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Design and Development of Pneumatic Stirrup Bending Machine

Automatic Stirrup Bending

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Abstract — *Major work involved in making Stirrups is done by a human. Stirrups are prepared manually in small construction sites which require effort and also time for production of a few stirrups is more. This leads in slow overall progress of work or requires more labour to save time. Stirrups are square or trapezoidal shape which is used in construction of columns and beams. The main objective of the Project "Design and Development of Pneumatic Stirrup Bending Machine (PSBM)" is to reduce such efforts and also at the same time at a faster rate with a higher Accuracy. The use of Pneumatic system makes it more cost effective for smaller constructors*.

Keywords-*Stirrup, Pneumatic Bending Machine, Automation, Scotch-Yoke Mechanism, PSBM, Mild steel Rod, Pneumatic cylinder.*

I. INTRODUCTION

Construction site requires a large number of labour and effort required. As population is increasing the need for construction. Use of machines is making life much easier and also increased in production rate. Stirrups are used in construction of a column or a beam. Stirrups are tied to steel rod with wire. Sizes of stirrups vary as per the application. Three Stirrups are prepared at a time, which makes the machine more productive. The use of Scotch yoke Mechanism is used to convert the reciprocating motion of pneumatic cylinder into rotary motion. Main purpose of use of pneumatic System is to save cost of overall machine. Main purpose of automation is fast and continuous production without much attention on machine. Need of automation was felt and so the machine is made automatic

II. MATERAL SELECTION

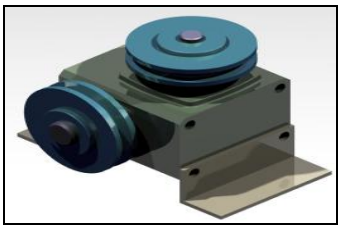
Whether it is required for construction or reinforcement mild steel is one of the best materials available. Mild steel can be cut, twist or bend in required shape, also it is cost, effective versatile, provides rigidity and so extensively used for construction purpose. Most of material used is mild steel.

III. COMPONENTS

3.1 Feed Motor:

Feed motor is used to feed the rods to the position where actual bending is done. A Washing Machine motor with 1200 rpm and AC supply is used. To stop the motor in desired position an Arduino controller with a relay circuit is used to actuate the motor.

3.2 Worm Gear box



A gear box is device which provides various speeds and torque ranges. In a Worm gear box, there is a worm and a gear, in which the driver is gear and driven is worm. Such type of gear box receives high speed and provides high torque.

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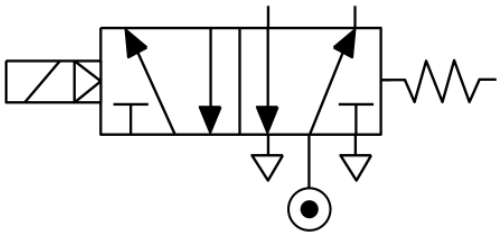
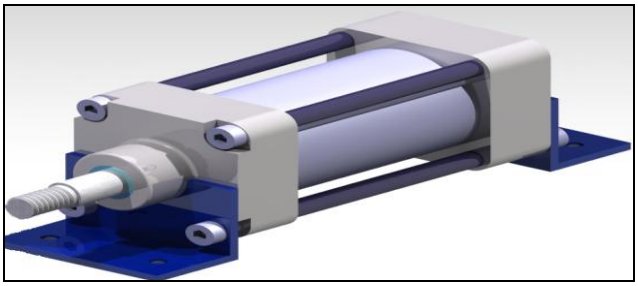
3.3 Direction Control Valve



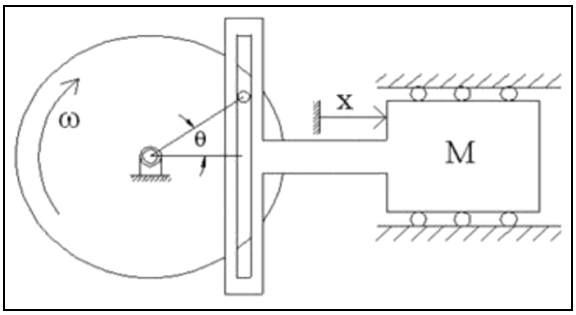
DCV is a device that control operation of Pneumatic Cylinder. DCV is operated by a single solenoid, which is electrically actuated by coil carrying current. Used mostly in automatic operation by an Arduino. DCV used in PSBM is 5/2 single solenoid.

3.4 Pneumatic Cylinder



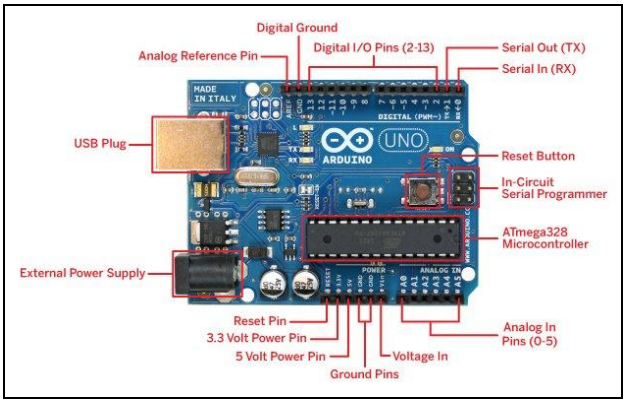
In PSBM, a double acting Pneumatic cylinder is used for drive the Scotch-Yoke Mechanism. A double acting cylinder acts in two directions, forward and backwards. The movement of the pneumatic cylinder is controlled by DCV.

3.5 Scotch-Yoke Mechanism



Scotch-Yoke Mechanism converts reciprocating motion into rotary motion or vice versa. In PSBM, the reciprocating motion of pneumatic cylinder is converted into rotary motion and transmits the force for bending rod to for stirrups.

3.6 Arduino Uno R3



Arduino Uno is a microcontroller board based on ATmega 328[1]. It has 14 digital input/output pins, 6 analog inputs, a 16 MHz crystal oscillator [1]. Program is uploaded by USB connection. Power supply is provided by an AC-DC adapter 12V and 1Amp. It control and receives signals from various parts such as Pneumatic cylinder, limit switches, DCV, feed motor.

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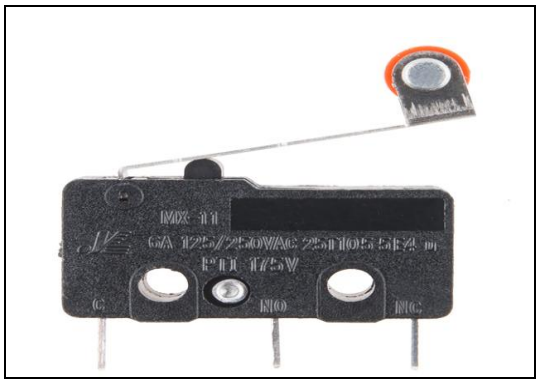
3.7 Limit Switches



Limit switch is device which provides input to the Arduino. In PSBM, when the rod reaches to desired position, limit are so placed that it operates and sends signal to Arduino circuit. Arduino then stops the feed motor, which stops the advancement of rod and also at the same time pneumatic cylinder is operated. Limit switches used in PSBM are of rolling type, in which rod rolls over the roller of limit switch.

IV. DESIGN

4.1 Design of Pneumatic Cylinder [1]

Pneumatic Cylinder in employed to provide the force required for bending the rod to form stirrups. As bending of three rods is to be done, the force required is more. Also bending of different diameter is required as per the application.

Bending Stress, $\sigma_b = \frac{My}{I}$

Bending Moment, M= P×L

$Y = \frac{d}{2}$ =6/2 =3

Moment of Inertia, $I = \frac{\pi d^4}{64}$ =63.63 mm^4

$\sigma_b = \frac{\sigma_{yield}}{FOS}$ =276.66 MPa (FOS=1.5)

$$\sigma_b = \frac{P \times l \times \frac{d}{2}}{\frac{\pi d^4}{64}}$$

Force required for 6 mm diameter rod:-

P=651.79 N

Force required for 8mm diameter rod:-

P=1545.16 N ≈1550N

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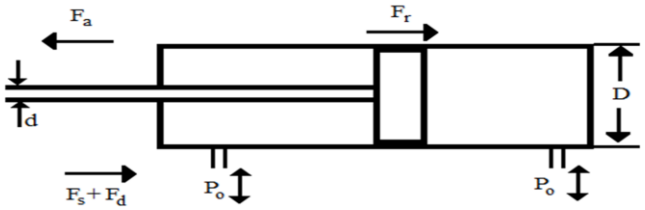

Design of piston cylinder of 3 stirrups:-

1) Maximum force = 1550×3 =4650 N
2) Friction force = 5% of 4650 = 232.5 N
3) Desired force of rotating disc(F_S) =
   Minimum thickness of disc =5mm
   Weight of disc =5 Kg =11.023 Pound … (Assumed)
   F= A× weight of disc in pound … (For bend)
   Therefore, F= 1×11.023 =11.023N (A= constant from table =1)

   Desired force with respect to speed (F_S) =F×s (S for speed 4-16 inch/sec =1.5)
   Therefore, F_S = 16.5345
   But for 3 stirrups,
   F_S =49.60 N

4) Total force = 4650 + 232.5 + 4960 = 4932.1 N i.e. F≈5000 N
   We know,
   F=P×A
   5000 = 0.7854 ×D^2 ×0.5 D^2 = 12732.36
   i.e. D = 112.83 mm

   D = 112.83 mm = 4.442 inch

Diameter of piston rod (d) = 0.3 to 0.8 D
d ≈ 0.5D
Therefore, d= 56.415 mm = 2.21 inch

Stroke = r×Θ
Where, r = distance between Centre of disc and Centre of yoke roller (in mm) =86 mm
ɵ=angle of bend + spring back angle
=90º + 10º
=100º = 1.7453 rad

Stroke = 150 mm =5.9055 inch

4.2 Design of Bearing:-

In this project we have used Single groove ball bearing because it gives some advantages to reduce friction. They are excellent for high speeds also have good radial load capacity. They have low torque capacity at startup and running speeds also they can operate with low noise and requires little maintenance.

The equivalent dynamic load and bearing life is given by, [5]

$$L_{10}=(C/P)^{p}$$

Where,
$L10$= Rated bearing life in million revolution
C= Dynamic load capacity in N
p= 3 (for ball bearing)
p= 10/3 (for roller bearing)
Rearranging above equation,

$$C=P\,(L10^{1/p})$$

Assuming L_{10}= 2 million revolutions
C= 6299.60 N

From SKF Bearing Catalog
Designation 6003

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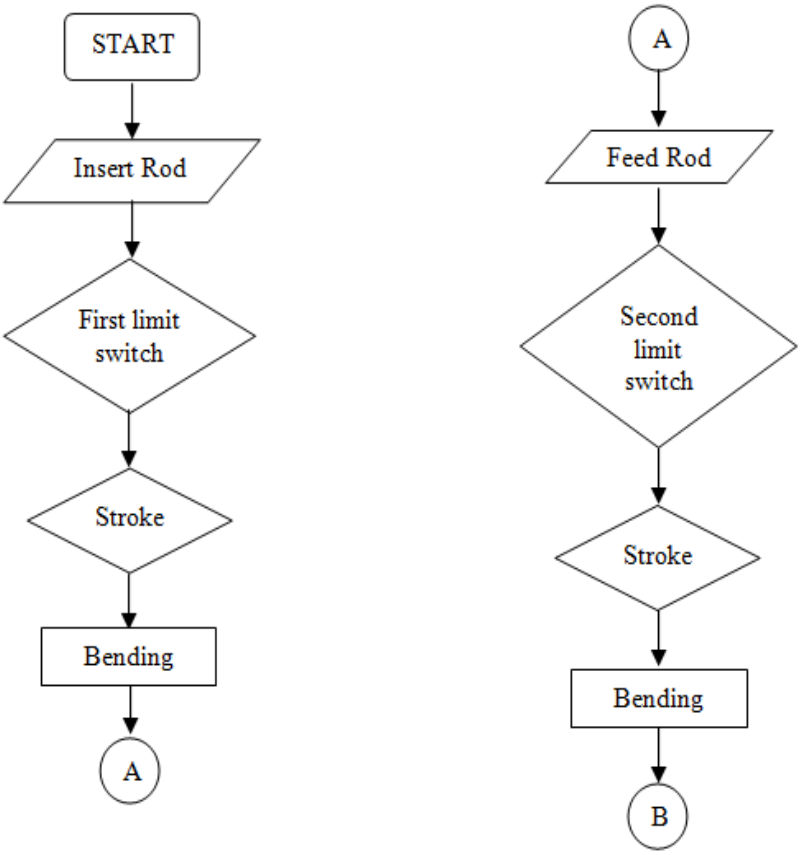
C=6370 N
d= 17 mm (I.D. of bearing)
D= 35 mm (O.D. of bearing)
B= 10 mm (Width of bearing)

IV. Operating Procedure

Operating procedure are the step carried out in PSBM. It algorithmic flow chart required in process of programming the Arduino.



1) When the reset button on Arduino is pressed, Arduino then with the help of a relay circuit starts the motor

2) Motor then feeds the rod, at a constant speed till the limit switch 1 is operated, limit switch when pressed by the passing rod over it, and send a signal to Arduino.

3) Arduino then stops the motor.

4) At the same time it actuates the DCV, which operates the pneumatic cylinder and their by operating scotch yoke mechanism. The force of piston is used to bend the rod.

5) Piston comes to its original position and again the rod feed by feed motor.

6) When the rod reaches the second limit switch again it send signal to the controller.

7) Similarly, for third limit switch again it undergoes same procedure.

8) The flow chart shows working, after (B) similar sequence is repeated till stirrup is formed.

V. Design of PSBM

5.1 Design of Pneumatic Stirrup Bending Machine:

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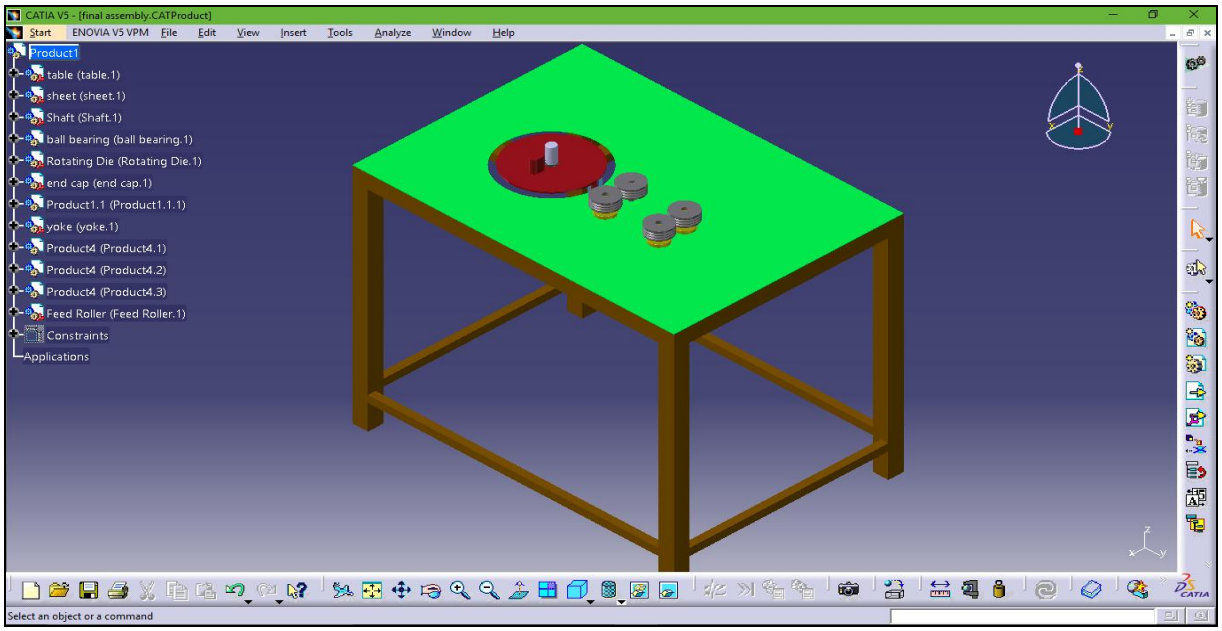
Design of PSBM is made in Catia V5 R20 Software. It is the assembly of all components used.



5.2 Actual Setup of PSBM:

Setup of PSBM consist of PSBM and a compressor which supply the compressed air to the DCV and then to Pneumatic cylinder.

CONCLUSION

Pneumatic stirrup bending machine is easy to use due to automation. It also operates manually and hence it provides ease and with less human effort. The production rate is also increased due to increase in the number of stirrups. At a single time or pass, PSBM can make three stirrups. Also a simple design makes the machine less complex and easy to maintain. Compact size of machine is very useful in carrying the machine at various construction sites. PSBM is

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mainly useful for small constructors as it is less costly as compared to other machines available. In this paper, we presented a new mechanism which is very useful in stirrup formation process.

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