

Design and Fabrication of Hydraulic Tube Bending Machine

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Abstract

The process of pipe bending finds its importance in many industries, instruments, fluids transportation etc. The aim of this research is to design and fabricate a hydraulic jack-based pipe bending machine which has ability to bend pipes used at construction sites, petroleum oil & gas supply sector and small-scale industries, while keeping in mind the requirements of a good pipe bending machine to provide high quality bends without defects but at the cost lesser than the existing pipe bending machines available in the marketplace. The fabricated pipe bending machine works on the principle of press bending method to perform the bending operation. The design of the proposed pipe bending machine is based on essential parameters of bending process such as radius and angle of the bend, diameter and thickness of the pipe. The single acting hydraulic jack of 20000 KG load capacity is used to apply the required pressing force to bend a circular pipe having the outer diameter ranging from ½ inch to 2 inches.

Keywords: hydraulic, pipe bending, tube bending, press bending.

Introduction

The key requirements of the bend and the material of the work piece undergoing the deformation determines the selection of bending processes and equipment to be used to fabricate a suitable pipe bending machine. There are various bending methods used each having different sets of advantages and disadvantages like bending of cold tubes using mechanical force or the bending performed for heated tubes. The most preferred methods are as follow:

- Press Bending
- Rotary Draw Bending

- Mandrel bending
- 3 Roll Bending
- Bending springs
- Heat induction bending
- Sand packing/hot-slab bending

Press Bending

There are many methods available to choose from to bend a pipe but the one which is the simplest and cheapest for bending cold pipe and tube is Press Bending Methods. The work piece (pipe) is placed in position over the bend die after which the die presses the pipe to form a bend. Also, to ensure the stability during bend operation work piece can be restrained using bobbins. The press bending process sometimes produces defects such as ovality, wrinkling and wall thinning and thickening considering the material properties and physical characteristics of used work piece. Hence, this process of pipe bending can be used where the key requirement is not a consistent cross section of the work piece.

Recent developments

V. SenthilRaja et al (2014) ^[1] designed and fabricated a mobile hydraulic pipe bending machine. They proposed that the hydraulic bender has higher productivity. Sometimes heat treatment is used during bending the pipe but the technique is unsafe because it causes many problems in the produced pipes namely wrinkles, curve formation, reduced thickness, hole forming, reduction in strength, makes it break easily. The hydraulic pipe bending machine based on press bending has superior characteristics as compared to one based on heat treatment methods. This type of bender is suitable for application in both industrial and domestic purposes.

E.O. Olafimihan (2015) ^[2] developed a bending machine based on hydraulic operation. He found the range of the levels upto which pipes were found to be oval to be in between 3% to 5%. The process of bending is economic when used for low & medium quantities due to less amount of tooling required. Portable bending machines make it convenient to perform multiple works on work pieces in the

constructional areas. The workforce involved in this field is not equipped with proper machine so as to provide uniformity in work piece instead they are using the tools which are harming as they are not able to provide the proper stress on the work piece.

Ankit Vyas et al (2016) ^[3] designed and fabricated a hydraulic pipe bending machine. They proposed in order to achieve high quality bends pipe can be heated, sand packed and also use of pipes of larger thickness can be important factors. More accurate and acceptable bends are obtained using the proposed proposed machines as compared to bending operation performed manually. Considering higher factor of safety and provision for automation makes the design highly safe.

Vikash Patial et al (2015) ^[4] designed and manufactured a pneumatic pipe bending machine. They proposed that the bend angle is dependent upon the displacement which the die horn travels. With increase in the angle of bending increase in spring back angle is also observed irrespective of what the material of pipe is. The same kind of change is observed for spring back angle in relation to brittleness of material.

S.A. KrishnaMohan (2014) ^[5] designed and fabricated a hydraulic pipe bending machine which is portable and compact. As proposed by him in such benders the pipe is placed between the rollers. Force is applied using hydraulic jack and the pipe is bent to the required vale of angle depending upon the die used. Such is economic, portable and has higher flexibility. Hence, it is a better alternative in comparison to bending machines which are manual.

Girish Gharat et al (2015) ^[6] designed and fabricated a pneumatic punching and bending machine. They developed automated pneumatic press by using a simple C-frame press due to its lesser space requirement & ease of operation. The machine finds its usefulness in washer production industry for producing washers having thickness less than 1mm.

Nilesh Nirwan et al (2013) ^[7] designed a portable rolling and bending machine with the help of CAD and analyzed it using FEA software. The technique used for bending operation is three roll push bending technique. They observed that the machine size is dependent upon the number of operations and types of feed. Also, as the hydraulic setup requires more space and causes the

weight of the machine to be increased so, only manual benders are suitable to slide over the work table.

Prashant P.Khandare et al (2016) ^[8] studied a portable 3 roller pipe bending machine using electric motor. They observed automatic benders reduce the human effort and also less skilled labor is required for operation of the machine. A pipe bending machine was developed using gears, motors, pulley and frame which can work in manual as well as in power operated mode.

Basil E Okafor et al (2014) ^[9] developed a motorized pipe bending machine using 2HP motor. They developed a bending machine which was electrical using a worm & wheel gear assembly and it could bend pipe up to 1 mm of thickness conveniently but found it difficult to operate for thickness of pipe above 1 mm. Problems noticed in pipes having lesser thickness were wrinkles and bulging of the pipe.

G.M. Ngala et al (2015) ^[10] designed and fabricated manually operated universal pipe bending machine. For reducing the human effort a long handle bar was used in their design.

H. A. Hussain et al (2014) ^[11] designed and developed a manual bicycle integrated pipe bending machine. Keeping in view the electricity cut-off in rural areas they proposed the bicycle integrated pipe bending mechanism as it will be readily available in most of the areas. Also, it is economically more viable.

GAP Analysis

A gap analysis is formulated from the above literature which is as follows:

Cost of the Bender: The industrial grade pipe benders which are commonly used in the industry are expensive and require huge investment initially. From the mini benders studied in the above literature, the minimum cost of fabrication can only be seen in hydraulic jack-based models as the other types of benders include additional components like air compressor in pneumatic bender and expensive motors in motorized benders.

Size of the Bender: The smallest benders are the manual ones. They can be fitted on workbench but to bend the pipes having larger thicknesses is difficult. Hydraulic pipe benders are fabricated in compact size as there is no requirement of additional accessories like in case benders types.

Main Components of Bending Machine

Frame: The outer frame of the bending machine consists two MS plates namely the front plate and the back plate, both the plates are fixed to the base plates and are connected at top using the bobbins. Both the plates have numbers of drilled holes as different bobbins locations are required for the different bend angles. For example, bobbins fixed at the last hole will be used to bend a pipe at right angle. The front plate and the back-plate material is selected considering the force applied by the hydraulic jack during the bending operation.

Base plate: For the stability of entire setup the thick MS plate is selected as base plate material. L angles is used to fix the front and the back-plate frame on the base plate. The front and back plate frame are bolted on the vertical surface of L angles while the base plate is welded with the horizontal surface of the L angles. Further the entire weight of hydraulic jack is also supported by the base plate.

Hydraulic jack: The most common jacks used today to lift heavy loads are screw threaded jacks or hydraulic jacks or cylinder jacks. Each has different mechanism of operation and range of applied force.

The main components of hydraulic jack are piston, piston rod, screw rod and hydraulic oil. The hydraulic jack operates manually by handle which can be reciprocated in upward and downward direction. The bending operation by hydraulic jack is achieved by the application of required force on pipe surface and the pipe is bended depending on the shape of the die used.

Bobbins: Bobbins are made of plastic, rubber, woods or metal and used to support the workpiece during the bending operation to achieve minimum deformation in cross section. The shape of bobbins especially the radius of curvature is selected considering outer diameter of the workpiece. So, if a pipe bending machine has to be fabricated for a range of workpiece diameters then different pairs of bobbins of different radius of curvature will be required.

Assembly

The component assembly during pipe bending machine fabrication is as follows: The base plate made of thick MS plate is kept on ground and the horizontal surface of the L angles are welded onto it then the front and back plate frames are bolted on vertical surface of L angles used. Then the hydraulic jack is bolted approximately around the center of base plate keeping symmetrical load distribution in mind. On the top section of the hydraulic jack i.e. the plunger of the jack bending die is mounted. The bobbins of required radius of curvature are selected and fixed with the bobbin pins. For the ease of operation, the whole setup can be mounted on workbench using nut & bolts as grooves have been provided.

Working of the bender

This hydraulic pipe bender is based on the press bending method. The required force is applied using the 20 Ton hydraulic jack. The plunger of hydraulic jack moves in upward direction when the operator reciprocates the provided handle manually in up and down direction. The bending die is mounted on plunger of the jack also used as support for the workpiece and further restrained by bobbins. The force is applied till the desired angle is achieved. The bent pipe is removed from machine by retracting the plunger after pressure valve release and removing the bobbins.

Calculations

Minimum force required to bend the pipe:

$$M/I = \sigma/Y \text{ [12]}$$

Where,

$$I = \text{Moment of Inertia} = \pi/64[25.4^4 - 21.4^4] \text{ [12]} = 10136.74 \text{ mm}^4$$

$$\sigma = 245 \text{ MPa [12]}$$

$$Y = d/2 \text{ [12]} = 12.7 \text{ mm}$$

$$M = (245 * 10136.74) / 12.7 = 195551.28 \text{ Nmm}$$

$$F = 2000 \text{ N}$$

Distance between bobbins:

The distance between two respective bobbins will always be different for every diameter of the pipe. These were calculated by adding the length of the die with the diameter of the pipe and the thickness of the bobbins.

1. For half-inch Diameter pipe = 140mm
2. For 1-inch Diameter pipe = 250mm

Height of bobbins:

1. For half-inch Diameter pipe = 1.5''+220mm = 258mm
2. For 1-inch Diameter pipe = 3''+220mm = 296mm

Material selected for Frame is **C15Mn75** ^[12]

Yield Strength=245 MPa ^[12]

Thickness of frame:

Load on one member = $(16 \text{ ton} * 1000 * 9.81) / 4 = 39240 \text{ N}$

Yield Strength, $\sigma = 245 \text{ MPa}$ ^[12]

Thickness = 10mm

Considering the Factor of Safety = 2

So, allowable stress = $245 / 2 \text{ MPa} = 122.5 \text{ MPa}$

$$\sigma = W / (b * t) \text{ }^{[12]}$$

$$\text{so, } b = W / (\sigma * t)$$

$$=39240 / (122.5*10) = 32 \text{ mm}$$

Safe load for bobbins:

Load on one bobbin = 78480 N

Yield Strength, $\sigma = 245 \text{ MPa}$ ^[12]

Considering the Factor of Safety = 2

So, allowable stress = $245/2 \text{ MPa} = 122.5 \text{ MPa}$

Generated stress in one bobbin = Load/min. Area

$$=39240 \text{ N}/3.14(30^2-8^2)$$

$$=29.85 \text{ MPa} \ll 122.5 \text{ MPa}$$

Since the generated stress is less than allowable stress so, bobbins are safe.

Safe load for pins:

The pins are in Double Shear

So, Load = $(16 \text{ ton} * 1000 * 9.81)/8 = 19620 \text{ N}$

Material selected = hardened steel bolt (grade 8)

Allowable value of stress = 10202.05 MPa ^[12]

Generated Stress, $\sigma = 19620/(\pi*8^2)$

$$=97.62 \text{ MPa} \ll 10202.05 \text{ MPa}$$

Since the generated stress is less than allowable stress so, bobbin pins are safe.

Design of the bender

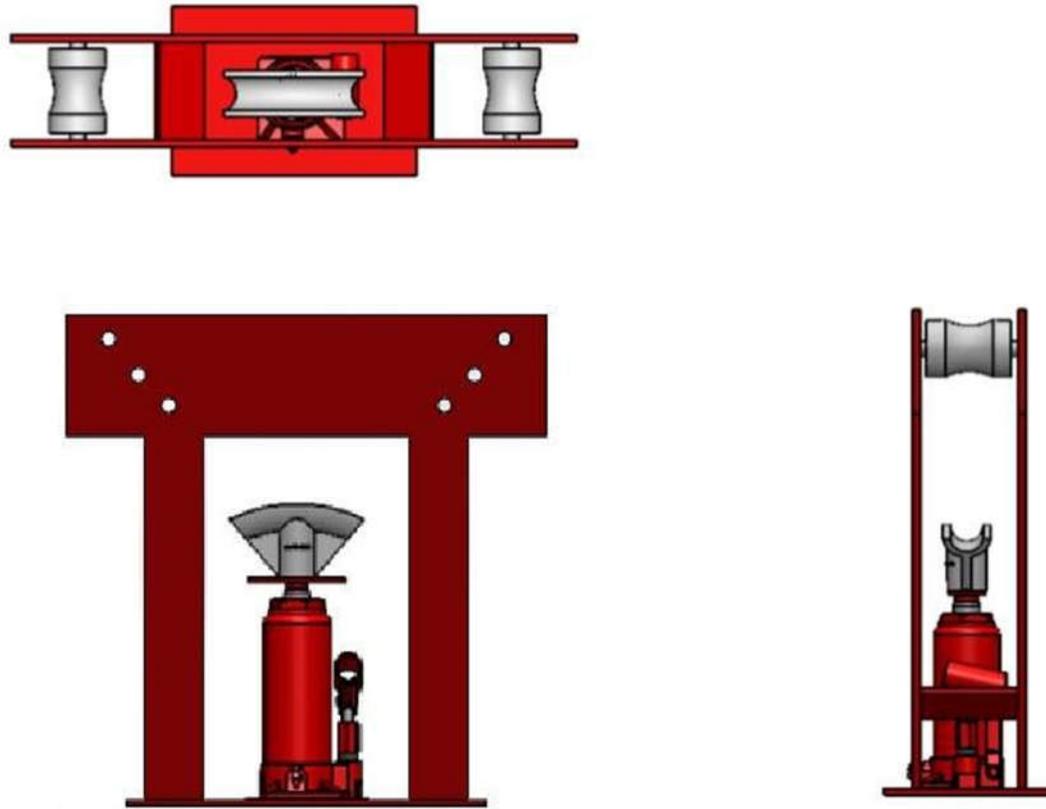


Fig: Top, Front & Side View of the Assembled bender

ANSYS Analysis

The analysis of MS Tube is performed on ANSYS Academic R15 software.

Following considerations are taken for MS tube during the analysis

$E = 210 \text{ GPa}$

$\nu = 0.33$

Density = 7700 Kg/m^3

Physical Parameters of the MS Tube assumed.

Outer Diameter = 25mm

Inner Diameter = 21mm

Length of the Tube = 200mm

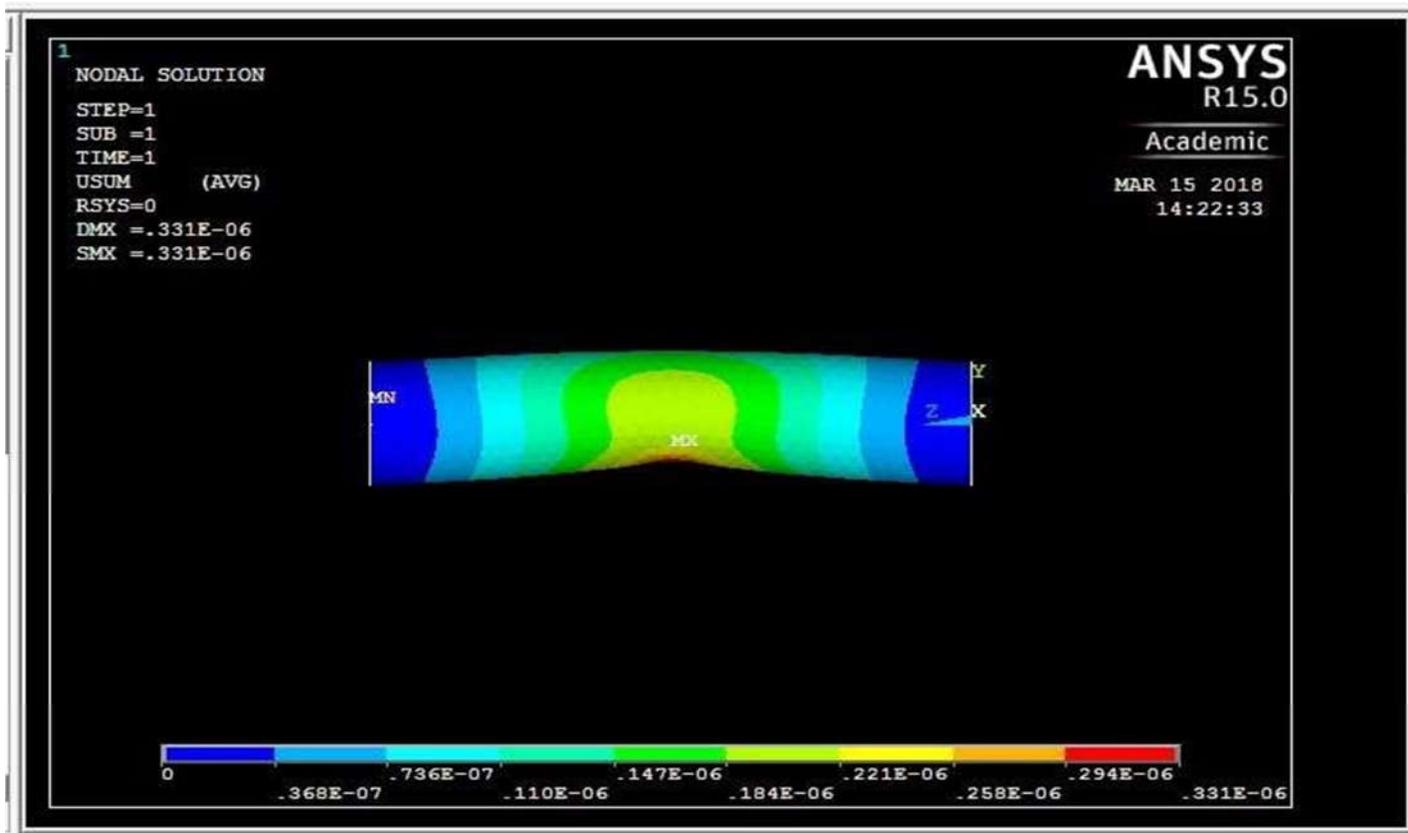


Fig: Nodal Analysis

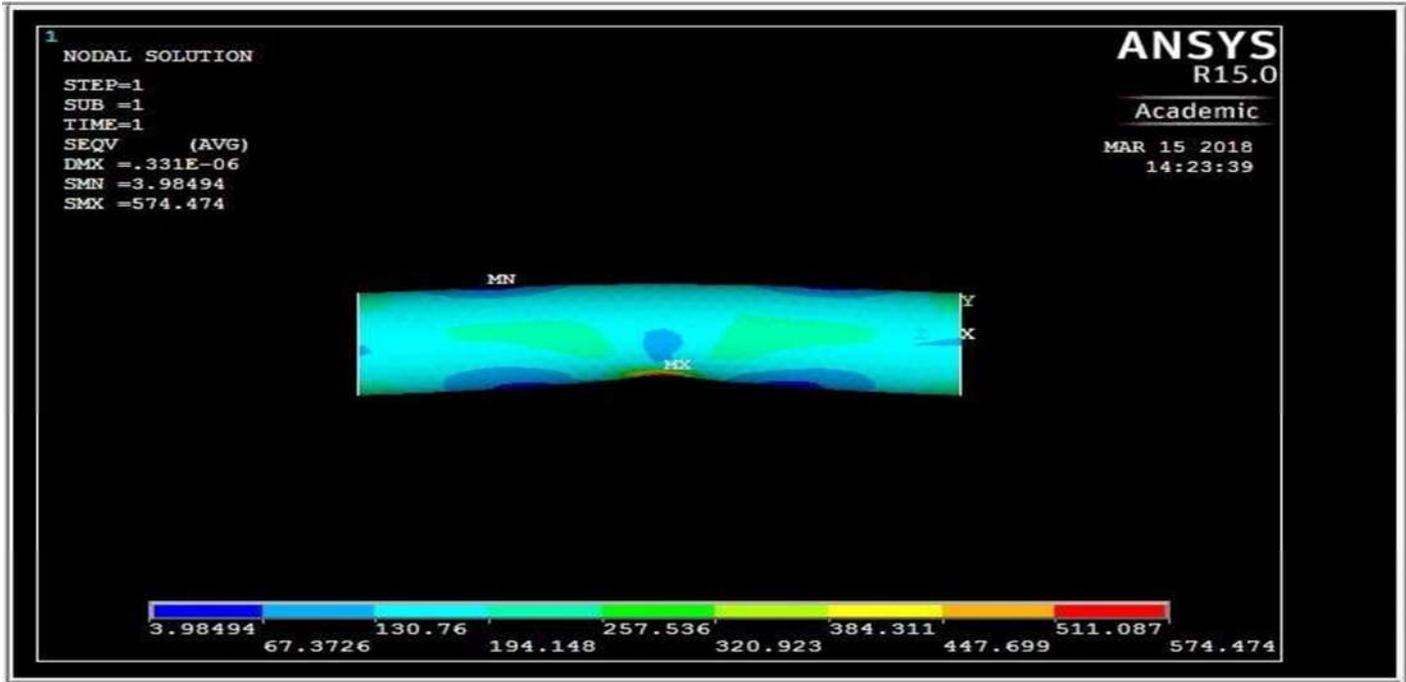


Fig: Von Misses Analysis

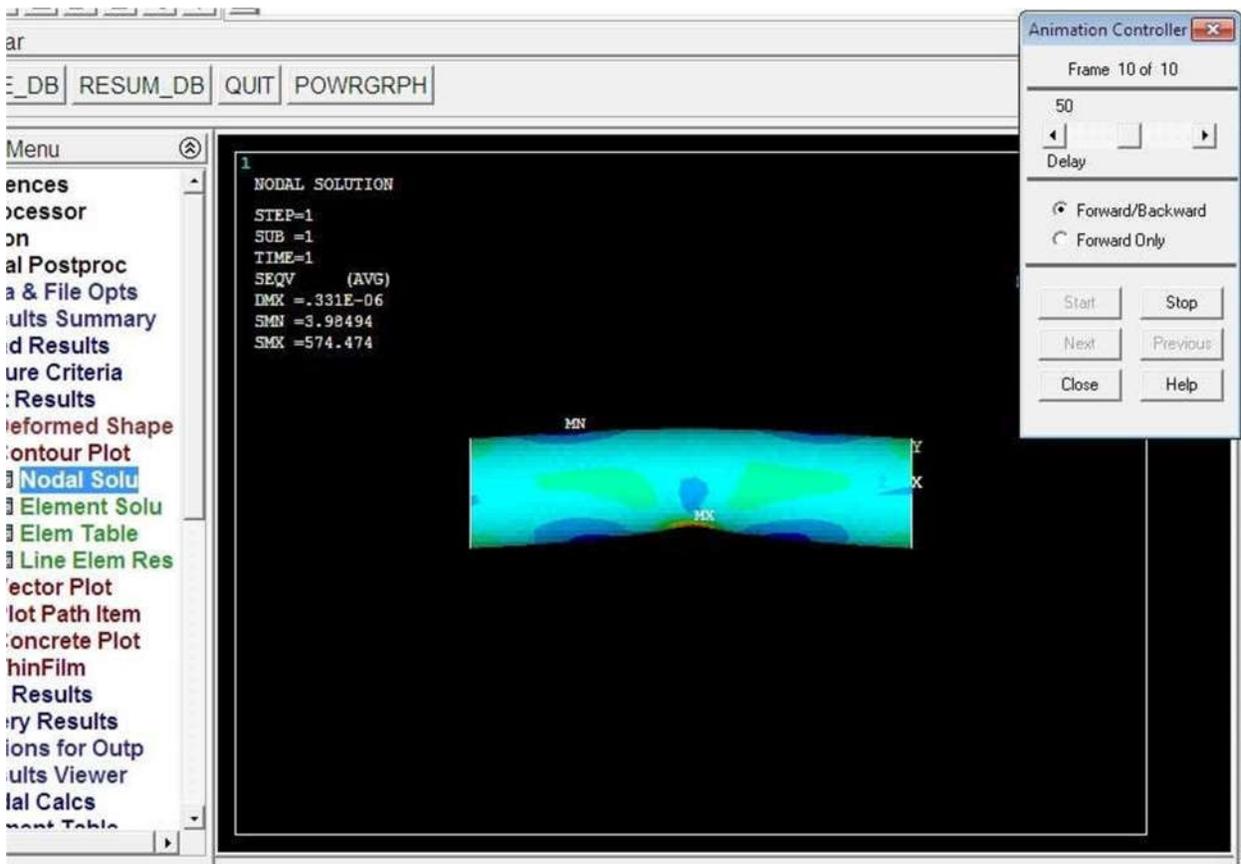


Fig: Deformation of Tube Animation 10th Frame.

Conclusion

The Results obtained from the ANSYS indicates that pipe bending operation done through the fabricated machine is more accurate and acceptable compared to manual bending machines. The dies with various tube diameters can be used in the same machine by providing minor modifications and higher bend angle can also be achieved. The fabricated machine can be used for a wide range of bend angle, bend radius and can perform bending operation on the range of tubes thickness, which is key advantage in comparison to other machines options present in the market in the same price range. The fabricated bending machine has several advantages like low cost, less space requirement, portability and accuracy over the manual counterparts.

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