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Design and fabrication of Manual Roller Bending Machine

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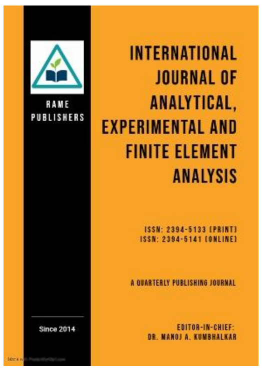

Abstract. This paper aims to develop a roller bending helpful machine to bend pipes and metal strips in the workshop. This project is to vogue and constructs a negotiable roller bending machine. This machine is utilized to bend steel pipes and meta strips into a curve and so the choice curvature shapes. The scale of the machine is very convenient for movable work. It is entirely created by steel. Moreover, it is easy to carry and use at anytime and anywhere. It reduces human effort and, in addition, required low less talent to figure this machine. We incline to face live arising with operated by hand roller bending machine using block, motors, gears, and support (frame). Power is that the machine for pipe bending, and everything works manually. Therefore, our objective is to extend preciseness at low costs while not moving the pipe bending's productivity. This machine works on the simple kinematic system instead of subtle vogue. Because of its mobility, it are usually utilized by workshop or fabrication search. A bending machine is also a standard tool in the workshop that is accustomed bend a metal.

Keywords: Roller bending machine Manual pipe bending Sheet metal forming Kinematic mechanism Workshop fabrication

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1. Introduction

Manufacturing industries utilize various fabrication methods and processes for producing mechanical components. Conventional manufacturing processes such as casting, metal joining, and metal forming are widely employed in the production of industrial parts and equipment. Among the various metal forming operations, bending is one of the most important processes used for shaping metal sheets, rods, and pipes into required profiles and geometries [1].

A manual roller bending machine is a mechanical device used for bending metal strips, sheets, rods, and pipes into curved or cylindrical shapes. Unlike automated bending machines, the manual roller bending machine operates through human effort, making it economical, simple in construction, and suitable for small-scale workshops and fabrication industries. The machine generally consists of rollers through which the workpiece passes repeatedly until the required curvature is achieved. Due to its portability and ease of operation, it is widely used in fabrication shops and maintenance work [2].

The present project focuses on the design and fabrication of a portable manual roller bending machine capable of bending steel pipes and metal strips into desired curved profiles. The machine is designed using simple mechanical elements such as rollers, gears, shafts, bearings, and supporting frames. The system operates manually and does not require complex mechanisms or electrical power, thereby reducing manufacturing and operating costs. The machine is easy to transport, simple to operate, and requires comparatively less skilled labor. The main objective of the work is to improve bending accuracy and operational efficiency while minimizing human effort and production cost [3].

The machine works on a simple kinematic mechanism instead of complicated automated systems, making it suitable for small workshops and fabrication industries. The design emphasizes portability, ease of handling, and cost-effectiveness while maintaining sufficient bending capability for industrial applications [4].

2. Project Objectives

The major objectives of the project are as follows:

1. To design a manual roller bending machine.
2. To design the necessary machine components required for the bending operation.
3. To develop a machine that is cost-effective, portable, and easy to handle.
4. To design a machine capable of performing bending operations efficiently with minimum human effort.

Several researchers have studied pipe and tube bending systems for industrial applications. Previous studies have focused on the development of advanced tube bending systems capable of producing different shapes and sizes with improved precision and efficiency [5]. Research has shown that bent tube components are increasingly used in lightweight and high-strength applications, especially in automotive and aerospace industries. Various studies have also investigated common bending defects such as wrinkling, wall thinning, cracking, spring-back effects, and cross-sectional deformation during tube bending processes [6]. Advanced bending techniques and process optimization methods have been proposed to improve bending quality and reduce manufacturing defects [7].

Researchers have also developed versatile bending machines capable of performing multi-axis bending operations without changing tooling arrangements. Such systems utilize advanced mechanisms and controlled motion systems to achieve complex bending profiles [8]. However, these systems are generally expensive and more suitable for large-scale industrial applications [9].

Some studies have focused on the design and fabrication of compact and portable pipe bending machines suitable for small workshops and fabrication shops. These machines are capable of bending steel pipes into various shapes while reducing human effort and operational complexity [10]. The major advantages of such systems include portability, ease of use, low manufacturing cost, and reduced requirement for skilled labor [11]. However, many existing machines are limited in their bending capacity and are mainly suitable for small-scale applications [12].

Therefore, there is a need for the development of a simple, economical, portable, and efficient manual roller bending machine capable of performing bending operations accurately with minimum effort and maintenance requirements 13].

3. Design Procedure

Following basic shearing operation on a sheet metal, components can be rolled to give it a definite shape. Bending of parts depends upon material properties at the location of the bend. To achieve bending, the work material must be subjected to two major forces; frictional force which causes a noslip action when metal and roller came in contact and a bending force acting against the forward speed and the torque applied to move the material.

Table 1. Main Component and its Quantity

Sr. No	Name of the Part	Material	Quantity
1	Bending Rollers	Mild Steel	3
2	Spindle wheel	Mild Steel	1
3	Chain drive	Mild Steel	1
4	Sprocket	Brass	2
5	Bearings	Steel	4
6	Elevating Screw	Stainless steel	1

7	Moving rollers	Mild Steel	2
8	Supporting frame	Mild Steel	2
9	Supporting Table	Cast iron	1

Where,

a = distance from exit zone to the no-slip point (assume a = L/2);

F = force applied to rollers;

T = torque applied to rollers;

L = roll gap;

r = radius of rollers;

μ = frictional force 0.4 Nm-1;

ho = thickness of the sheet before and after time t.

At least two rollers are involved in flat rolling depending on the thickness and properties of material while three or multiple roller system is required in shape rolling. A work material under bending load is subjected to some form of residual stress and deformation as it bends. Materials at the outer bend radius undergo tensile plastic deformation while the material at the inner bend radius undergoes compressive plastic deformation.

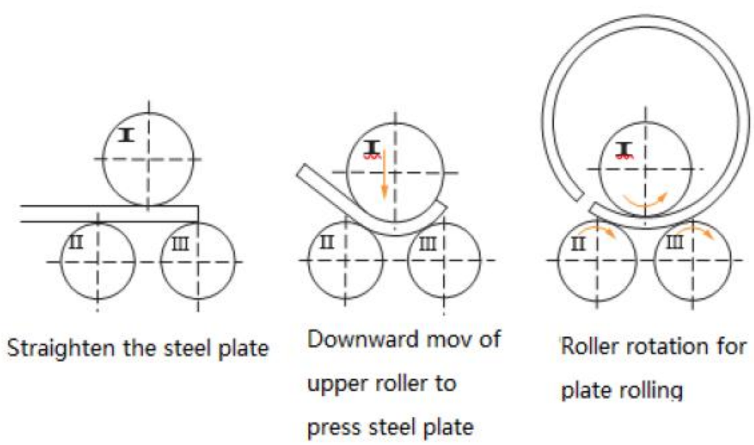

Figure1: Bending Process

Design of Chain drive:

Specifications:

Z1: Number of teeth on driving sprocket=15

Z2: Number of teeth on driven sprocket=15

a: center distance between driving sprocket and driven sprocket=201mm

D1: diameter of driving sprocket

D2: diameter of driven sprocket

3.1 Length of the chain

L = Ln * P

Where,

Ln: number of links

P: Pitch = 0.25 inch = 6.35 mm

Ln= $2\left(\frac{a}{p}\right) + \left(\frac{z1+z2}{2}\right)\left(\frac{z2-z1}{2n}\right)^2 * \left(\frac{p}{a}\right)$

Ln= $2\left(\frac{201}{6.35}\right) + \left(\frac{15+15}{2}\right) + \left(\frac{15-15}{2n}\right)^2 * \left(\frac{6.35}{201}\right)$

Ln= 78.30mm

L= 78.30*6.35

L= 497.205mm

D = $\frac{p}{\sin(\frac{a}{2})}$

α = $\frac{360}{z}$

α = $\frac{360}{15}$ = 24^0

D = $\frac{6.35}{\sin 12}$ = 30.54≈ 30mm

D= 30mm

D=D1=D230mm

3.2. Design of power screw

Specifications

μ: co-efficient of friction=0.15

W: weight of the roller=2.5Kg=24.525N

α : Helix angle

∅ : Friction angle

dc: major diameter=7.4mm

do: minor diameter=6.04mm

P: pitch=6.35mm

Torque required lifting the load:

Lead= pitch (single trapezoidal thread)

Lead= 6.35mm

Helix angle

Tanα=$\frac{lead}{nd}$

D = $\frac{do+ac}{2}$

D= $\frac{7.4+6.04}{2}$ = 6.72mm

Tanα = $\frac{6.35}{\pi * 6.72}$

α = 5.41^0

tan ∅ = μ

∅ = tan^{-1} μ

∅ = 8.53^0

Torque required raising the load (for 1 revolution of one screw)

T1= W*tan(α + ∅) * $\frac{d}{2}$

T1= 24.525*tan(5.41 + 8.53) * $\frac{6.72}{2}$

T1= 20.45 N-mm

: it is the load acting on one screw.

Total torque= 20.45*54

= 1104.3N-mm

Total force= $\frac{Torque}{distance}$

=$\frac{1104.3}{85}$= 12.99 $\approx 13N$

Force for 1 rev = $\frac{13}{1.4}$ = 9.28N

Efficiency of screw (η)

Ƞ = $\frac{\tan\alpha}{\tan(\alpha + \emptyset)}$

Ƞ = $\frac{\tan 5.41}{\tan(5.41+8.53)}$

Ƞ = 0.38 = 38%

Torque required to lowering the load

T2 = W*tan($\emptyset - \alpha) * \frac{d}{2}$

T2 = 24.525*tan(8.53 – 5.41)*$\frac{6.72}{2}$

T2 = 4.47N-mm

It is the load acting on one screw

As the lowering load is positive, the screw is self locking i.e, as $as\ \acute{\emptyset} > \alpha\ screw$ is self locking

3.3. Force analysis

Maximum torque required for a cylinder rolling

Specifications

s: material yield limit=218 N/mm2 (from data hand book)

B: maximum width of rolled shield= 40mm

δ : Thickness of rolled sheet in mm

1) For thickness $\delta = 2mm$

When considering the deformation of the material, there is reinforcement and the reinforcement co-efficient K is introduced to modify the equation

Mt = s N-mm

In the above formula K: reinforcement co-efficient=1.15

$\delta =$ =2mm

Mt = 10028 N-mm

2) For thickness δ =3mm

Mt = 22563 N-mm

3) For thickness δ = 4mm

Mt = 40112 N-mm

3.4. Force condition

When rolling steel plate, the force condition is shown in above Figure. According to the force balance, the supporting F2 on the roll plate can be obtained via the following formula.

F2 =

θ= the angle between defined line 001 and 002

$\theta = \sin^{-1} a\backslash dmin + d2$

a = lower roller center distance in mm.

dmin = minimum diameter of the rolling plate in mm = 388mm

d2 = lower roller diameter in mm = 62mm

$\theta = \sin^{-1} 201\backslash 388 + 62$

$\boldsymbol{\theta = 26.53^0}$

1) For thickness $\boldsymbol{\delta = 2mm}$

R = neutral layer's radius of the rolling in mm

R = 0.5 dmin

R = 0.5*388

= 194 mm

F2 = 115.63 N

According to the force balance, the pressure force F1 which is generated by the upper roller, acting on the rolling plate i.e.,

F1 = 2F2

F1 = 2*115.63

F1 = 206.91 N

2) For thickness $\boldsymbol{\delta = 3mm}$

F2 = $\frac{22.563*103}{194*\sin(26.53)}$

F2 = 260.3 N

F1 = 2F2 cosθ

F1 = 2*260*cos 26.53

F1 = 460.98 N

3) For thickness $\boldsymbol{\delta = 4mm}$

F2 =$\frac{40.112*10}{194*sin26.53}$

F2 = 462.90 N

F1 = 2*F2cosθ

= 2*462.90* F1 = 828.31 N

3.5. Calculation of driving Torque

The lower roller of the plate of plate rolling machine is the driving roller and the driving torque on the lower roller is used to overcome the deformation torque Tn1 and friction torque Tn2.

Tn1 = N-mm [for 2mm MS plate]

=$\frac{10.02*103*62}{2*194}$

=1601.13 N-mm

The friction torque includes the rolling friction torque between the upper and lower roller and steel plate, and sliding friction torque between the roller neck, and shaft sleeve which can be calculated as follows.

Tn2=f(F1+2F2)+ (F1 +F2D2) (N-mm)

In the above formula,

f=co-efficient of rolling friction = 0.008*103 mm

μ=co-efficient sliding friction

d1,d2= upper roller and lower roller diameter (mm)

D1, D2= upper roller and lower roller neck diameter (mm)

Di=0.5di (i=1,2)

D1=0.5d1

D1=0.5*62=31 mm

D1=D2 (same size)

Tn2=0.008*103[206.91+2(115-63)] +0.04*103[206.91($\frac{31*62}{2*62}$)+115.63*31]

Tn2=3508.07 N-mm

Total torque T = Tn1 + Tn2

T=1601.13+3508.07

T=5109.206 N-mm

3.6. Shaft analysis

Specification

Shaft Material =steel (FeE580)

Tensile strength of the material (Sut) = 770N/mm2

Yield stress of material (Syt) = 580 N/mm2

fs = factor of safety

τ max = $\frac{0.5\ sut}{fs}$

= 145 N/mm2

Calculating torque

T = 0.18 Sut

= 0.18*770

T = 139 N/mm2

139<145 N\mm2, hence design is safe

Table 2. Comparison of Experimental and theoretical value

Pipe Diameter Mm	Deflection mm	Bending diameter in mm		Deviation	
		Experimental (De)	Theoretical (Dt)	(De – Dt) mm	% (De – Dt)/ Dt
15	31.755	457.20	539.75	82.55	15.30
	38.100	412.75	461.52	48.77	10.56
	50.800	330.20	368.30	38.10	10.34
20	31.755	495.30	539.75	44.45	8.24
	38.100	444.50	461.52	17.02	3.69
	50.800	361.95	368.30	26.35	1.72

4. Results and Discussion

For 15 and 20 mm tubing, a schematic depiction of the contrast between theoretical and experimental bending radius (diameter) values is displayed. As can be seen in the table, the variance decreases as the bending radius increases. The pipe is balanced on the bottom roller when bent, and the middle roller applies friction. In any case, it's possible that the two ends aren't bending properly.

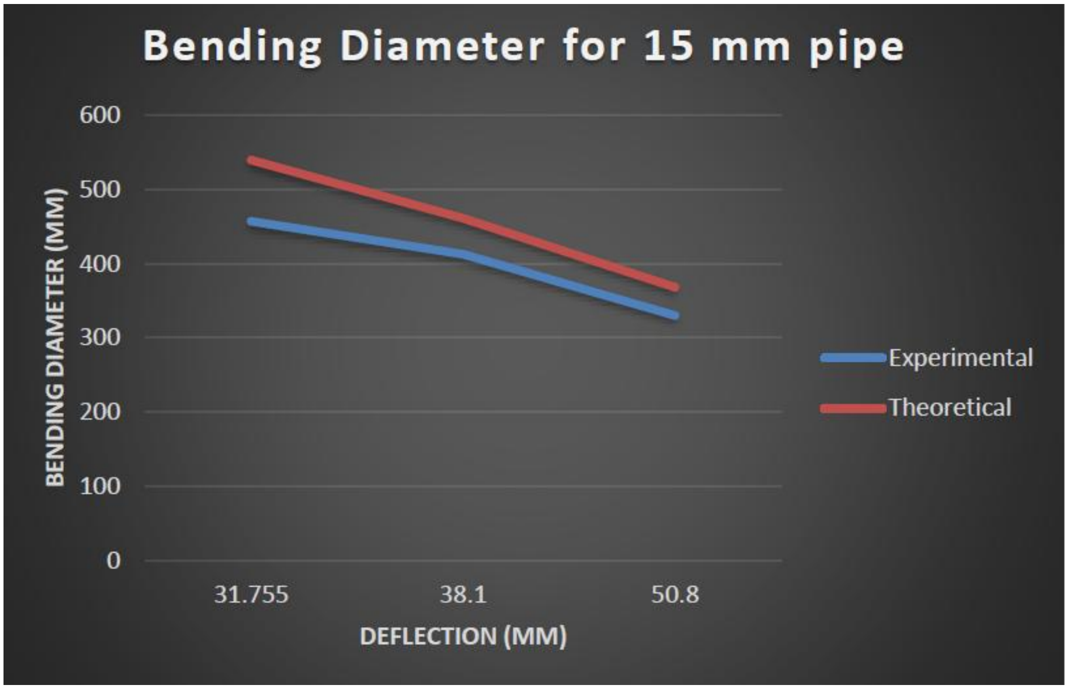

Figure 2. Graphical representation of experimental and theoretical value for bending of 15 mm pipe.

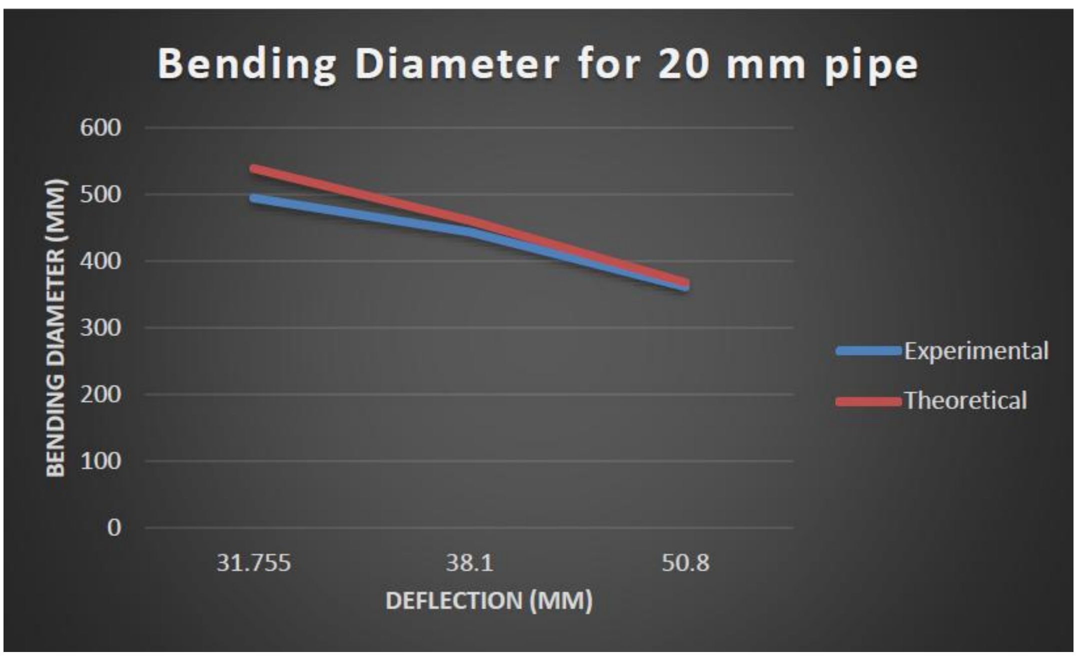

Figure 3. Graphical representation of experimental and theoretical value for bending of 20 mm pipe.

There are two ways to adjust the bending angle and radius in a three-roller bending machine:

one is to change the distance between two fixed rollers, and the other is to change the vertical displacement in the middle roller. In this initiative, the above is taken into account in order to reduce design complexity. As a result, the bending radius is solely determined by the middle roller's bending power. The bending radius is calculated using the above-mentioned equation Since the distance between the two rollers is set, the distance 'd' is the only one that can be

changed. The findings are showing deviation in results. This deviation could be minimized by using a steady and smooth operation. Also, the variation is decreased as the middle roller displacement increases. The theoretical value is significantly higher than the experimental value, as seen in charts 1 and 2.

The curves in 15 mm pipe are parallel.

For 20 mm tubing, though, the two curves appear to converge, resulting in greater deflection.

It can be concluded from the results that there is no difference between theoretical and experimental values. The variance may be minimized by ensuring a proper bending procedure and smooth operation.

5. Conclusion

Nowadays, pipe bending is a common occurrence. Various automatic and semi-automatic bending systems are used in mass manufacturing. However, automated and semi-automatic pipe bending machines are expensive for limited manufacturing. They still cannot be used in areas where electricity is scarce and expensive. Manual pipe bending, on the other hand, is less costly and simple to build and run. The plans, development, and performance tests are all depicted in this article. Also, below is a summary of the successful test results:

1) With two fixed rollers, the bent diameter is solely determined by the mid roller's deflection.

2) The deviation in outcomes is decreased as the deflection increases.

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