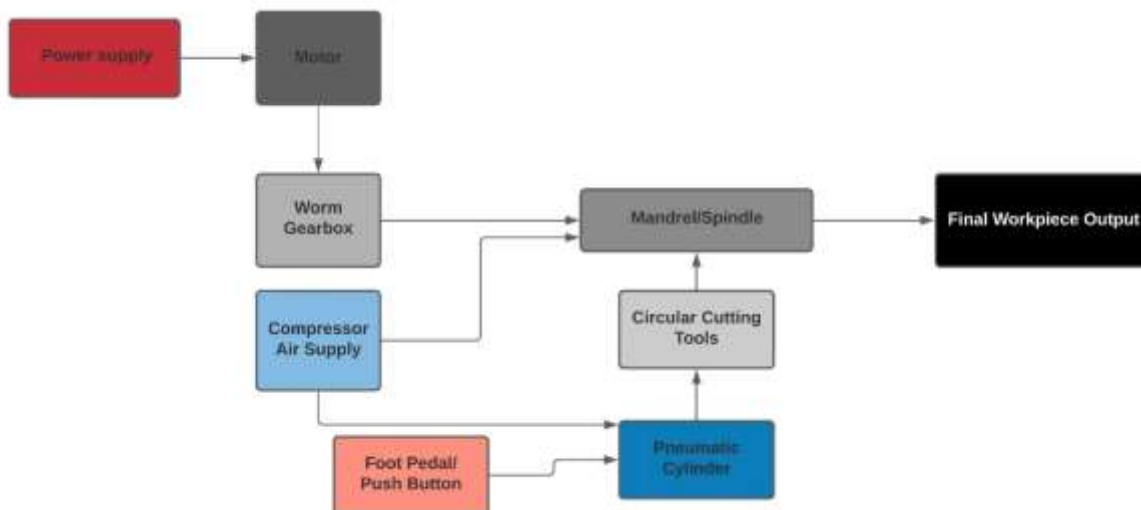


Fig 13: Block Diagram of the machine



Fig 14: Actual Pneumatic Rubber Pipe Cutting Machine

10. Calculations

To calculate production efficiency we will use formula:

$$(\text{Actual output rate} / \text{Standard Output rate}) \times 100.$$

Where : Actual Output rate is that of Pneumatic Rubber Pipe Cutting Machine.

Standard Output rate is that of Manual Rubber pipe Cutting Machine.

Table 2. Production Data

Type of Machine	Manual Rubber Pipe Cutting Machine	Pneumatic Rubber Pipe Cutting Machine
Quantity of workpieces	800	800
Time required.	12 hours	5 hours

1) Standard Output Rate = $800/12 = 66.66$.

2) Actual Output Rate = $800/5 = 160$.

3) Production efficiency = (Actual output rate/ Standard Output rate) x 100.

$$= (160/66.66) \times 100$$

$$= 240\%$$

11. Results and discussion.

The pneumatic rubber pipe cutting machine is fabricated according to proposed design. The mechanism of pneumatic cylinder, electrical motor, worm gearbox, circular cutters enables the operator to cut three workpieces in one cycle. The air inlet to the mandrel enables easy mounting and removal of workpieces. The ergonomics aspects of the machine allows the workers to cut the workpiece with ease with reduced work fatigue. The pneumatic rubber pipe cutting machine reduced the time required to cut a batch of 800 workpieces from 12 hours to 5 hours thus increasing efficiency of the machine by 140%.

12. Conclusion

In this project the problems identified due to the Manual Rubber pipe Cutting Machine like reduced run time, inconsistent output, poor Ergonomic design are solved by designing and fabricating a Pneumatically Operated Rubber Pipe Cutting Machine. Pneumatic rubber pipe cutting machine gives higher productivity in a short time period in comparison with the manual machine. The major advantages of this machine are intervention of labour is reduced and efficiency of machine is increased i.e. operator can cut 3 workpieces in one cycle while improving the Ergonomic aspects of design for ease of operation. In this rapidly emerging industry, the use of pneumatic pipe cutting machines is wide, time and labour plays a major role in production. This can be overcome by using this type of pneumatic machine.

13. References

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