Review Paper on Stirrup Making Machine

Sahil J. Mahendra[1], Omkar S. Chilmulwar[2], Shantanu S. Kuntawar[3], Ubed S. Mirza[4], Dr. Deepak V. Bhope[5]

[1,2,3,4]U.G. Student, Department of Mechanical engineering, RCERT Chandrapur, Maharashtra, India
[5]Professor, Department of Mechanical engineering, RCERT Chandrapur, Maharashtra, India

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Abstract - *As presently rod bending and stirrups making operations are one of the essential operations in the construction industry. In construction sites & workshops usage of machines, whether it is manual, semiautomatic or fully automatic has become common for bar bending and stirrups making. In this research paper, a review of available methods & machines used for bending and stirrups making is presented.*

***Key Words*: Stirrup, Pneumatic Bending Machine, Automation, Stirrup making**

1. INTRODUCTION

The demand of construction industry is increasing for the construction of bridges, buildings and human living places. Stirrups and bars play an essential role in the construction industry in the formation of reinforcement structure also called as shear reinforcement. Reinforcement safeguards any structure against failure caused by diagonal tension. Bar bending operations are carried in different ways i.e. using hydraulic, pneumatic, electric motor and manually applied force. Each of this type has different processes for bending the bars. Here bars of 6mm, 8mm, and 10mm diameter are used to make stirrups or to make bends. The machines were designed in order to reduce human efforts with the least cost. Another attempt is made to increase productivity by reducing human labor.

2. LITERATURE REVIEW

2.1 DESIGN AND FABRICATION OF MULTIROD BENDING MACHINE

In this paper, the need for reducing the lead time of stirrup making operations is described in order to uplift the rate of production. By considering this as the need, Anbumeenakshi et al. [1] designed a mechanized hydraulic bending machine which is capable to produce more than one stirrup at a time. The machine utilizes hydraulic power which is safe as well as easy to control. The machine consists of steel frame and hydraulic reservoir at the bottom. The bending mechanism in the top section of the frame includes a base plate which is fixed and provides a base for index plate. Index plate having a curved profile with four cuts guides the index cylinder for making the die ready for next bend. The guide plate is mounted above index plate which performs the function of providing the right profile to the stirrups. By varying the size and shape of guide plate it is possible to produce different types of stirrups. Two hydraulic cylinders are used; one is termed as Bending cylinder and another one as Index cylinder as per their functions. Bending cylinder is completely fixed to the frame, whereas Index cylinder is connected such as way that, it can oscillate on one of the ends. A pivot joint is used, which allows the cylinder to have some angular movement up to few degrees. A hydraulic power pack is placed just above the hydraulic reservoir which contains a motor, safety valve, control valve, strainer etc.

Fig -2.1: Multirod Bending Machine [1]

As the bending rod is feed around the guide plate and it is clamped with the help of locking key to retain its motion. After a dry run of the hydraulic system, the systems desired pressure operates the bending cylinder. As bending cylinder contain grooved roller on its plunger, it presses the rod between the guide plate and a successive bend is formed. Now as the bending plunger comes back to its initial position, Index plunger is operated as it has a pin which is temporarily attached to indexing plate profile. As the plate turn 90° the pin losses its contact and come back to its initial position. Similarly next bend is performed. After completing four such bends, a complete stirrup is formed. The advantages of this system are, it can handle multiple rods at a time, it is easy to operate and also portable. It is concluded that for 20 stirrups machine requires 15 minutes.

2.2 DESIGN AND FABRICATION OF PNEUMATIC BAR BENDING MACHINE

Thokale et al. [2] realized that since long a time construction works desperately need a large amount of labor work for mixing aggregate-sand-water-cement, digging works for foundations, pouring concrete in beams and columns, cutting and forming stirrup of required length etc. As population increased rapidly and demand for houses, as well as other infrastructure, are too increasing. On the other hand, resources as well as technologies are available to overcome this demand. By using the conventional method some problem comes into picture, due to which it is not possible to increase the production time and reduce the physical fatigue of work. Hence, Adopting automation in construction system is needed. The paper is based on pneumatics principles and by using automation productivity has been increased.

In this, the pneumatic force is responsible for the rod bending. The sole purpose of the machine is to make a square stirrup. For feeding the rod two rollers one with the motor powered is used. As the rod is fed automatically, a limit sensor is used to cut off the power supply of motor when a required length of the rod is fed which is controlled by a microcontroller. The arrangement is such that it contains two pneumatic cylinders, first one is used to make a bend and the second one is for holdings purpose. In about three to four strokes, a complete stirrup is formed.

While testing the machine it is observed that loading and unloading operation requires almost 4 to 5 seconds and time requires for forward stroke is about 6 to 7 seconds. The total time required to complete one stirrup is about 25 seconds. Considering ergonomics of the machine, it is very easy to operate, as the total system is automated. 140 stirrups can be made in one hour. Likewise in 8 hours, production of 1200 stirrups is possible very effectively. As it has simple design it is cheap and can be used by any operator. By using various fixtures, different shapes and sizes of the stirrups can be obtained.

2.3 DESIGN AND DEVELOPMENT OF PNEUMATIC STIRRUP BENDING MACHINE

Gujar et al. [3] find out that basically, making of stirrups is mostly done by the human. Construction site requires a large number of worker and effort. Stirrups are used in the construction of column and beam. With the help of the pneumatic system, the aim is to save the time and cost. Here, the reciprocating motion of pneumatic cylinder is converted into rotary motion with use of Scotch yoke Mechanism. Most of the material used is mild steel. The components used are feed motor to feed the rod, a worm gearbox for low speed and high torque, Direction Control Valve device which controls operation of Pneumatic Cylinder. Arduino is a microcontroller board to control various parts of the system. A limit switch is used which provides input to the Arduino. In this project ball bearing is used to reduce friction and compressor which supply the compressed air to the DCV and then to Pneumatic Cylinder.

When reset button on Arduino is pressed, Arduino with help of relay circuit starts the motor. The motor then feeds the rod, till the first limit switch is operated. The limit switch get pressed by the feeding rod over it and a signal is send to the Arduino which stops the motor quickly and DCV gets actuated, which operates pneumatic cylinder and hence the Scotch yoke mechanism. The force of piston is used to bend the rod. Again the rod is feed until it reaches the second limit switch, and the signal is send to the controller. Similarly, third limit switch again undergoes same procedure till stirrup is formed.

Use of machines is making the life of labor much easier. The production rate is also increased due to increase in the number of stirrups. At a single pass, PSBM can make three stirrups. PSBM can be mainly used for small constructors.

2.4 DESIGN OF AUTOMATIC PNEUMATIC SHEET METAL AND PAPER CUTTING MACHINE

In the present era of technology, automation is need of time. For this cause, Raj et al. [4] come up with an idea of developing an automatic sheet metal cutting to replace the manual operation and increase productivity. Less lead time and higher accuracy is the need for any machine to develop it into an optimum way. As air is freely available and safe to use, a pneumatic based sheet metal cutting is introduced by the Author. Presently there are different mechanisms used for sheet metal cutting machines like pneumatic, hydraulic, mechanical such as cam and follower type, rack and pinion type, spring operated etc.

In this paper, the setup contains the types of equipment such as a pneumatic cylinder which uses pressure energy of air and converts it into force by means of piston and plunger. A double acting type is used in the setup for easy control of the cutter motion to both the directions. A solenoid valve is an electromechanically operated valve which changes the direction of flow of air as per the requirement. They are mostly used in fluid machinery to control the flow of fluid and it operates on 24V d.c. For cutting sheet metal a high-speed cutting blade of 8 inch long is used. Another equipment is a single stage air compressor which provides compressed air to the cylinder. For controlling the motion of the cutting arm i.e. motion of cylinder's plunger a 5/2 solenoid valve is used whose power requirement is fulfilled by Lead-Acid Battery of 12V 7 AH. Two of such batteries are used to provide 24V d.c voltage. For cutting action, timer control valve is used to vary the speed as per the thickness of the sheet metal and as well as the quality of the cut needed.

Fig -2.4: Paper Cutting Machine [4]

The construction and working of the machine is simple, a pneumatic cylinder and cutter with some metal plates forms the cutting mechanism. Power source i.e. battery, as well as controlling device such as solenoid valve, is placed separately. A toggle switch is used to operate the upward or downward movement of the cutter arm to provide a cut. Finally, it has been seen that a very quick response is achieved. Cost of the unit, as well as maintenance cost, is less. It is easy to repair. One more major advantage is that it is fire hazard proof. It can be used in various fields.

2.5 DESIGN AND DEVELOPMENT OF HYDRAULIC PIPE BENDING MACHINE

In this paper, it has been described that how rod or pipe is bent accurately with simple pipe bending machine. As pipe or rod bending operations are one of the essential Industrial operations which are required in small scale as well as large scale industries. Presently there are many methods by which one can perform the bend such as Press bending, Rotary Draw bending, Mandrel bending, Heat induction bending etc. But all this contain high capital investment as well as complicated machines except press bending. Vyas et al. [5] bring up a new approach in press bending operation; as it is a need of small-scale industries, where low cost and precise output is required.

Basically, the main components are 1)Front and back Plate 2)Base Plate with L angles 3)Hydraulic Jack 4)Connector 5)Bending die 6)Bobbin pin as shown in figure 2.5. The construction of the system is simple as it is only fastened by bolt and nut. The base plate contains L angles which have holes by which front and backplate is mounted on it. In the same way, Hydraulic jack is mounted at the centre point. As plunger of hydraulic ram is small in size hence a connector is needed in order to increase its height as well as it allows varying the bending die according to the different size of pipe as well as the angle of bend needed. As bending requires force from three points, which is given by bending die and the other two are provided by Bobbin pins. They are screwed between front and back plates. The shape and material of the pins are so designed and selected that they should provide minimum deformation. For the different size of pipe and bending angles, bobbin pins are placed accordingly in the respective holes. This allows bending pipe from ½" to 3" diameter, as well as it is possible to bend maximum up to 50° without a wrinkles. Hence the high quality of bend is archived with use of simple but efficient machine. One of the advantages of using hydraulic jack than screw jack is it's having no maintenance and high precision control. With the use of this approach a wide range of bending w.r.t size of pipe and angle of bend is possible which is much convenient compared to other Press bending machines.

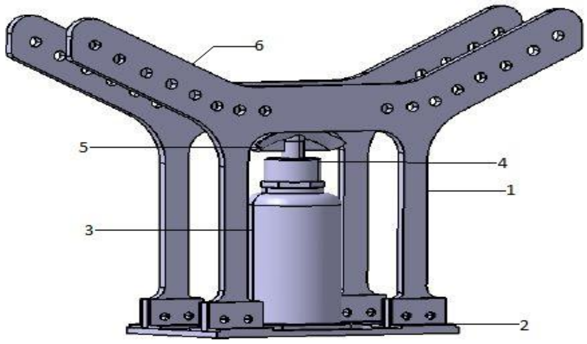

Fig -2.5: Hydraulic Pipe Bending Machine [5]

2.6 DESIGN, DEVELOPMENT AND FABRICATION OF STIRRUP MAKING MACHINE ENERGIZED BY HUMAN POWERED FLYWHEEL MOTOR

Waghmare et al. [6] demonstrated a new concept regarding stirrup making machine as presently the stirrup are made by manual stirrup making methods. But, this process causes drawbacks like lack of accuracy, low productivity. The workers not only subject their hard work but also suffer an injury to his body. In the present age electricity, petrol and fossil fuels, etc. are used for production but environmental pollution caused by fossil fuels again brought the human power into the mainstream of renewable power resources. A system similar to a bicycle having flywheel is conceptualized as Human Powered Flywheel Motor (HPFM) in which a human being spins a flywheel at about 600 RPM to store energy. The stored energy in the flywheel will be made available through a suitable clutch and torque-amplification if needed. It is not necessary to pedal the flywheel while supplying energy to the processing unit.

The operator accelerates the flywheel to the desired speed in about one minute through a chain and a pair of gears. The chain drive is used for first stage transmission. A freewheel is used between pedals and the flywheel to prevent the backflow of energy from the flywheel to pedals. When flywheel attains desired speed, pedaling is stopped and it is connected to the processing unit through torque amplification gears by engaging two jaw spiral clutch. The energy stored in the flywheel is supplied at the required rate to stirrup making unit. The small size of 6mm and 8mm rod can be bent, and this size is important for bending the stirrup with column rods. Then second, the third and fourth bend is made to make the stirrup, according to size. Finally, the fifth bend is made which is tied with first anchor and stirrup is prepared.

It is seen that, HPFM require less effort and reduced internal injury of the workers. With the use of human energy of workers, the stirrup can be made at low cost. Currently available machines are electrically powered and hydraulic type machine which cannot work where electricity is unavailable. This machine is useful in rural areas.

2.7 DESIGN AND FABRICATION OF HYDRAULIC STIRRUPS MAKING MACHINE

Productivity is an essential concern of an engineer. Regarding this Shinde et al. [7] designed a concept of stirrups making machine using hydraulic power. Compared to pneumatics, hydraulic uses incompressible fluid which can bear high-pressure and which results out in high force. By this multiple rods can be bent in a single go. The experimental setup for this design contains elements such as hydraulic actuator which is a dual acting cylinder used to compress fluid (generally oil) for the forward moment of its plunger. A vertical rod is attached at the end of the plunger which gets in contact with the bending rod. A square shaped plate having the stud at the four end acts as a fixture, around which the final stirrup is made. For the different size of stirrups, different fixtures can be used. This fixture is connected to a shaft at the bottom; on the other hand, a pinion is mounted on the same shaft which is driven by a rack.

The working of the machine takes place by placing the rod in the fixture. As the plunger extends in the forward direction the rack follows the same, but the shaft does not rotate as a free-wheel is introduced in pinion arrangement. On the return stroke, the rack rotates the pinion in the anticlockwise direction, which set the rod and fixture ready for next bending operation. In this way, in four steps a cycle is completed and a finished stirrup is obtained. The proper observation shows that, loading and unloading take about 5 seconds to 6 seconds and each bend requires 10-11 seconds. Approximately every stirrup consume 20 seconds, hence 180 stirrups per hour and 1500 stirrups can be made in one day having 8 working hours. In this way, an effective alternative to a manual bending machine is developed.

2.8 Pneumatic TMT Bending Machine

Today we live in the world of technology and availability of technology gives motivation to automate each and every manual functions or operation. It has plenty advantages such as reduction of human intervention which not only improve quality as well as reduce operational time. As based on this approach Pal et al. [8] developed a bending machine which uses pneumatic power to perform bend. It comprises with simple elements like pneumatic cylinder which is a two way operating. Solenoid valve is hand toggle operated and it is 5/2 DCV. Pressure regulators maintain constant pressure in the system which has to be set. The guide plate through which the bending rod is feed in it also guides the incoming rod. Bending plate it is similar to guide plate physically but the major difference is that, it has one degree of freedom and its motion is constrained by the motion of plunger of pneumatic cylinder. At lasts a steel frame which allows all elements to mount over it. Air compressor is the heart of this setup which is a two-stage reciprocating type used for high discharge and moderate pressure.

The working of setup is quite simple as less number of elements is used. Forward and backward movements of pneumatic plunger purely depend upon the mass flow rate inside the cylinder. The pressure regulator plays a vital role to maintain the amount of bend of the bending plate. The rod is placed through guide plate as well as through bending plate. The next step is to operate the solenoid valve which actuates the cylinder, as due to linkage it provides the oscillating movement to the bending plate which further bends the rod passing through it. For bending sheet metals, different size of plates is needed according to the width of a job. For different angles, different setups need to be done. In this way, rod bending and sheet bending operation are performed. This setups is simple to manufacture as simple elements are used and it is non-hazardous; as air is used compared to oil. It is durable as well as reliable, portable and light. The application of this machine is for angle bending, metal bending, at construction site or in production.

2.9 DESIGN AND DEVELOPMENT OF STIRRUP MAKING MACHINE

In this paper Amonkar et al. [9] come up with a solution to fulfill construction material demand caused by globalization i.e supply of stirrups. For this, author introduced a new design of stirrup making machine which works on an electric power supply and can meet all the possible demand of stirrups in optimum time. Many past designs are available for this. A set of a worm gear and the worm wheel is used which is best for higher speed reduction and high torque transmission.

The setup consists of following 1) Stationary impactor 2) Rotary impactor 3) Rotary disc 4) Gearbox 5) Worm and the worm wheel 6) Base table 7) Motor foundation 8) A.C. motor as shown in figure 2.9.

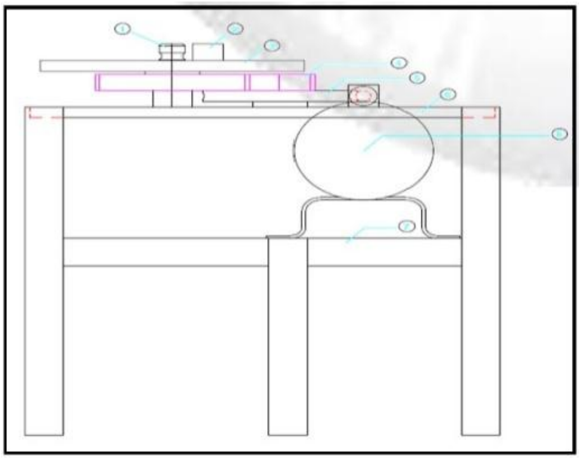

Fig -2.9: Block Diagram of Stirrup making machine [9]

An electric single phase AC motor of 0.5 HP is used for power transmission. As the speed of an AC motor is high up to 1440rpm, hence a set of a worm gear and the worm wheel is used for speed reduction as well as to increase torque. This worm gear which is connected to the motor shaft drives worm wheel at a speed of 16rpm. Above worm wheel a gearbox is introduced which has a single pair of spur gear having a gear ratio of 6:1; where pinion shares the same shaft with worm wheel and the spur is connected to the rotary disc. The rotary disc has a solid wedge pin welded to some eccentricity away from the centre, arrangements are so done that rotary plate rotates with a speed of 8 rpm. At the centre of the rotary disc, one more solid pin is present but it does not provide any motion. The motor is possible to rotate in both directions, by which bending and unloading operation is done.

The machine shows that it is capable of bending the rod up to 6 mm. Time required to complete one stirrup is 55 Sec, which is 10-15 Sec less as compared to past machines. It is easy to carry it from one place to another as it weighs only 18 kg and it costs up to Rs. 18,000.

2.10 REINFORCED BAR BENDING MACHINE

In this paper, Thillairaja et al. [10] developed a Reinforced Bar Bending Machine, which works on electric power and uses a new concept of semi tooth gear instead of cam and follower to provide bending action. As a new approach is designed and developed and it eliminates some limitations like wear and tear of machine parts, heavy vibration etc. The setup contains an induction motor, which is single phase slow speed motor of 180 W and 1400 rpm. As the speed of the bender pin needs to be slow, hence V belt and pulley are used for power transmission; by which it brings down it to 330 rpm followed by a gearbox. It has a set of gear train containing gears on three intermediate shafts. The velocity is so selected that the final gear rotates at a speed of 28 rpm. A bending pin is attached to the final gear, which is responsible for the bend. The gear which drives the final gear is a semi tooth gear, which has teeth up to 90° rotation of the final gear. After 90° rotation, it losses contact with the other gear and transmission of rotary motion is ceased. A spring is connected to the final gear which assists the gear (bending pin) to regain its initial position after a successive bend. To eliminate vibrations a strong iron frame it is made of six legs and used to hold the entire machine component. A wooden plate is used as a working table which allows holding pins and bending pin to be visible and all other components are invisible by it. It also serves the purpose of damping vibrations. Its working is simple as it requires cutting out the electric power supply after each bend, and the feeding action is manual. It provides convenient control as an operator only need to operate the switch for the bend or for ideal time i.e. the feeding time where a machine is supposed to be in an unoperated mode.

Fig -2.10: Mechanism view [10]

As a result of this, a noiseless and portable machine is produced which is capable of bending small rods up to 6 mm. It is Economical in use, easy to operate as well as less maintenance is needed. It has longer component life as cam and follower arrangement is eliminated.

2.11 A CASE STUDY OF BENDING OF TMT STEEL BARS

Pathak et al. [11] performed a case study on TMT steel bars as TMT bars are preferred as a construction material for numerous reasons. Their unique properties have made them ideal for various types of construction work. The properties of TMT bars include super ductility, superior strength and weldability. TMT bars are widely used in the buildings construction and other concrete structures. One of the main advantages of using TMT bars for constructing houses is that the TMT bars do not need the additional process of cold twisting which makes the bars corrosion resistant. But because of increased strength and toughness of TMT bars it creates a problem during a manual bending operation. Hence machine bending operation is adopted. A systematic study reveals that there is an improvement in the quality of bending while preferring machine bending over subsequent manual bending. In this paper, the problem which is associated with manual bending operation and adaptation of machine bending are discussed.

Manual bending and machine bending operation are performed on bars. Three bars which are of 20 mm in diameter and 12 m long are used while performing bending operation. Manual bending is performed by moving then around a pivot point. The mechanical bending machine is designed as per required bend specification. The bars are bent using a rotating disc with a pivot point and anchor point. The disc is rotated with the help of wire rope and winch mechanism. Manual bending results in a 'V' shape non-uniform bend. While performing machine bending operation 'U' shaped uniform bend are obtained. The result of manual bending and machine bending of three bars are noted and their average is calculated. Following conclusion is made.

Acquiring machine bending saves about 77% of floor area. Cost is the most important factor in any work. Machine bending of TMT bars saves up to 28% cost over the manual bending operation. The average time required for the machine bending is drastically reduced as compared to that of manual bending. Machine bending reduces the time of bending by 33%. The reduced time increases the productivity. With the adoption of machine bending of TMT bars 66% of manpower is saved as in that of manual bending. With the adoption of machine bending over manual bending above advantages are achieved.

2.12 DESIGN OF EXPERIMENTATION FOR FORMULATION OF EXPERIMENTAL DATA BASED MODEL FOR STIRRUP MAKING OPERATION USING HPFM

In this paper human powered flywheel motor (HPFM) is used by Waghmare et al. [12] in the establishment of stirrups making operation which is done by using experimentation investigation and sequential classical experimentation technique. Stirrups making operation performed by human-powered flywheel motor are formulation of experimental data based model which is formed by using Design of Experimentation (DOE). In a research study DOE is the planning process to meet specific objectives. In order to achieve the research objectives efficiently and clearly with the right type of data and appropriate sample size, it is very important consideration to plan the experimentation properly. To evolve a human-powered stirrups making is quite complex. Many factors affect the performance of stirrups making operation. As in this chapter, the constant efforts are taken in order to present the acquired design of experimentation in detail and to generate design data in the form of evolving experimental data-based models for various dependent/response variables of stirrups making operation using human power by carrying out experimentation.

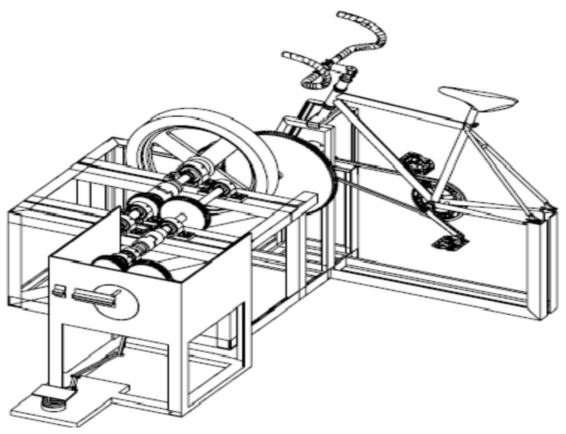

Fig -2.12: CAD Model of Experimental Set up [12]

Fig. 2.12 shows a model of stirrups making machine which is used for performing stirrups bending operation and stirrups making operation by HPFM. The mechanism includes an externally fitted bicycle. The operator drives the bicycle by pedaling the mechanism while the clutch is not engaged. The energy source of the machine is the human-powered operated flywheel motor. This energy source energizes the stirrups making unit through clutch and transmission. As flywheel gets accelerated and energized it stores some amount of energy within it. When the operator stops pedaling, a clutch is engaged. By engaging the clutch, stored energy of flywheel is transferred to the processing units input shaft by means of clutch. Pi (π) terms are formed for all dependent and independent variables which affect the phenomenon of human-powered stirrups making operation by using Buckingham's - π Theorem. In this work design of experimentation is used which have made it easier for proper planning of an experiment in order to achieve the objectives of research more clearly and efficiently with the right type of data and appropriate sample size. From the starting of formation of test points and envelopes to the end, it became possible to assure the complete range over which the entire experimentation is to be carried out.

2.13 PNEUMATIC SHEARING AND BENDING MACHINE

In sheet metal industry shearing and bending machine is of great significance. These machines are mostly used for straight cutting with broader applications. Despite of this hand sheet cutter, hand bender are used in some industries. Such machines require human efforts to operate and they are time consuming as well as its output is very less. Any machine must be simplest in operation and should be easier to maintain, hence Tambat et al. [13] have attempted to develop the Pneumatic Shearing and Bending Machine with improved efficiency of required output and increased production with quality output. Pneumatic System is used in this work as this is appropriate for the applications involving less force than hydraulic applications and they are cheaper than electric applications.

The system developed comprises of one machine which performs both shearing and bending operation just by changing the machine die according to the given application. In which there is a C-frame body on which Pneumatic System is installed with required attachment. Pneumatic Cylinder is vertically placed on C-frame body with front flange mounting. This model is capable to work in 100 psi air pressure, which can cut various sheet metals between 20 to 24 gauge. A V bending die is used for bending.

As the Pneumatic Shearing machine is less expensive compared to a hydraulic Shearing machine, hence by arranging a high-pressure compressor cutting thickness range can be increased. This machine is very useful for small sheet metal cutting industries as they do not use expensive hydraulic shearing machine.

2.14 OPTIMAL DESIGN OF MECHANISM FOR STIRRUP MAKING MACHINE – A COMPUTER APPROACH

Stirrups are square, rectangular or circular shaped reinforced element made out of 6 mm, 8mm or 10 mm bar in plain mild steel. For avoid structural failure reinforcement is required, this reinforcement is called as Shear reinforcement which is provided by the stirrups. They perform the following functions such as to hold the horizontal and vertical mild steel rods, to provide rigidity and reinforcement to columns and beams, to prevent buckling action of long columns and sagging of beam, to provide anchorage effect during natural calamities like earthquake, high-speed winds etc. Today, stirrups are made manually with the help of a wooden block with three pins located on it. The operator cuts the bar equal to the perimeter of a stirrup, then followed by chalk marking and finally applying manual force with the help of lever-like hand-tool. After having a bend operator lift and reposition bar for next bend, in this way after 4 bends a complete stirrup is made.

There are some Stirrups making machine which are designed and presented by past authors, which works on an electric motor, cylindrical cam and 'L' shaped follower. But they have some limitations like 1) After completion of a bend the follower should fall down, to ensure this a spring is introduced but due to frictional forces sometime it ceases the follower downward moment. 2) As time passes spring losses its stiffness that means it needs frequent replacement. 3) The follower moves in the topmost position over the cam profile, which is the spring motion which leads to cracks and reduces its life; hence heat treatment is needed which increases cost. 4) Sudden fall of follower results in heavy vibrations, which affect the quality of the stirrup.

A.V. Vanalkar et al. [14] worked in this direction to overcome all these limitations and developed a mechanism synthesis of stirrup making machine computer stimulation using a circular path of pin rotating in an anti-clockwise direction. In order to simplify the construction of the system, rotation of the pin is made anticlockwise and centre of rotation is offset by some distance 'e' from the guide axis. Due to anticlockwise rotation stirrup wire is positively released by bending pin. Compare to the past machines of having clockwise pin rotation it completes a bend(A-B) in first 60° and approximately 300° rotation time(B-C-D-A) is free for feeding rather than previously its only 80° is used to left. And as bending action (A-B) occur very near to the guide plates it makes possible to form a small bend up to 10cm, which can save the material. Refer text in figure 2.14; where 1) Stirrup rod 2) Circular path followed by pin 3) Guide plate.

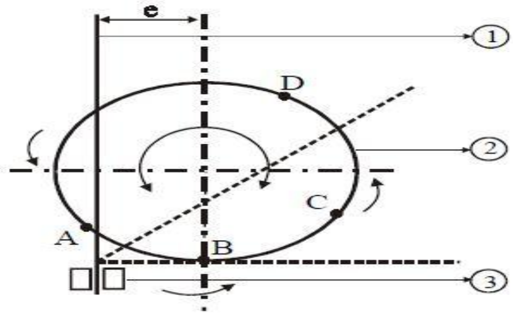

Fig -2.14: Simulation using circular path of pin rotating in clockwise direction [14]

A successful solution is achieved for manual stirrup making. The machine is capable of producing stirrup of various sizes (104 x 104 to 635 x 635). An extended length of 25mm bending is possible with this system. As the system is light in weight it is portable and can be operated by any operator. It is estimated that in a normal working shift of 7 hours, 800 to 850 stirrups are possible to produce effectively per day. And from a price point of view, its worth of Rs. 40,000/- which has a minimum payback period of 8 months.

2.15 PROCESS DRIVEN AUTOMATED REBAR BENDING

This paper presents a new concept for rebar bending which assists by electronic sensors, computer controlled motors and data communication with a computer. The complexity such as spring back of rebar and impedance control is difficult to predict. A new approach is introduced for processing the bar bending starting from designing stage to site delivery by using CAD-integrated concept. Initially, the same process is done in following stages such as design, engineering, detail drawing, fabrication, shipment, site storage, and placement. But here is a drawback as all the procedure takes place in the production plant up to shipment. This leads to delay the construction work by means of late deliveries, construction schedule changes etc. To eliminate this risk and time loss, Bernold [15] introduced the zero lead time concepts. Half of the processes up to shipment of raw bar are done in the production plant, and fabrication and placement are done according to the requirement. It saves cost as well as material. Only one additional step needs to be added i.e. Return of scrap bars. All this activity is a thread of one control system i.e. CAD-integrated planning system/CAM.

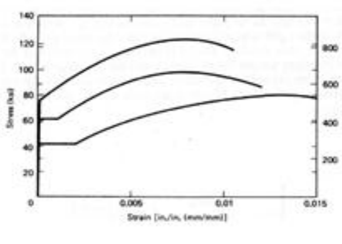

Fig -2.15.1:Typical Stress-Strain Diagrams for Various Steels[15]

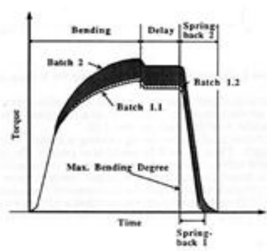

Fig -2.15.2: Bending Torque Diagrams[15]

Second thing over which author spread the light is an analysis of spring back effect, which is caused by the elastic property of steel which it experience while bending. Forgetting the desired angle, it is necessary to consider some additional value as spring back value in bending angle to overcome the position change of rod after completion of the bend. This spring back value is different for different diameters as well as the grade of steel. For counting this value use of stress-strain diagram is done as shown in figure 2.15.1. The mechanical behavior of bar depends on its characteristics such as elasticity, yield and ultimate strength. However steel is not uniform in a batch, hence three torque profiles are compared for identifying the characteristic patterns. By the experimental setup of simple bar bending operation, the final result is shown in figure 2.15.2. Hence principles of impedance control pattern recognition are utilized to fulfill the objectives i.e. optimum bends with least lead time.

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