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Design and Fabrication of Pneumatic Stirrup Making Machine

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Abstract - *Stirrups are main elements which are tied with wires to the vertical and horizontal rods in column and beam, so that it can gain enough strength to support concrete structure. Stirrups can be rectangular, square or circular in shape. Presently in smaller construction sites worker use to prepare stirrups manually, which is a traditional way of making stirrups. Manual work consumes time and needs a lot of efforts. In order to overcome this, automation is needed. An attempt is made to design and fabricate pneumatic stirrups making machine which works on the pneumatic actuator. Its use has reduced human effort and construction lead time.*

Key Words: **Stirrup, Pneumatics, Automation, Arduino board**

1. INTRODUCTION

Due to increase in population, the demand for construction of the houses, overhead bridges, building for industries and other infrastructure has also been increased. To fulfill this demand a large number of construction works is going on, which involves a huge labor force. As due to the availability of technology it has been essential to decrease the human efforts as far as possible. It not only helps to avoid fatigue injuries to the labor but also increases the rate of production. By considering this, a machine is designed and developed which utilizes the pressure energy of compressed air to perform the stirrups bending operation by using pneumatic actuator. As stirrups are required in a large quantity to provide reinforcement in the structure, this setup can save huge human intervention and make stirrups making process semi-automated.

2. LITERATURE REVIEW

2.1 DESIGN AND FABRICATION OF MULTIROD BENDING MACHINE

In this paper C. Anbumeenakshi, et. al. [1] investigated and designed a stirrup making machine which utilizes the hydraulic power of fluid. Two hydraulic cylinders one for bending operation and another for feeding the rod for the next bend are used. The stirrup is clamped on a fixture plate which is free to rotate in one direction with the help of hydraulic cylinder. It contains a control valve which provides the direct control of the fluid, so as to control the movement of the plunger. Different shape and size of stirrup are possible to prepare by varying the die specification.

2.2 DESIGN AND DEVELOPMENT STIRRUP MAKING MACHINE

In this paper Saish D Amonkar, et. al. [2] described a stirrup making machine which works on electric power. As electricity is available easily at any place hence they used an electric motor to produce bending force. A set of the worm wheel and the worm gear are introduced for speed reduction as well as for higher torque. An arrangement of the fixed plate and moving pin are used to perform bend. A spring brings back the setup to its initial position as soon as one bending operation is performed.

2.3 REINFORCED BAR BENDING MACHINE

This paper gives information on stirrup making machine using electrical energy. The biggest drawback in other electrical stirrup making machine is an electric motor needs to be tripe off after 90° movement of the bending pin. To overcome this S.Thillairaja et. al. [3] introduced a concept of using semi-tooth gear which serves this purpose. A set of spur gear arrangement is used which decrease the speed of the bending pin, and bending is performed between fixed and moving pin arrangement.

3. OBJECTIVE AND MOTIVATION

3.1 OBJECTIVE

The objective of this paper is to design and fabricate pneumatic base stirrups making machine and to introduce automation in production of stirrups.

3.2 MOTIVATION

Many of the stirrups making machine use either hydraulic actuator or electric motor for its operation. As hydraulic is slower in action and when hydraulic fluid gets leaked out it is hazardous to the surrounding. Problem with electric base stirrups making machine is its heavy weight. In order to overcome problem motivation played an essential role. So here an attempt is made to design a machine which will be faster in action than hydraulic base stirrups making machine and lighter in weight than the electric base machine.

4. CONCEPT AND DESIGN OF STIRRUPS MAKING MACHINE

Concept and design of the machine are described as follows,

4.1 SCHEMATIC LAYOUT AND DESCRIPTION OF THE MACHINE

The initial conceptual design is prepared with the help of sketches. It shows the various components used in the machine along with their systematic arrangement. Figure 1 and Table 1 shows the schematic layout of machine with component used respectively.

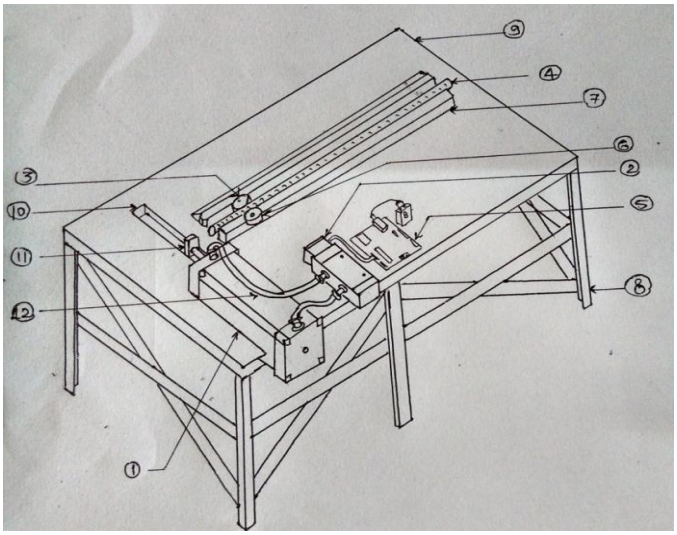

Fig. 1- Schematic Layout of Pneumatic Operated Stirrups Making Machine

Pneumatic operated stirrups making machine consist of various components as shown in Fig. 5. It consists of a rigid frame (8) in which proper spacing is provided for mounting of different components like Pneumatic cylinder (1) and table. A slot is provided on the table for piston movement, and holes for mounting the fixture(7).Two rollers that are driving and driven roller are used for rod feeding mechanism.

Table 1- Components with Component Number

Component Number	Component Name
1	Pneumatic cylinder
2	Solenoid valve
3	Driven roller
4	Rod
5	Electronic circuit
6	Roller connected to a DC otor
7	Guide (fixture)
8	Frame
9	Table
10	Slot
11	Block connected to the cylinder piston
12	Air tube

The driving roller is mounted on DC motor which is controlled by electronic circuit (5) and it consists of Arduino board. The solenoid valve (2) is connected to a pneumatic cylinder (1) with the help of air tube (12). DC motor is placed below the table.

4.2 DESIGN CALCULATIONS

Diameter of Rod = 8 mm, Material – Mild Steel
Allowable bending stress (σ_b) = 300 N/mm^2
Force required for bending the rod is analytically estimated as 1508 N.

Pneumatic cylinder design - Pressure is given by

$$P = \frac{F}{A}$$

$$A = \frac{\pi}{4} * D^2$$

Assume pressure is constant at 5 bar

$$P = \frac{1508}{\frac{\pi}{4} * D2}$$

D = 0.06196 m
D = 61.96 mm

Select standard cylinder diameter as 63 mm

Stroke Length:

Minimum Bending length of bar = 40 mm
Clearance between striker and
Rod dia=20mm

Cylinder Stroke length = bending length + clearance
= 50 mm + 20 mm = 70 mm
Select standard length of 120 mm.

Roller calculations for rod feeding:

Diameter of roller = 6.37cm = 63.7 mm

Circumference of roller = π D = π * 63.7 = 200.12 mm

AS the speed of DC motor is 60 rpm, in 1 rotation roller can push the rod by 200.12 mm in the time duration of 1000 milli second. The time required for various stroke length is given in table 2.

Table 2- Time for required stroke length

Sr.No.	Stroke (mm)	Time required (millisecond)
1	50	250
2	180	900
3	250	1250

5. DESCRIPTION OF COMPONENTS OF STIRRUP MAKING MACHINE

5.1 PNEUMATIC CYLINDER

Pneumatic cylinders (sometimes known as air cylinders) are mechanical devices which use the power of compressed gas to produce a force in a reciprocating linear motion. Like hydraulic cylinders, something forces a piston to move in the desired direction. The piston is a disc or cylinder, and the piston rod transfers the force it develops to the bar which has to bend.

5.2 SOLENOID VALVE

A solenoid valve is an electromechanically operated valve. The valve is controlled by an electric current through a solenoid. In the case of a two-port valve the flow is switched on or off; in the case of a three-port valve, the outflow is switched between the two outlet ports.

5.3 AIR COMPRESSOR

An air compressor is a device that converts power (using an electric motor, diesel or gasoline engine, etc.) into potential energy stored in pressurized air (i.e., compressed air). By one of several methods, an air compressor forces more and more air into a storage tank, increasing the pressure.

5.4 AIR PIPE

Air pipe is a tubular section or hollow cylinder, usually but not necessarily of circular cross-section, used mainly to convey substances which can flow liquids and gases (fluids), slurries, powders, masses of small solids.

5.5 PRESSURE GAUGE

Pressure regulators, commonly called pressure-reducing valves, maintain constant output pressure in compressed-air systems regardless of variations in input pressure or output flow. Regulators are a special class of valve containing integral loading, sensing, actuating, and control components. Available in many configurations, they can be broadly classified as general purpose, special purpose, or precision.

5.6 ARDUINO BOARD

Arduino is a prototype platform (open-source) based on an easy-to-use hardware and software. It consists of a circuit board, which can be programmed (referred to as a microcontroller) and ready-made software called Arduino IDE (Integrated Development Environment), which is used to write and upload the computer code to the physical board.

5.7 DC MOTOR

There are some types of application of electrical motor where rotation of the motor is required for just a certain angle not continuously for long period of time. For these applications, some special types of motor are required with some special arrangement which makes the motor to rotate a certain angle for a given electrical input (signal). For this purpose, DC motor comes into the picture. But instead of using a DC motor, a DC motor is preferred as it is cheap in cost and it can be easily controlled with moderate accuracy. This is normally a simple DC motor with reduced speed and higher torque.

6. WORKING

The rod is bent with the help of pneumatic force. The rod is fed automatically with the help of motor. The aim of this is to bend 8 mm diameter of the bar. It is possible to prepare the stirrup of required dimension with this machine.

This machine is designed to make stirrups from the 6mm and 8 mm size of mild steel rod. The rod is cut into pieces as per the dimensions of stirrups, the operator has to place the rod manually on the fixture guide touching the roller assembly and start the machine by ensuring that the compressor has necessary pressure (above 5 bar). As the machine starts, the electronic circuit comprised of Arduino uno r3 board takes the charge and it controls all other component mainly solenoid valve and DC motor. The electronic circuit works in a cyclic manner, and the cycle starts from the start of DC motor. The DC motor is started for required duration so that rod can be passed between two rollers up to the required length of the first bend measured from the fixed bending support. As DC motor stops, the pneumatic cylinder is activated so that it makes the first bend of 90°.The DC motor is again started for required duration so that rod is advanced for the second bend and as DC motor stops, pneumatic cylinder is activated resulting in the second bend of 90°. Similarly, all four bends are made and stirrups are formed. This machine is fully automatic and only rod inserting and removing operation has to be carried manually.

The photograph of stirrup making machine is shown in figure 2.

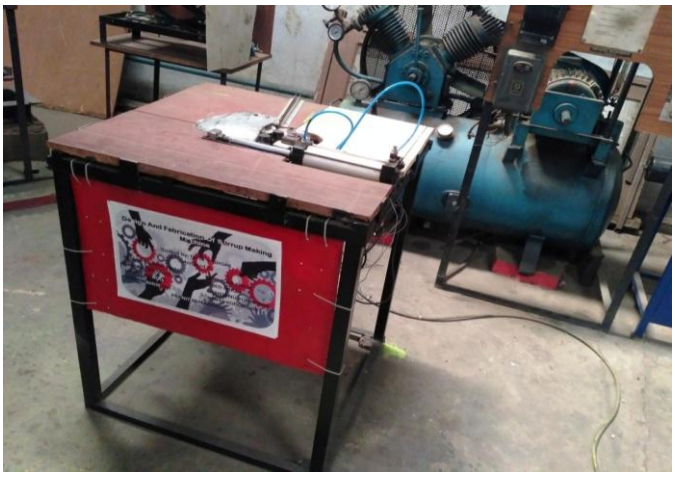

Fig. 2 – Photograph of Stirrup Making Machine

7. TESTING OF MACHINE AND CONCLUSION

7.1 TESTING OF MACHINE

The machine is tested at different pressures and during the testing it is found that machine works smoothly between certain pressure ranges. For this machine, it is essential to check that the stirrups need 90° bend and the exact angle between the piston displacement and rod feed is calculated to make exact 90° bend and given in Table-3.

The angle between the line of piston displacement and rod feed has to be more than 90° that is 125° as to compensate for the spring-back effect of the rod.

Table 3- Theoretical and actual value of parameters

Sr. no.	Parameter	Theoretically Expected Value	Actual Value Observed
1	Pressure at which rod start to bend	5 Bar	6.5 Bar
2	Force required to bend the rod	1508N	1767N
3	Angle between line of piston displacement and rod feed to make 90° bend.	90°	125°

8. CONCLUSION

There are two purposes of this project, one is to introduce automation in production and the second is to reduce human efforts. It is found that this machine can produce one stirrup in 18-20 second which is nearly at the same speed that of the skilled worker when he is most productive. Due to the automation in stirrups making, this machine has greatly reduced human efforts. As due to some constraints machine has to run between a pressure ranges and hence 7 stirrups can be made with available air compressor fully filled up to the maximum pressure limit. Because of this machine, it has become possible to reduce the human effort to a great extent.

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