

Design and Fabrication of Motorised Sheet Metal Rolling Machine

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Received: 1 May 2025 / Accepted: 29 May 2025 / Published: 2 June 2025

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Abstract

In Sheet Metal working industry, a wide range of power and hand operated machines are being used. As the sheet metal industry is a large and growing industry different types of machines are used for different operations. Rolling is a fabricating process in which the metal, plastic, paper, glass, etc. is passed through a pair (or pairs) of rolls. There are two types of rolling process, flat and profile rolling. In flat rolling the final shape of the product is either classed as sheet (typically thickness less than 3 mm, also called "strip") or plate (typically thickness more than 3 mm). In profile rolling the final product may be a round rod or other shaped bar, such as a structural section (beam, channel, joist etc.). In this project the sheet metal rolling is very simple in operation by using roller which is coupled with motor. This machine produces cylindrical objects of different diameters. In normal practice of the roller bending, heavily depends upon the experience and skill of the operator. Trial and error are a common practice in the industry. This project reduces the manpower so that the human errors are reduced. This machine consists of three rollers of 80mm dia and 1.37m length which are meshed with a gear at the end and the gear box is coupled with a 2hp motor. This machine is simple in construction and working.

Keywords: Sheet metal, Rolling Machine, Design, Fabrication, Motorised

1. Introduction

Sheet metal forming is a vital subset of manufacturing processes that involves the plastic deformation of metal sheets to achieve desired geometries without significantly altering the material's volume. Among various forming techniques, rolling has emerged as a crucial method employed in numerous industrial applications for transforming flat sheet metal into cylindrical or conical forms. This process is widely utilized in the fabrication of components such as cylindrical tanks, pipes, ductwork, and structural shells in sectors like construction, automotive, aerospace, and mechanical engineering. Traditionally, many workshops and small-scale fabrication units rely on manual sheet metal rolling machines, which require the operator to physically rotate the rollers using hand cranks or levers to feed and curve the metal sheet. While these machines are cost-effective and relatively simple to maintain, they suffer from several drawbacks: they are labor-intensive, time-consuming, and limited in their ability to maintain consistent results, especially when working with thicker sheets or performing repetitive tasks.

The increasing demand for higher efficiency, better precision, and faster production in the metal fabrication industry calls for an improvement in existing technology. As industries grow and evolve, there is a shift toward automated and motorized systems that minimize human effort and maximize output quality. A motorized sheet metal rolling machine integrates an electric motor to drive the rollers, automating the feeding and rolling process. This innovation not only reduces the physical burden on the operator but also enhances production speed, accuracy, repeatability, and safety. Motorized systems are especially beneficial in small- and medium-scale fabrication workshops, where labour costs and production time directly impact profitability. Such systems provide a modern, efficient alternative to traditional manual machines without requiring the high capital investment of fully automated industrial machinery. In light of these factors, this study focuses on the design and fabrication of a motorized sheet metal rolling machine that is

affordable, efficient, and suitable for use in small to medium fabrication environments. The machine will be designed using locally available materials and components to ensure cost-effectiveness, easy maintenance, and adaptability for various sheet metal thicknesses and applications.

In the domain of sheet metal fabrication, the process of bending or rolling flat metal sheets into curved or cylindrical shapes is a fundamental operation that plays a critical role in the production of numerous structural and mechanical components. Despite the widespread industrial reliance on this process, many small- and medium-scale fabrication workshops, technical institutions, and artisan-based manufacturing setups continue to rely on manually operated rolling machines. While these machines offer basic functionality at a low cost, they present significant limitations that impede productivity, safety, and output quality.

Firstly, manual rolling machines are inherently labour-intensive, requiring constant physical effort from the operator to rotate the rollers via hand cranks or levers. This not only leads to rapid operator fatigue but also limits the duration and efficiency of continuous production cycles. The variability in manual effort further results in inconsistencies in rolling speed and force, which directly affect the uniformity and dimensional accuracy of the final product. Secondly, manual machines struggle to handle thicker gauges of sheet metal or tougher materials such as stainless steel and mild steel beyond a certain thickness. The mechanical advantage provided by manual input is often insufficient to overcome the elastic resistance of the material, making it challenging or impossible to form the desired curvature without significant pre-heating or multiple passes—both of which further reduce process efficiency. Moreover, precision and repeatability—two critical factors in modern manufacturing—are difficult to achieve consistently with manual rolling due to human error, lack of force control, and difficulty in maintaining a uniform rolling speed. In fabrication environments where a high level of accuracy is required, such as in the production of pressure vessels or aerospace components, manual machines simply do not meet the required tolerances. In addition to technical inefficiencies, manual operation also poses ergonomic and safety concerns. Prolonged use of manual rolling machines can lead to musculoskeletal stress and increase the risk of accidents, particularly when dealing with sharp-edged sheet metals or high-tension rolling scenarios. On the other hand, industrial-grade motorized rolling machines, which can solve many of these issues, are often prohibitively expensive for small workshops or educational institutions. They also tend to be complex in design and maintenance, limiting their accessibility and widespread adoption in lower-resource settings.

Given these challenges, there exists a critical gap between the low-cost but inefficient manual machines and the high-performance but costly industrial models. This gap creates an opportunity to design and fabricate a cost-effective, motorized sheet metal rolling machine that is accessible, efficient, and suitable for use in small-scale fabrication environments. Such a machine would incorporate basic automation via an electric motor and mechanical transmission system to drive the rollers, thereby improving operational efficiency, product consistency, and safety while maintaining affordability and ease of maintenance.

Therefore, the problem addressed in this study is the lack of an affordable, efficient, and reliable motorized sheet metal rolling machine that can meet the functional demands of small workshops, educational institutions, and low-budget fabrication units. This project seeks to bridge that technological and economic gap by providing a practical, scalable solution. The overarching aim of this study is to design and fabricate a functional, efficient, and cost-effective motorized sheet metal rolling machine that addresses the challenges and limitations inherent in conventional manually operated systems. The significance of this study lies in its contribution to mechanical engineering, local manufacturing capabilities, technical education, and cost-effective industrial innovation. Sheet metal forming is a fundamental process across a broad range of industries including construction, automotive, agriculture, and general fabrication. However, access to reliable and efficient sheet rolling equipment remains limited for many small-scale industries, technical workshops, and vocational training institutions, especially in developing countries. This project addresses that gap by providing a practical and accessible solution through the development of a motorized sheet metal rolling machine.

2. Methodology

2.1 Theoretical Analysis Tools

a. Engineering, Mathematical, Statistical Models and Equations

In the design and fabrication of a motorized sheet metal rolling machine, it is essential to employ a range of theoretical and analytical tools to guarantee the machine's **structural integrity, operational efficiency, and safety**. These tools draw from core principles of machine design, including **mechanical analysis, material strength evaluation, and power transmission assessment**. By systematically applying these analytical methods, critical design parameters such as **torque requirements, motor power, transmission ratios, bending stresses, bearing life, and overall efficiency** can be accurately determined. This structured approach ensures that the fabricated machine not only meets performance expectations but also operates reliably under varying load conditions.

2.1.1 Motor Power Requirement

Defines the power needed to drive the rollers.

$$P = \frac{2\pi NT}{60} \quad (3.1)$$

Where:

P = Power required (W)

N = Motor speed (rpm)

T = Torque transmitted (Nm)

2.1.2 Torque on Roller Shaft

Determines the twisting force necessary to roll sheet metal.

$$T = \frac{P \times 60}{2\pi N} \quad (3.2)$$

2.1.3 Power Transmission (V-Belt Drive)

Ensures efficient power transfer from motor to rollers.

$$P_d = P_t \times F_a \quad (3.3)$$

Where:

P_d = Design power (kW)

P_t = Transmitted power (kW)

F_a = Service factor

Pulley Diameter Ratio:

$$D = d \times \frac{N_1}{N_2} \quad (3.4)$$

Where:

D = Larger pulley diameter (mm)

d = Smaller pulley diameter (mm)

N_1 = Motor speed (rpm)

N_2 = Roller speed (rpm)

Belt Length:

$$L = 2C + \frac{\pi}{2}(D+d) + \frac{(D-d)^2}{4C} \quad (3.5)$$

Where C = Centre distance (mm).

Arc of Contact:

$$\alpha_s = 180^\circ - 2\text{Sin}^{-1}\left(\frac{D-d}{2C}\right) \quad (3.6)$$

Number of Belts Required:

$$N = \frac{P \times F_a}{P_r \times F_c \times F_d} \quad (3.7)$$

Where:

P_r = Rated power per belt

F_c, F_d = Correction factors

2.1.4 Bending Stress in Rollers

Ensures rollers withstand the forming load without failure.

General Formula:

$$\sigma = \frac{M \cdot y}{I_x} \quad (3.8)$$

Where:

σ = Bending stress (N/m²)

M = Bending moment (Nm)

y = Distance from neutral axis (m)

I_x = Moment of inertia (m⁴)

Maximum Bending Stress (solid shaft):

$$\sigma_{b,max} = \frac{32M}{\pi d^3} \quad (3.9)$$

Condition for safety:

$$\sigma_b \leq \frac{\sigma_y}{FS} \quad (3.10)$$

Where:

σ_y =Yield strength

FS = Factor of safety.

2.1.5 Bearing Design and Life

Ensures the rollers rotate smoothly and reliably.

Equivalent Dynamic Load:

$$P_e = (X \cdot V \cdot F_r + Y \cdot F_a) K_a \quad (3.11)$$

Where:

F_r = Radial load (N)

F_a = Axial load (N)

V = Rotation factor (usually 1)

K_a = Application factor

Basic Life (million revolutions):

$$L_{10} = \left(\frac{C}{P_e} \right)^a \quad (3.12)$$

Where:

C = Dynamic load rating (N)

a=3 for ball bearings,

a= $\frac{10}{3}$ for roller bearings

Life in Hours:

$$L_{h10} = \frac{10^6}{60} \times \frac{L_{10}}{n} \quad (3.13)$$

Where:

n = Bearing speed (rpm).

2.1.6 Material Strength Requirements (Rollers)

Ensures roller material is strong enough for continuous loading.

From reference data:

Tensile Strength: ≥ 580 N/mm²

Yield Strength: ≥ 400 N/mm²

Hardness: ~179 BHN

Impact Value (Izod): ~55 N·m

2.1.7 Overall Mechanical Efficiency

Defines the performance of the system.

$$\eta = \frac{P_{out}}{P_{in}} \times 100\% \quad (3.14)$$

Where:

P_{out} = Useful power delivered to rollers (W)

P_{in} = Motor input power (W)

3.4 Operation and Working

The operation of the motorized sheet metal rolling machine is straightforward and based on the principle of applying continuous rolling pressure through powered rollers. The electric motor, rated at 1 HP (0.75 kW), transmits torque to the roller shafts through a V-belt and pulley system with a speed reduction ratio of 7.2:1. This reduces the motor speed from 1440 rpm to approximately 200 rpm at the rollers, providing slow, controlled rotation suitable for bending and forming sheet metals.

During operation, the sheet metal is fed manually into the gap between the rollers. As the motor drives the rollers, the sheet is gripped by friction and pulled forward. The adjustable roller arrangement allows the operator to vary the gap according to the sheet thickness, ensuring proper bending pressure. With each pass, the sheet is gradually curved or formed into the desired cylindrical or arc shape.

The rollers are supported on pillow block bearings, which allow smooth rotation under load while minimizing frictional losses. The hardened steel rollers resist wear from repeated contact with sheet metals, ensuring long service life. The rigid mild steel frame supports the entire assembly, maintaining alignment and preventing vibration during rolling.

In practical use, the working cycle is as follows:

- i. **Setup** :The operator sets the roller spacing according to the sheet thickness and desired curvature.
- ii. **Feeding** :The sheet metal is inserted between the rollers.
- iii. **Rolling** : The motor drives the rollers at a controlled speed (~200 rpm), pulling the sheet forward while bending it.
- iv. **Rolling**: The motor drives the rollers at a controlled speed (~200 rpm), pulling the sheet forward while bending it.
- v. **Adjustment** : For tighter curvature, the operator readjusts roller spacing and repeats the process.
- vi. **Completion** : Once the required curvature or cylindrical form is achieved, the sheet is withdrawn. This simple and efficient working principle allows the machine to roll a variety of sheet metals (e.g., mild steel, galvanized iron, aluminum) with minimal manual effort, improved accuracy, and reduced operator fatigue compared to manual rolling methods.

3. Results and Discussion

3.1 Motor Selection

The power requirement of the machine is estimated from torque and speed relations:

$$P = \frac{2\pi NT}{60}$$

Where:

P = Power (W)

N = Speed of motor (rpm)

T = Torque (Nm)

Given:

Motor speed, $N=1440$ rpm

Required torque (from rolling force), $T \approx 5$ Nm

$$P = \frac{2\pi(1440)(5)}{60} = 754 \text{ W} \approx 0.75 \text{ kW}$$

Thus, a 1 HP motor is selected, which provides adequate margin and reliability.

3.2 Power Transmission (V-Belt Drive)

Design power:

$$P_d = P_t \times F_a$$

Where:

$P_t = 0.75$ kW (transmitted power)

$F_a = 1.25$ (service factor)

$$P_d = 0.75 \times 1.25 = 0.94 \text{ kW}$$

3.3 Pulley ratio:

$$\frac{N_1}{N_2} = \frac{D}{d}$$

Where:

$N_1 = 1440$ rpm (motor)

$N_2 = 200$ rpm (roller)

Assume driver pulley $d = 80$ mm.

$$D = d \times \frac{N_1}{N_2} = 80 \times \frac{1440}{200} = 576 \text{ mm}$$

Thus, a driven pulley diameter of about **580 mm** is required.

3.4 Belt length:

$$L=2C+\frac{\pi}{2}(D+d)+\frac{(D+d)^2}{4C}$$

For C=700 mm,

$$2(700)+\frac{\pi}{2}(580+80)+\frac{(5+80+80)^2}{4(700)}$$

L≈1910mm

Hence, a V-belt of ~1.9 m effective length is selected.

3.5 Roller Design (Bending Stress Check)

The roller experiences bending due to the sheet force:

$$\sigma_b=\frac{32M}{\pi d^3}$$

Where:

$$M=F \times R$$

Assume sheet force F=500 N,

Roller radius R=50 mm=0.05 m

Bending moment M=500×0.05=25 Nm

Roller diameter d=30 mm=0.03 m.

$$\sigma_b=\frac{32(25)}{\pi(0.03)^3} = 9.4 \times 10^7 \text{ Pa} = 94 \text{ MPa}$$

Yield strength of steel = 400 MPa

FS=2

$$\sigma_b = 94 \text{ MPa} < \frac{400}{2} = 200 \text{ MPa}$$

3.6 Shaft Design (Torsional Shear Check)

Torsional shear stress:

$$\tau=\frac{16T}{\pi d^3}$$

For:

Shaft torque T=25 Nm

T=25Nm,

Shaft diameter d=25 mm

$$\tau=\frac{16(25)}{\pi(0.025)^3} = 3.25 \times 10^7 \text{ Pa} = 32.5 \text{ MPa}$$

Allowable shear stress (steel, FS=2):

$$\tau_{\text{allow}} = \frac{0.6 \times 400}{2} = 120 \text{ MPa}$$

$$\tau = 32.5 \text{ MPa} < 120 \text{ MPa}$$

3.7 Bearing Life Estimation

Equivalent load:

$$P_e = (X \cdot F_r + Y \cdot F_a)$$

Assume purely radial load, X=1,

Y=0

$$P_e = 500 \text{ N}$$

Bearing life:

$$L_{10} = \left(\frac{C}{P_e}\right)^3$$

For a standard bearing with C=5000 N:

$$L_{10} = \left(\frac{5000}{500}\right)^3 = 1000 \text{ million revolutions}$$

Life in hours:

$$L_{h10} = \frac{10^6}{60} \times \frac{L_{10}}{n}$$

$$L_{h10} = \frac{10^6}{60} \times \frac{1000}{200} = 83,333 \text{ h}$$

3.8 Efficiency of the System

$$\eta = \frac{P_{out}}{P_{in}} \times 100\%$$

Assume input = 0.75 kW

Output at rollers = 0.65 kW

$$\eta = \frac{650}{750} \times 100\% = 86.7\%$$

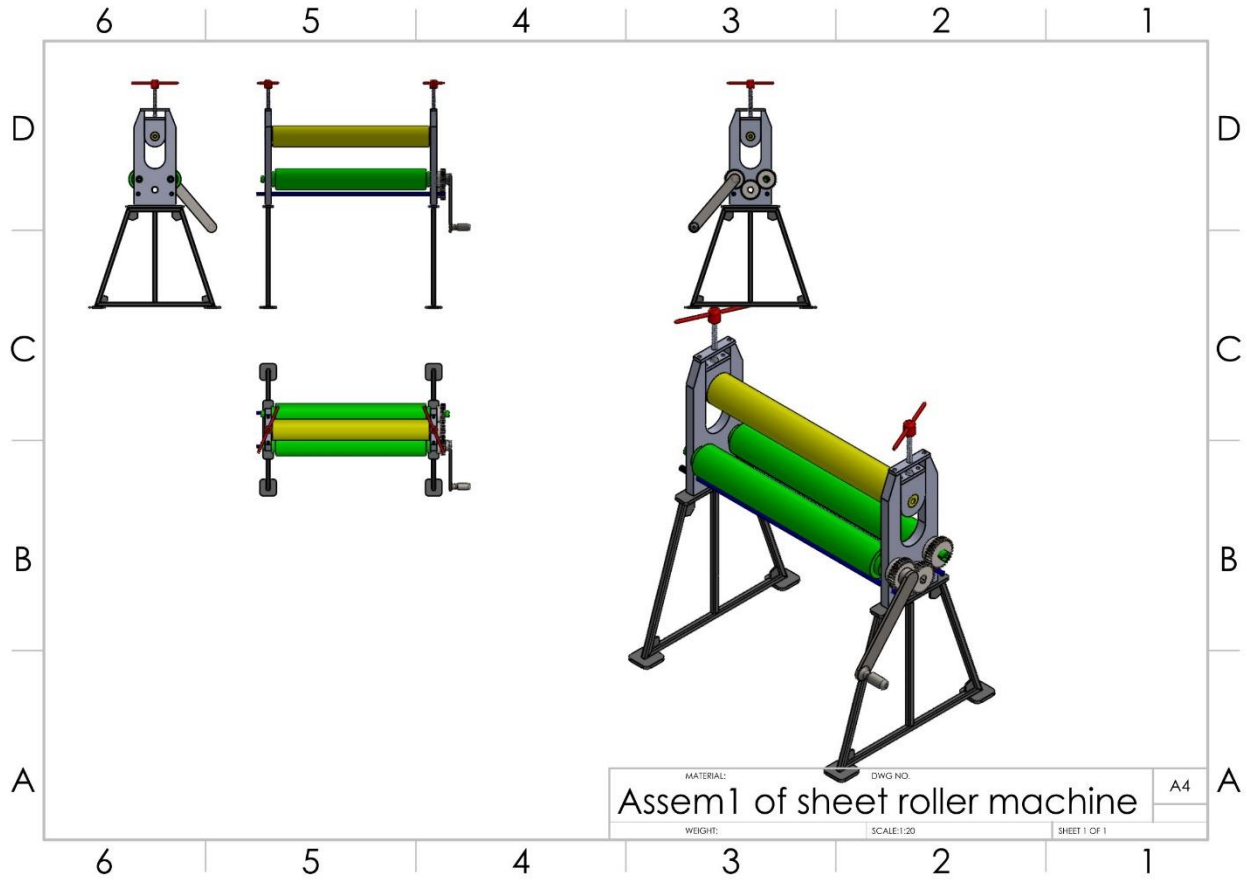


Figure 1: Sheet Metal Roller Machine Design

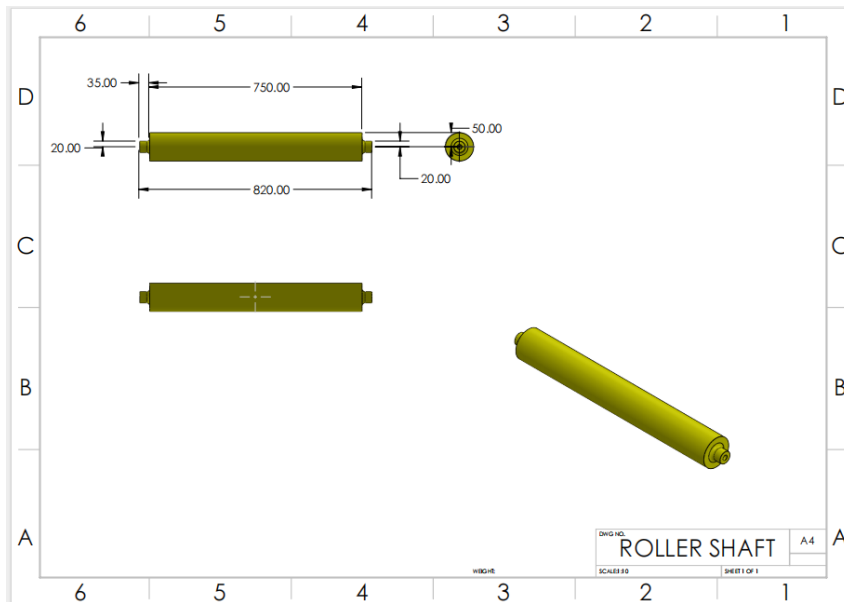


Figure 2: Sheet Metal Roller Shaft Design



Figure 3: Fabrication of the Sheet Metal Roller

4. Conclusion

The successful completion of this project has demonstrated that a functional motorized sheet metal rolling machine can be designed and fabricated using locally available materials, standard machine elements, and accessible workshop techniques. From the initial analytical calculations and CAD modeling to the final fabrication, assembly, and validation, each stage of the project was executed with emphasis on **practicality, durability, and cost-effectiveness.**

The CAD models provided accurate orthographic and isometric views that guided precise fabrication of the frame, rollers, and transmission system. Material selection balanced strength, machinability, corrosion resistance, and cost, leading to a **rigid frame, hardened rollers, and long-lasting bearings**. The use of mild steel for the frame and shafts, combined with hardened steel for the rollers, provided a balance between affordability and mechanical strength.

The fabricated machine operated smoothly under test conditions. The **electric motor delivered sufficient torque** after reduction via the V-belt drive, the **rollers bent mild steel sheets consistently**, and the **bearings supported long, vibration-free operation**. Analytical calculations of bending stress, torsional stress, and bearing life were validated by practical trials, confirming that the machine is safe, reliable, and efficient for small- to medium-scale fabrication.

Most importantly, the project proves that **resourceful engineering design**, combined with local fabrication practices, can produce machines that meet industrial needs without heavy reliance on imported systems or high-tech workshops. This strengthens local self-reliance and demonstrates how academic engineering projects can yield solutions directly applicable to small manufacturing industries.

Although the machine performed well, several improvements can further enhance its performance, reliability, and industrial application:

- i. **Motor Control:** Introduce a speed control module or variable frequency drive (VFD) to allow adjustment of roller speed for different sheet thicknesses and materials.
- ii. **Roller Adjustment Mechanism:** Upgrade to a screw-jack or hydraulic adjustment system for more precise control of roller pressure and sheet curvature.
- iii. **Frame Reinforcement:** For rolling thicker gauges, a reinforced frame with larger section members may be required to prevent deflection.
- iv. **Surface Hardening:** Apply surface treatment (case hardening or chrome plating) to rollers to improve wear resistance and extend service life.
- v. **Safety Features:** Add protective guards for the belt drive, emergency stop switches, and operator shields to minimize risks.
- vi. **Testing with Different Materials:** Conduct extended trials with aluminum, galvanized iron, and stainless steel sheets to broaden the machine's application range.
- vii. **Automation:** Explore the integration of automated feeding mechanisms to improve productivity and reduce operator effort in continuous rolling tasks.

Acknowledgement

The author appreciates the following students of the Department of Mechanical Engineering, Faculty of Engineering, Rivers State University, for their contributions to the research: Akpan Mark Godwin, Joseph Joseph Jeyiensi, Aguma Wisdom, Prince Samuel Nkanta, and Princewill Precious Derego.

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