

## Design and Development of Pipe Bending Machine

Mahesh Laxman Rathod<sup>1\*</sup>, Avadhut Balkrishna Kadam<sup>2</sup>, Balkrushna Popat Kale<sup>2</sup>,  
Vijay Gorakhnath Kamble<sup>2</sup>, Rohan Gulab Mali<sup>2</sup>

### Abstract

*The design and development of a pipe bending machine are crucial for various industrial applications, including the construction, automotive, and manufacturing sectors. Bending is a fundamental metalworking process that involves deforming pipes, tubes, square hollows, and rods without compromising their structural integrity. This study focuses on designing a cost-effective and efficient pipe bending machine that can accommodate different pipe sizes and materials. The key design considerations include selecting an appropriate roller bender type, determining whether the machine is power driven or manually operated, and optimizing its structural strength. Unlike conventional bending machines that primarily cater to sheet metal applications, this project aims to develop a robust pipe bending machine suitable for both small- and large-scale applications. The proposed machine is designed to enhance bending accuracy, reduce material wastage, and minimize manual effort. The research involves analyzing existing bending techniques, selecting appropriate materials for machine components, and implementing a mechanical system that ensures smooth and precise bending. The final outcome of this project is a functional prototype capable of bending pipes of varying diameters and thicknesses with minimal deformation. This machine aims to offer a cost-effective alternative to expensive industrial bending equipment while maintaining efficiency and precision. By addressing industry demands and enhancing bending capabilities, this design contributes to improving fabrication processes and broadening the applications of pipe bending technology.*

**Keywords:** Pipe bending mechanism, machine design, metal fabrication, design and development, metal forming

### INTRODUCTION

This study focuses on the design and development of a pipe bending machine, which is essential

#### \*Author for Correspondence

Mahesh Laxman Rathod

E-mail: maheshrathod579@gmail.com

<sup>1</sup>Assistant Professor, Department of Mechanical Engineering, Yashoda Technical Campus (Affiliated to Dr. Babasaheb Ambedkar Technological University, Lonere), Satara, Maharashtra, India

<sup>2</sup>UG Student, Department of Mechanical Engineering, Yashoda Technical Campus (Affiliated to Dr. Babasaheb Ambedkar Technological University, Lonere), Satara, Maharashtra, India

Received Date: March 24, 2025

Accepted Date: April 29, 2025

Published Date: May 13, 2025

**Citation:** Mahesh Laxman Rathod, Avadhut Balkrishna Kadam, Balkrushna Popat Kale, Vijay Gorakhnath Kamble, Rohan Gulab Mali. Design and Development of Pipe Bending Machine. International Journal of Manufacturing and Production Engineering. 2025; 3(1): 22–30p.

for shaping metal pipes, tubes, square hollow sections, and rods. Each type of metal has its own thickness and bending properties that require careful consideration during the design process. Factors such as the type of metal, roller bender mechanism, power source (manual or motorized), and machine capacity play crucial roles in determining the efficiency and functionality of the bending machine [1–4].

Currently, most of the bending machines available in the market cater to sheet metal and tube bending applications. Manufacturers design machines with varying capacities and power sources, including pneumatic, hydraulic, electrical, and manual options. The advancement of a nation relies on continuous innovation in science and

technology. Therefore, the development of an efficient, user-friendly, and cost-effective pipe bending machine is essential to meet industrial and commercial demands [5–7].

As energy resources have become increasingly scarce, it is vital to explore sustainable alternatives. The proposed machine integrates both manual and powered operations to ensure adaptability to different users and industries. In India, several industries manufacture manual pipe bending machines; however, a dual-function machine capable of performing both pipe and rod bending operations is a novel approach. By combining these functions into a single unit, this machine enhances efficiency, reduces costs, and eliminates the need for multiple machines, thereby making it a valuable contribution to the manufacturing sector [8–10].

## OBJECTIVES

1. To make a bending machine to bend a metal pipe up to 32 mm.
2. Modeling and design of “motorized pipe bending machine”.
3. Time consumption is less for bending the pipe.
4. Accuracy is achieved more compared with manual pipe bending machines.

## MECHANISM AND FABRICATION

The mechanism of the pipe bending machine is based on a roller-bending system, where a pipe is fed between the rollers and gradually deformed to the desired angle. The primary components include a bending die, clamping system, and force application mechanism, which may be manual or power driven. The bending process involves rotary draw, roll, or compression bending. The machine was designed to minimize spring-back effects and maintain uniform bending along the pipe length (Figure 1).

The fabrication process involved material selection, machining, and assembly of components. The key materials include mild steel for the frame and rollers to ensure durability and strength. The machine was constructed using welding, turning, and milling. Proper alignment and calibration were performed to achieve precision. Finally, tests were conducted to validate the bending accuracy and efficiency of the developed system.

### Design

The design of the pipe bending machine is centered around achieving efficient and precise bending while ensuring durability and ease of operation. The machine consists of a sturdy frame, bending rollers, and a mechanism for force application, which can be manual, hydraulic, or motorized depending on the required bending capacity.

### Selection of Pipe

For our project, we selected a 32 mm diameter pipe, as it would be economical.

*Pipe specifications:* OD-32 mm ID-30 mm

*Pipe material:* Mild steel and aluminum.



**Figure 1.** Concept of bending.

### **Effort Required for Bend Pipe**

#### *Assumption*

W is provided by the pipe's resistance to the bend. The effort arm x has both horizontal and vertical components, with the vertical component representing the active force.

Horizontal component,  $F_h = F \sin \theta$   $\wedge$  Vertical component,  $F_v = F \cos \theta$

Taking moment at the support reaction, R;

$$F_x \cos \theta = WY; F = WY/x \cos \theta;$$

Where F = Effort required to bend the pipe

Let  $\theta = 180^\circ \wedge x = 5y$  (i.e., depending on the length of the effort arm)

$$F = 23.3 \times 10^3 Y/5 Y \cos 180^\circ = 62.5 \text{ kN}; \text{ (Where } W = \text{average bending force of pipe, } 23.3 \times 10^3 \text{ N).}$$

#### *Power Requirement*

A gradual application of this effort bend the pipe smoothly. This means that a very low velocity is required. Therefore, an available motor capacity standard was selected and reduced to an appropriate speed output.

Choosing a motor of 1.5 kW;

$$\text{Power (P)} = \text{Force (F)} \times \text{Velocity (V)};$$

$$\text{Thus, } V = P/F = 1500 / 5500 = 0.273 \text{ m/s}$$

#### **Motor Specification**

A simple motor was used to drive the shaft of the stationary pulley (Figure 2). A 2HP, 1400 rpm, three-phase induction motor was selected to drive the shaft of the stationary pulley.

#### **Gearbox**

To reduce the speed and maximize the torque, a planetary gearbox was used with a speed reduction ratio of 130.

#### *Selection of Gearbox*

As per details provided by the company, gearbox selection steps from top gear catalog specification

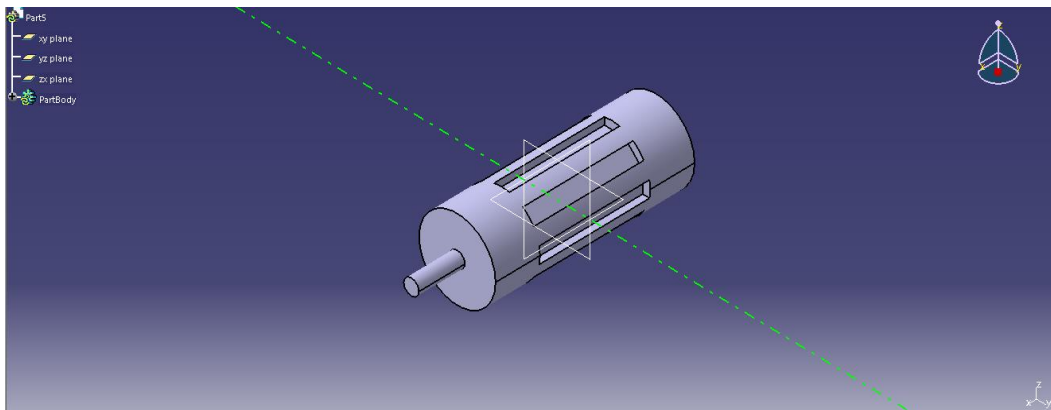
1. *Speed reduction ratio*

$$= \frac{1400}{11} = 127.27 \cong 130$$

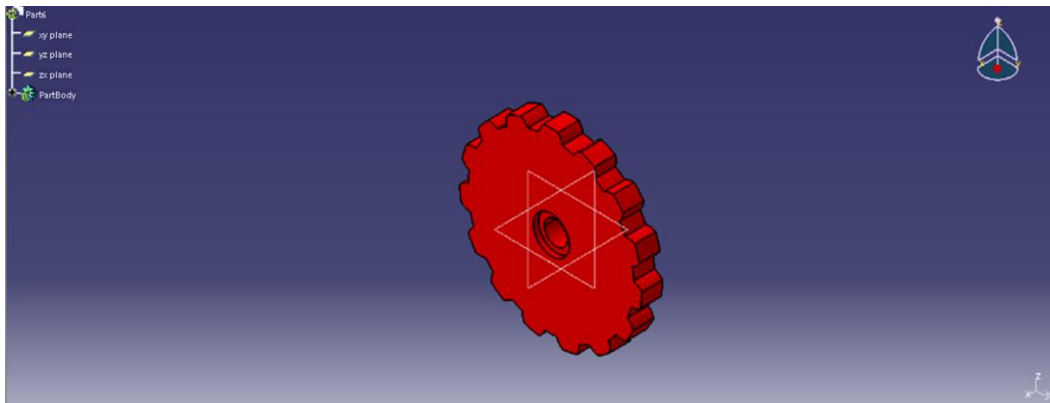
2. *Torque finds*

$$\text{Input torque } T = (P \times 9546) / N = \frac{(1.5 \times 9546)}{1400} = 10.22 \text{ N.m}$$

$$\text{Require torque} = (P \times 9546) / N = \frac{(1.5 \times 9546)}{11} = 1301 \text{ N.m}$$



**Figure 2.** Motor specification.



**Figure 3.** Spur gear.

3. *Service factor table* = 1.25
4.  $Overloading = \frac{19100000}{(d \times n)} \times fc = \frac{19100000}{(1.25 \times 11)} \times 1.25 = 26.04 \text{ kw}$
5. *Select of model*  
Model No. 31842 (From the table of Top Gear Technical Catalog)  
“Flange mounted vertical downward three-stage planetary gearbox”

### **Spur Gear**

The spur gear is shown in Figure 3.

1. The gear ratio and module are given by the company.  
 $m = 8 \text{ mm} \wedge i = 3.5$
2. Number of teeth in drive  
 $i = 3.55, Z1 = 12, Z1 = 43, Z = 55$
3. Selection of material of gear from the material chart, 3.55 modules near four selected materials is C45.
4. Basic dimensions of external meshing standard cylindrical gear for one for pinion and two for wheel
5. *Center distance (a)*  
 $a = m (Z1 + Z2)/2 = 8(12 + 43) = 220 \text{ mm}$
6. *Bottom clearance (c)*  
 $c = 0.25m = 0.25 \times 8 = 2 \text{ mm}$
7. *Height factor (f)* = 1
8. *Tooth depth (h)* =  $2m = 2 \times 8 = 16 \text{ mm}$
9. *Pitch diameter*  
For Pinion ( $d1$ ) =  $mZ1 = 8 \times 12 = 96 \text{ mm}$  &  
For Wheel ( $d2$ ) =  $mZ2 = 8 \times 43 = 344 \text{ mm}$
10. *Tip diameter*  
For Pinion ( $da1$ ) =  $(Z1 + 2f)m = (12 + 2 \times 1) \times 8 = 112 \text{ mm}$  &  
For Wheel ( $da2$ ) =  $(Z2 + 2f)m = (43 + 2 \times 1) \times 8 = 360 \text{ mm}$
11. *Root diameter*  
For Pinion ( $df1$ ) =  $(Z1 - 2f)m - 2c = (12 - 2 \times 1) \times 8 - 2 \times 2 \wedge$

$$\text{For Wheel } (df_2) = (Z_2 - 2f)m = (43 - 2 \times 1) \times 8 - 2 \times 2.$$

12. *Number of teeth check*

$$Z_1 = 2a/m (i+1) = (2 \times 220)/8 \times (3.55+1) = 12.08.$$

$$Z_2 = i \times Z_1 = 3.55 \times 12 = 42.91.$$

13. *Torque transmitted pinion*

$$\begin{aligned} M_t &= \frac{97420 \times kW}{N} \text{ (as per the "Design Data Book" formula)} \\ &= \frac{97420 \times 1.5}{11} \\ &= 13213.69 \text{ kgf. cm} \end{aligned}$$

14. *Young modulus for C45*

$$\begin{aligned} E &= 21000 \text{ N/mm}^2 \\ &= \frac{21000}{0.0980} \text{ (Convert N/mm}^2 \text{ into kgf/cm}^2\text{)} \\ &= 214140.40 \text{ kgf/cm}^2 \end{aligned}$$

15. *Face width (b)*

$$b = 10 m = 10 \times 8 = 80 \text{ mm}$$

16. *Compressive stress*

$$\begin{aligned} \sigma_c &= 0.74 \times [(i+1)/a] \sqrt{\{(i+1) \times (E \times M_t)\}} \\ &= 0.74 \times [(3.55+1)/22] \sqrt{\frac{3.55+1}{3.55 \times 8} (214140 \times 13213)} \end{aligned}$$

$$\sigma_c = 3258 \text{ kgf/cm}^2$$

$$\text{Limit range of C45 } \sigma_c \leq 5000 \text{ kgf/cm}^2$$

$$3258 \text{ kgf/cm}^2 \leq 5000 \text{ kgf/cm}^2$$

Design is safe (as per "Design Data Book" formula and table)

17. *Bending stress*

$$\begin{aligned} \sigma_b (i+1) &= (3.55+1) / (22 \times 0.8 \times 8 \times 0.456) \times [13213] \\ &= 936.41 \text{ kgf/cm}^2 \end{aligned}$$

$$\text{Limit range of C45 } \sigma_b \leq 1600 \text{ kgf/cm}^2$$

$$936.41 \text{ kgf/cm}^2 \leq 1600 \text{ kgf/cm}^2$$

Design is safe.

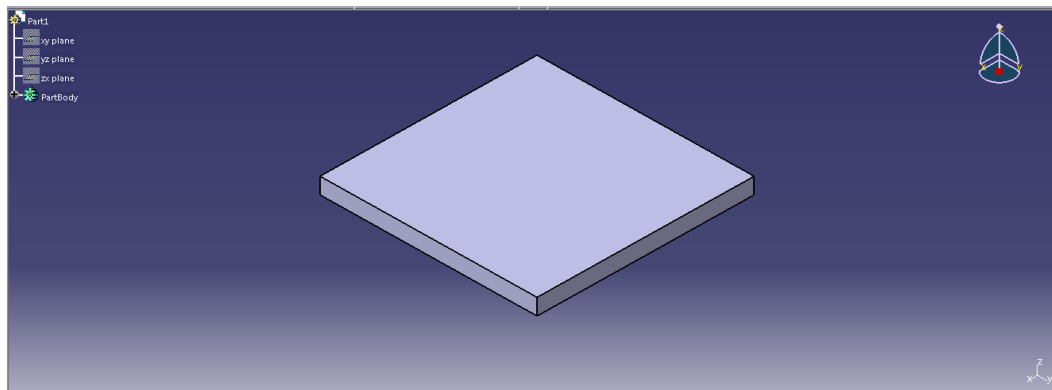
### **Base Plate**

The base plate provided structural support to the entire machine. It has dimensions of 650 × 650 mm and is made of mild steel (Figure 4).

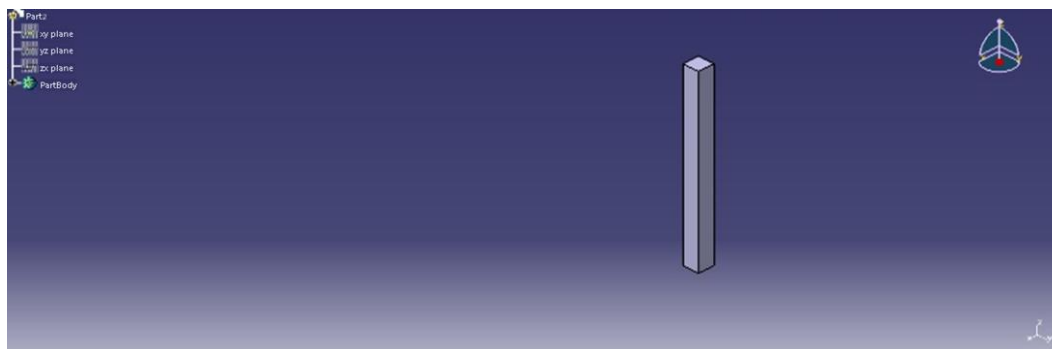
Base is the supporting member for all parts of a machine.

*Specification:* 650×650 mm.

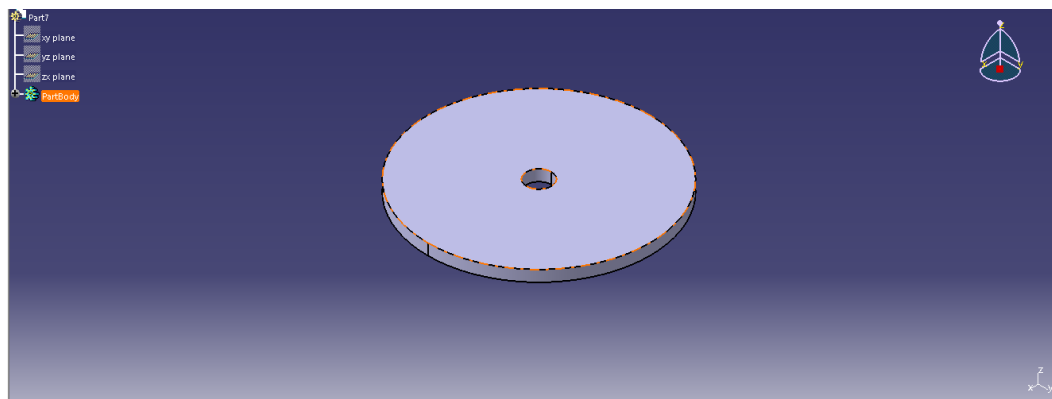
*Material:* Mild steel.



**Figure 4.** Base plate.



**Figure 5.** Base column.



**Figure 6.** Angular plate.

#### **Base Column**

*Specifications:* Height, 850 mm; square box,  $50 \times 50$  mm; thickness, 3 mm; *material:* mild steel (Figure 5).

#### **Angular Plate**

The angular plate facilitates proper alignment during the bending process (Figure 6).

*Specification:* OD-350 mm, ID-40 mm.

*Material:* mild steel.

#### **Design of Bearing**

Bearing selection is crucial to reduce friction and enhance longevity. Bearings are designed based on industrial requirements and standards.

1. Pipe bending machine is used for 8 hours of service per day.
2. Bearing life required for industrial purpose 12000–20000 h.

3. Selection of bearing from manufacturing catalogs.
4. Select the type of bearing.
5. Find the radial and thrust factors.

Using trial and error method assuming shaft diameter = 70 mm.

It is observed from the table that the value of x is constant, and the value of y varies.  $F_a/f_r > e$

For a 70 mm shaft

Static load  $C_o=9150$  from the table.

Load factor = 3.5

Static load  $C_o = 3.5 \times 9150 = 32025$  N.

$F_a/C_o = 0.025$

$F_a/32025 = 0.025$

$F_a = 0.025 \times 32025 = 800.625$  N.

$F_a/f_r > e$

$F_a/f_r > 0.22$

$F_r = 3639.2045$  N.

Calculate the equivalent dynamic load from the equation,

$P = xF_r + yF_a$

$0.56 \times 3639.2045 + 2 \times 800.625$

$P = 3639.20$  N.

Bearing life

$L_{10} = 60 \times n \times L_{10(h)} \times 10^6$

$60 \times 1400 \times 20000/10^6$

$L_{10} = 1680$  million rev.

Calculate the dynamic load capacity.

$C = P(L_{10})^{1/3}$

$C = 3639.20(1680)^{1/3}$

$C = 43262.24$

Dynamic load capacity comparing

From the table.

$C = 43262.24 = 61800$

$C_o = 37500$

$D = 125B = 24$

$d = 70$

Bearing designation = 6214.

Second bearing design is be the same as the above. Bearing designation = 6208.

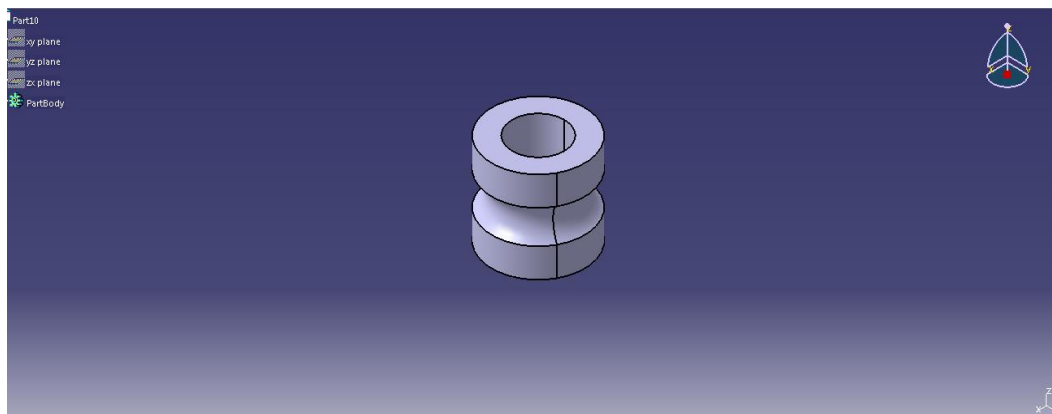
### ***Design of Pulley***

The material selected for the roller was case-hardened steel with a roller diameter that was five times the pipe diameter (Figure 7).

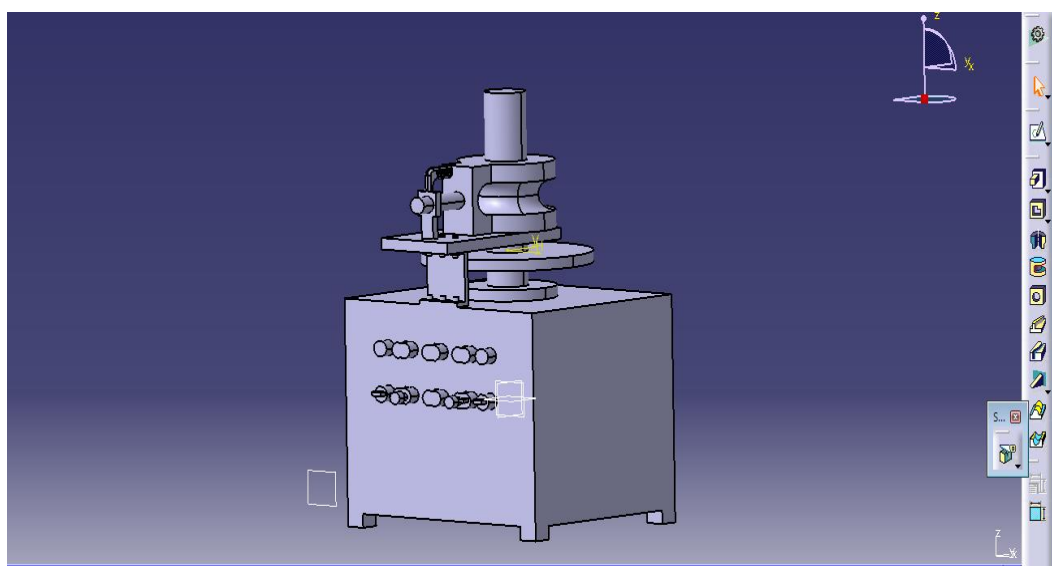
Case-hardened steel was selected as the material for the roller. For fewer defects in bending, a roller diameter five times the pipe diameter is required.

$D = 160$  mm

$d = 150$  mm.



**Figure 7.** Design of pulley.



**Figure 8.** Assembly model.

### EXPERIMENTAL SETUP SUMMARY

Bending machines are widely used across various industries for different applications, including conical bending, which can be expensive when using conventional methods (Figure 8).

### FUTURE SCOPE

1. To bend the Rod and pipe in one system.
2. To operate the system motorized.
3. To ease the operation in small-scale industries.

### CONCLUSION

The design and development of a pipe bending machine plays a crucial role in various industries, enabling efficient and precise bending of metal pipes, tubes, and rods, which emphasizes the significance of factors such as material type, machine capacity, and power source in the design process. By integrating both manual- and power-operated mechanisms, the proposed bending machine ensures versatility, ease of use, and cost-effectiveness. Furthermore, the innovation of a single machine capable of performing both pipe and rod bending operations enhances productivity, while reducing the need for multiple machines. The proposed design addresses these needs, contributes to industrial advancements, and supports sustainable manufacturing practices. The machine was powered by a 2HP motor and pipe bending could be achieved at 180°. Electrical bending can be achieved with the aid of a gearbox assembly. For pipes of lower thickness, a mandrel should be introduced to prevent collapse.

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