Mongia GAAIA, Petruţa PETCU, Ana-Maria NICOLAU

ANALYSIS OF A ROLL BENDING MACHINE: ENHANCING EFFICIENCY AND FUNCTIONALITY

Abstract: *This study delves into the analysis of roll bending machines, which are indispensable in the sheet metal forming industry. The primary goal is to investigate the diverse characteristics and versions of roll bending machines available in the market and to propose enhancements to boost their efficiency. Through an in-depth analysis of the current systems and an exploration of potential improvements, especially regarding the upper roll's transmission system, this research aims to optimize the operational performance of roll bending machines. Additionally, an internal functional analysis is conducted to provide a thorough understanding of the product and its mechanics, focusing on improving reliability, product quality, and cost-effectiveness.*

Keywords: *roll bending machine, sheet metal forming, hydraulic transmission, gear motor, functional analysis, energy chain.*

1. GENERAL INTRODUCTION AND DEFINITIONS

This scientific study aims to analyze and enhance the system of a roll bending machine.

A roll bending machine is a mechanical device used to bend metal sheets or plates into curved or cylindrical shapes.

This process, known as roll bending, involves passing the metal workpiece through a series of rollers that apply pressure to the material, inducing plastic deformation and resulting in a desired curvature.

Roll bending machines can be categorized into three-roller or four-roller configurations, each offering different capabilities and precision levels.

They are widely used in the manufacturing of pipes, tubes, and other cylindrical metal structures [1 – 6].

These machines apply pressure via rollers, inducing plastic deformation to achieve the desired curvature. Roll bending machines are essential in manufacturing processes for producing pipes, tubes, and structural components, with applications in industries such as automotive, aerospace, and construction [7 – 9].

The research focuses on improving the machine's performance while ensuring reliability, high-quality output, and cost efficiency.

2. INFORMATION ON ROLL BENDING MACHINES

For Roll Bending Machines we have a lot of types with different characters that can help us with different needs. Types of Roll Bending Machines:

- Pyramid Roll Bender:
  Utilizes three rollers positioned in a triangular configuration (two lower and one upper), where the top roller applies downward pressure to the metal sheet positioned on the bottom rollers. This type of machine is commonly used for medium to large diameter bending. This process leaves flat areas at the ends, requiring a press brake to complete the bending [10].
- Three-Roll Plate Roll: Features an upper roll above one of the lower rolls to press and bend the sheet. The second lower roll feeds the sheet and exerts upward pressure, initiating bending on one side. To ensure uniform bending, the piece must be flipped.
- Four-Roll Plate Roll: It is ideal for bulky and thick pieces. Incorporates four rollers, with two central rollers providing the main bending force and two outer rollers guiding and feeding the metal sheet. This configuration allows for more precise control and the ability to bend smaller diameters. It is ideal for bulky and thick pieces. [11].
- CNC Roll Bending Machine A computer numerically controlled (CNC) roll bending machine that offers automated and highly precise bending operations. The CNC system ensures repeatability and accuracy, making it ideal for complex and high-volume production. Widely used in the production of custom metal parts and components in industries requiring high precision, such as robotics and advanced manufacturing [10].

Also, we note different versions of Roll Bending Machines that are designated for different sizes of parts to be blended [11].

Versions of Roll Bending Machines:

- Manual Version: Capable of bending sheets up to 1.6 mm thickness.
- Electric Version: Capable of bending sheets up to 2.3 mm thickness.
- Hydraulic Version: Capable of bending sheets up to 3.5 mm thickness.

Sizes of Roll Bending Machines: Available in large and small sizes.

3. PROBLEMATIC

The current systems present a series of deficiencies that affect their efficiency, sustainability, and performance.

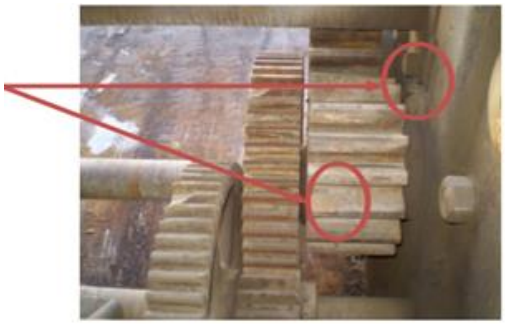

Figure 1: Issue 1 - Gear Teeth Breakage

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The main challenge is the frequent breakage of gear teeth, which results in system downtime and expensive repairs.

Solution Focus**:** Identify the root causes of gear teeth failure, such as material fatigue, misalignment, or overloading, and apply corrective actions to improve durability and system performance.

Figure 2: Issue 2 - Flywheel Damage Due to Pulley Malfunction

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The second highlighted issue is the flywheel damage caused by pulley malfunction, leading to significant system interruptions.

Solution Focus: Conduct a thorough analysis of pulley-flywheel interactions, identify weaknesses in the current design or materials, and develop robust solutions to prevent recurrent damage.

Figure 3: Issue 3 - Production of a Partial Gear for Pivot Bearing Guidance

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The issue involves challenges in the production of partial gear required for guiding a pivot bearing, impacting overall system efficiency.

Solution Focus: Optimize the manufacturing process for the partial gear, ensuring precision and consistency to improve the guidance of the pivot bearing and reduce wear and tear.

Table 1

Price table of components of a geared motor

Component	Main functions	Cost
2 Réducteur	FT1	400 €
2 Moteur électrique	FT2	
2 Vérin hydraulique	FT3	400€
Pompe	FT 6	60€
Moteur hydraulique	FT1	90€
2 distributeurs	FT2	75€
Vanne	FT9	10 €
Limiteur de pression	FT5	40€

By making a small comparison between the technical functions and services of the two main functions: "transmit hydraulic energy into mechanical energy" and "transmit electrical power into mechanical power" we find that the first seems more complex, long and requires several components compared to the second function, so we will adapt the second solution (motor-reducer) for the transmission of the upper roller.

4. RESULTS

After analyzing the issues, we identified three potential solutions:

- Pulley and belt system.
- Gear system.
- Sprocket and chain system.

To identify the best solution, we must analyze all of them and compare them.

The first one was the Pulley and belt system.

A pulley and belt system transmits power in the rotational motion from one shaft to another. The shafts can be at a considerable distance from each other.

This system has flowing advantages.

- One driving shaft can have multiple driving shafts.
- Economical setup and easy maintenance.
- Absorbs vibrations and transmission shocks, thereby increasing the lifespan of both the driving and driven components.
- Ensures quiet operation.

Also, it’s normal to have some disadvantages.

Belts have a shorter lifespan compared to most mechanical components, necessitating regular monitoring of wear and a periodic maintenance plan (preventive maintenance) to counteract belt aging.

Table 2

Functional Analysis Table TAF

Function / **Cost/ piece**	**Fp1** [€]	**Fc1** [€]	**Fc2** [€]	**Fc3** [€]	**Fc4** [€]	**Fc5** [€]	**Design Function** [€]
P1/ 200€	70	40	40		30		20
P2/ 150€	50	40	40				20
P3/ 150€	70	50					30
P4/ 40€	15	15					10
P5/ 100€	50					20	30
P6/ 400€	50	40	30	100	40	40	100
P7/ 50€				20	20		10
∑ **Cost**	440	185	110	30	90	60	220
	915€						

Efficiency:

Efficiency = (Design function cost ÷ Total cost) x 100

= (220 ÷ 915) x 100

= (24.04%) ≤ (40%)

Figure 3: Pulley and belt system

The second solution was the Gear system.

A gear system consists of two meshed gears that serve to either:

- Transmit rotational motion between them, or
- Propel a fluid (referred to as a gear pump).

The advantages of this system are:

- Transmission of high power at high rotational frequencies.
- Constant and precise transmission ratio.
- Perfectly homokinetic transmission.
- Capability to transmit power between multiple shafts.
- Good overall efficiency, depending on quality class.
- Long lifespan.
- High reliability.

And about the disadvantages, are a bit more than the ones of the first solution:

- Requires a precise and constant center distance.
- Variable noise levels depending on the type of gear.
- Transmits shocks and vibrations.
- Requires lubrication, often by fluid.
- Reversibility possible depending on the type of gear.
- Cost varies greatly depending on the type of gear and quality class.

Figure 4: Gear system

Finally, the last one is the Sprocket and chain system. To transmit continuous rotational motion between two distant parallel shafts using an articulated link, the „chain”.

Figure 5: Gear system

This system has the following advantages:

- Long lifespan;
- Ability to drive multiple receiving shafts simultaneously.
- Suitable for "low" transmission speeds (13 to 20 m/s for silent chains);
- Can withstand harsher working conditions compared to belt-pulley systems.

Also, we have some disadvantages compared to Belt-Pulley Systems:

- Noisier;
- Lower rotational speeds;
- Requires lubrication.

5. DISCUSSION

Using the advantages and disadvantages of the aforementioned solutions, we have created the following table.

Table 3

Comparison Table of Solutions

Criteria	Belt and Pulley System	Gear System	Pulley and Chain System
Durability	-	+	+
Efficiency	+	+	+
Cost	+	-	-
Shock Resistance	+	-	-

Based on the comparative analysis presented in Table 3, the Belt and Pulley System emerges as the optimal solution for enhancing the roll bending machine's performance. Despite its lower durability, the system's advantages in terms of cost-effectiveness, efficiency, and shock resistance outweigh its drawbacks. Its balance of operational benefits makes it the most suitable choice for improving system performance in this context.

While other systems may offer greater durability or efficiency, the Belt and Pulley System's overall performance and economic advantages position it as the best fit for the application, providing a well-rounded solution for enhancing the roll bending machine.

6. CONCLUSIONS

The results enable the improvement of the selection of suitable solutions for this system, relying entirely on research using functional analysis and value analysis methods.

Functional analysis and value analysis are highly important, effective, and systematic tools that consistently assist in the comprehensive study and optimization of any product. These methodologies provide a structured approach to understanding a product's functionality and value, making them indispensable in the process of redesigning or improving existing systems. By breaking down a product into its fundamental components and examining their functions, functional analysis helps identify areas of potential enhancement. Similarly, value analysis focuses on optimizing the cost-to-function ratio, ensuring that every element of the product contributes effectively to its overall performance without unnecessary expenditure.

The application of functional and value analysis methodologies in this study has been crucial in evaluating and enhancing roll bending machines. By systematically addressing the identified issues and comparing potential solutions, this research contributes to optimizing the design and functionality of roll bending machines, ensuring improved performance and cost-effectiveness in manufacturing applications.

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Authors:
Mongia GAAIA student Engineer, Master, Faculty of Engineering in Foreign Languages – FILS, National University of Science and Technology POLITEHNICA Bucharest. E-mail: kenza.gaaia@gmail.com
Petruța PETCU, PhD Student Engineer**,** Department of Engineering Graphics and Industrial Design, Faculty of Engineering Aerospace, National University of Science and Technology POLITEHNICA Bucharest. E-mail: petruta.toderasc@yahoo.com
Ana-Maria NICOLAU, PhD Engineer, lecturer, Department of Engineering Graphics and Industrial Design, Faculty of Engineering Aerospace, National University of Science and Technology POLITEHNICA Bucharest. E-mail: avr_ana@yahoo.com