Automation of Aluminum Rolling Mill Process Using ABB 800xA

Manuj. P [1], Pavan Ramesh [1], Dr. Anand Jatti [2], Mukesh Kumar Singh [3], Madhu Dabhole [3]

[1] UG student, Department of Electronics and Instrumentation Engineering, RV College of Engineering, Bengaluru, Karnataka, India.
[2]Associate Professor, Department of Electronics and Instrumentation Engineering, RV College of Engineering, Bengaluru, Karnataka, India.
[3]Project Lead Engineer, PA Department, ABB India Ltd., Peenya, Bengaluru, Karnataka, India

Abstract: The paper analyzes the application of ABB's 800xA distributed control system (DCS) to the automation of aluminum rolling mills. It explores the various rolling processes, the important components involved, and the 800xA platform's automation implementation approach. The possible advantages of automation are covered throughout the paper, and then its effects on the aluminum rolling industry are looked at in the last part.

Keywords: Automation, Rolling Mill Process, Coils, Aluminum, DCS, Coils

A. Introduction

Aluminum rolling mills are vital to producing premium aluminum foils and sheets that are utilized in the packaging, automobiles, and aviation sectors, among other industries. Aluminum slabs are rolled through a succession of rolling stands in order to reduce their thickness. In order to maximize this process, guarantee consistency, and enhance the quality of the end result, automation is essential. The ABB 800xA system is a sophisticated DCS designed to optimize industrial operations by combining control, monitoring [1], and optimization features. This study examines the use of ABB 800xA in aluminum rolling mills, with an emphasis on how it affects both product quality and process efficiency. Table I shows the basic mill Specifications for aluminum rolling mill process. Schematic of rolling bite geometry is shown in Figure. 1

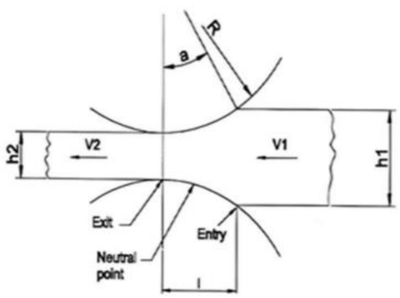

Fig. 1. Roll Bite Geometry

TABLE I.

Basic mill specifications	
Four-high cold reducing mill light to intermediate gauge non - reversing	
Material	Aluminum - alloys
Work rolls	18 to 16" diameter 72" roll face
Back-up rolls	48" to 44" diameter 66" roll face
Strip entering thickness	0.125" max - 0.006" min
Strip delivery thickness	0.064" max - 0.004" min
Strip width	62" to 25"
Coil inside diameter	20"
Coil outside diameter	76"
Coil weight	400 pounds/inch width

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 06 | June - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

Draft range	5 - 70%
Extrusion compensation	0 - 20%

B. Types of Rolling

1. Hot Rolling

Hot rolling is the initial stage of forming aluminum slabs into thinner sheets or coils. Here's a detailed breakdown of hot rolling in the aluminum rolling mill process:

I. Process Description

a) Heating: The aluminum slabs, typically cast and homogenized beforehand, are fed into a furnace. This furnace heats the slabs to a specific temperature range, typically between 300°C and 500°C (572°F and 932°F). The exact temperature depends on the aluminum alloy being processed and the desired final properties [8]. Heating makes the aluminum more malleable and easier to deform. Schematic of hot rolling is shown in Figure. 2

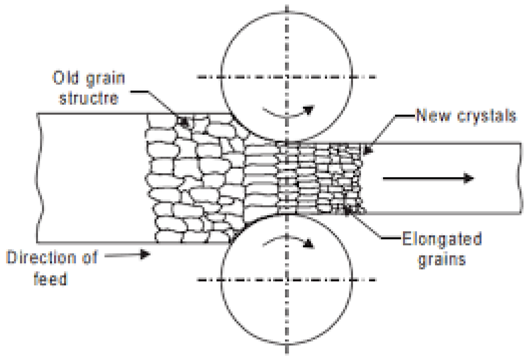

Fig. 2. Hot Rolling

2. Cold Rolling

Following the hot rolling stage, cold rolling takes center stage in the aluminum rolling mill process. This stage refines the thickness of the aluminum sheet further, enhances its dimensional accuracy, and improves its surface finish. Here's a detailed breakdown of hot rolling in the aluminum rolling mill process:

I. The Process

a) Room Temperature Operation: Unlike hot rolling, cold rolling is performed at room temperature or slightly above. This eliminates the need for preheating furnaces, making it a more energy-efficient process.

b) Types of Mills: Cold rolling can be achieved using various mills, including single-stand mills, cluster mills, and temper rolling mills. Single-stand mills are commonly used for thicker gauges, while cluster mills with multiple stands are employed for achieving very thin gauges like those used in aluminum foil.

c) Reduction in Thickness: Similar to hot rolling, the aluminum sheet is passed between powerful rolls. However, the roll gap reduction in cold rolling is typically smaller compared to hot rolling, leading to more precise control over the final thickness.

d) Work Hardening: Cold rolling plastically deforms the aluminum at room temperature. This process, known as work hardening [7], strengthens the aluminum but also reduces its ductility (ability to deform without breaking). Schematic of cold rolling is shown in Figure. 3

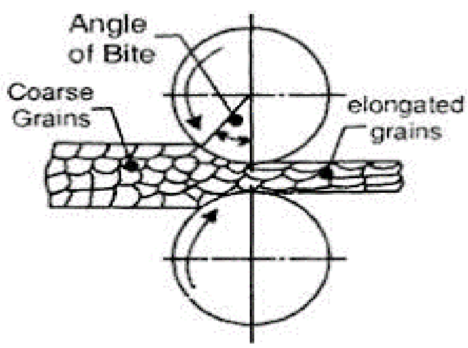

Fig. 3. Cold Rolling

C. Plant Model

The basic equations of cold mills are as follows.

(1) Mass Velocity Equation

$M_1 \cdot V_1 = M_2 \cdot V_2$ (1)

M_1 is mass before entering work roll

V_1 is velocity before entering work roll

M_2 is mass after entering work roll

V_2 is velocity after entering work roll

(2) Roll Separation Force (RSF)

$F = L \cdot w \cdot \sigma$ (2)

F is RSF

L is the length of contact between the rolls and the strip.

w w is the width of the strip

σ is the average flow stress of the material.

(3) Interstand Tension

$\Delta T = A \cdot \frac{E}{L} \cdot \Delta\varepsilon$ (3)

ΔT is Interstand tension

A is cross section area

E is Young's modulus of strip

L is distance between stands

Δε is longitudinal strip strain between stands

(4) Thickness Velocity Equation

$H_1 \cdot V_1 = H_2 \cdot V_2$ (4)

H_1 is thickness before entering work roll

V_1 is velocity before entering work roll

H_2 is thickness after entering work roll

V_2 is velocity after entering work roll

D. Types of Rolls

In the aluminum rolling mill process, various types of rolls are used to achieve different rolling outcomes. Each type of roll is designed for a specific purpose, providing the necessary deformation and shaping of aluminum sheets and products. Here are the primary types of rolls used in aluminum rolling mills:

1. Work Rolls

I. Description: These are the rolls that come in direct contact with the aluminum material being processed. They are responsible for the actual reduction in thickness and imparting the desired surface finish to the aluminum sheet.

II. Material: Typically made from high-strength steel or cast iron with a hardened outer layer.

III. Usage: Used in both hot and cold rolling processes.

2. Backup Rolls

I. Description: These rolls provide support to the work rolls to prevent them from bending under the rolling force. Backup rolls help maintain the shape and consistency of the work rolls, ensuring uniform thickness of the aluminum sheet.

II. Material: Made from hardened steel or cast iron.

III. Usage: Primarily used in cold rolling mills where high rolling forces are involved.

3. Intermediate Rolls

I. Description: Intermediate rolls are placed between the work rolls and backup rolls in multi-roll mills [9]. They help distribute the load and further reduce the thickness of the aluminum material.

II. Material: Made from steel or iron with a hard outer layer.

III. Usage: Commonly used in multi-roll mills like 4-high or 6-high mills. Schematic of types of rolls is shown in Figure. 4

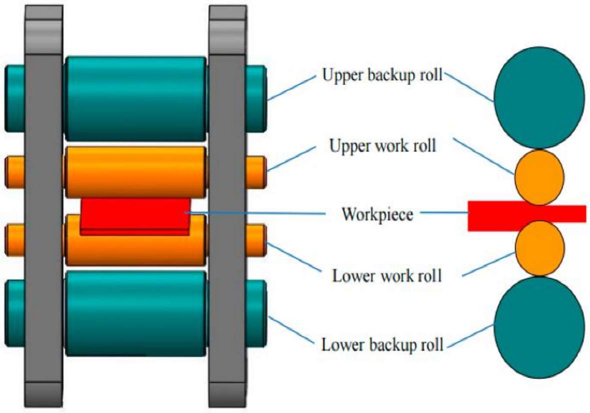

Fig. 4. Types of Rolls

4. Cluster Mill Rolls

I. Description: In cluster mills, several smaller work rolls are used with multiple backup rolls to achieve very high rolling pressures and precise control over thickness reduction.

II. Material: High-strength steel or alloy.

III. Usage: Used for rolling very thin aluminum sheets and foils.

5. Edger Rolls

I. Description: These rolls are used to maintain the width of the aluminum sheet and to prevent edge cracking during the rolling process.

II. Material: Made from hardened steel.

III. Usage: Used in both hot and cold rolling processes to ensure edge quality.

These rolls work together in the rolling mill to produce aluminum sheets and products of varying thicknesses and surface finishes, suitable for various applications in industries such as automotive, aerospace, packaging, and construction.

E. Types of Configurations

In the aluminum rolling mill process, various configurations are used to achieve different production goals, such as reducing the thickness of aluminum sheets, improving surface finish, and enhancing mechanical properties [5]. Here are the main types of configurations used in aluminum mills:

1. Two-High Rolling Mill

I. Description: This configuration consists of two opposing rolls that reduce the thickness of the aluminum strip.

II. Usage: Primarily used for roughing passes, where large reductions in thickness are required.

2. Four-High Rolling Mill

I. Description: Consists of two smaller diameter work rolls and two larger diameter backup rolls. The backup rolls support the work rolls to prevent them from bending under the rolling force.

II. Usage: Commonly used for both intermediate and finishing passes.

3. Six-High Rolling Mill

I. Description: Includes an additional set of intermediate rolls between the work rolls and backup rolls, providing additional support and control over the rolling process.

II. Usage: Suitable for producing high-quality thin aluminum sheets with precise control over thickness and flatness. Schematic of types of configuration is shown in Figure. 5

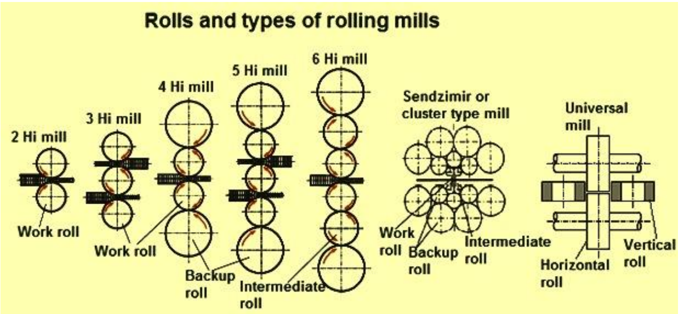

Fig. 5. Types of Configurations

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 06 | June - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

4. Cluster Mill

I. Description: Features a cluster of small-diameter work rolls supported by larger backup rolls. This configuration allows for high rolling pressures and precise thickness control.

II. Usage: Ideal for rolling very thin aluminum foils and sheets with excellent surface finish and tight tolerances.

5. Planetary Mill

I. Description: Contains a pair of large backup rolls surrounded by a number of smaller work rolls in a planetary arrangement [9]. The work rolls rotate around the backup rolls while the aluminum strip passes through.

II. Usage: Suitable for reducing thick slabs into thin sheets in a single pass.

6. Continuous Rolling Mill

I. Description: A series of rolling stands arranged in a line where the aluminum strip passes through each stand in succession.

II. Usage: Used for high-volume production of aluminum sheets and strips with consistent properties.

7. Reversing Rolling Mill

I. Description: A mill where the direction of the rolling process can be reversed to allow the aluminum strip to pass through the rolls multiple times for gradual thickness reduction.

II. Usage: Suitable for flexible production schedules and for producing a variety of thicknesses with a single mill.

E. Components Used

1. Rolling Mills

Rolling mills consist of several components, including work rolls, backup rolls, roll chocks, and mill stands [1]. These elements work together to apply compressive forces to the aluminum slab, reducing its thickness.

2. ABB 800xA System

The ABB 800xA system is a comprehensive automation solution that integrates control, monitoring, and optimization functions. Key components include:

I. Controllers: High-performance processors that execute control algorithms.

II. I/O Modules: Interface devices that connect sensors and actuators to the control system.

III. Human-Machine Interface (HMI): User interfaces that allow operators to monitor and control the process.

IV. Communication Networks: High-speed data networks that facilitate communication between system components. Picture of ABB DCS is shown in Figure. 6

Fig. 6. ABB 800xA DCS

3. Sensors and Actuators

Various sensors and actuators are used to measure and control process parameters such as temperature [8], pressure, thickness, and speed. Examples include:

I. Thickness Gauges: Devices that measure the thickness of the aluminum sheet in real-time.

II. Load Cells: Sensors that measure the rolling force applied to the aluminum slab.

III. Temperature Sensors: Devices that monitor the temperature of the rolling mill and aluminum slab.

IV. Actuators: Devices such as hydraulic cylinders and electric motors that adjust the position and force of the rolling mill components.

F. Methodology Used

1. Process Control

The ABB 800xA system employs advanced control algorithms to optimize the rolling process. Key control strategies include:

I. Feedback Control: Uses real-time sensor data to adjust process parameters and maintain desired output.

II. Feedforward Control: Anticipates process disturbances and adjusts control actions accordingly.

III. Model Predictive Control (MPC): Utilizes mathematical models to predict future process behavior and optimize control actions.

2. Data Acquisition and Analysis

The system continuously collects data from sensors and instruments throughout the rolling process. This data is analyzed to identify trends, detect anomalies, and optimize process parameters [6].

3. Integration and Communication

The ABB 800xA system integrates various subsystems, including mechanical, electrical, and hydraulic components. High-speed communication networks ensure seamless data exchange and coordination between system components.

4. Flow Chart

I. Mill Entry Process

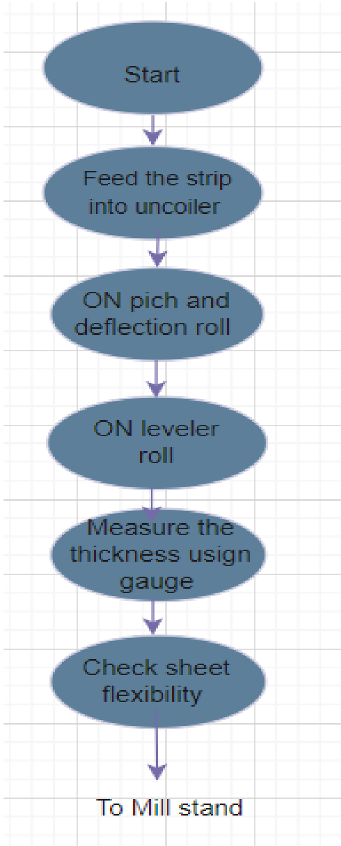

Fig. 7. Mill Entry Flow Chart

a) In the mill entry side, it starts with feeding the aluminium around the un-coiler.

b) When the process starts, the un-coiler starts to rotate, while a thin sheet of aluminium is fed into the mill stand with the help of pinch rolls and deflection rolls

c) Then the surface of the aluminium is flattened if found to be uneven with the help of leveller rolls

d) Then the thickness of the strip is measured with the help of Thickness measurement gauge.

e) It is done with the help of passing the X-rays or Lasers

Then it under goes flexibility testing to make sure the aluminium is not completely rigid and make it useful for further process. Flow chart of mill entry is shown in Figure. 7

II. Mill Stand Process

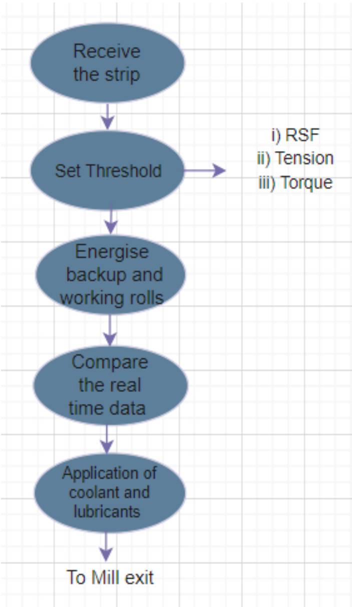

Fig. 8. ABB 800xA DCS

a) The functioning of processes in the mill stand can be visualized as shown in the figure.

b) It contains the following components

i) Load cell

ii) Speed gauge

iii) Thickness gauge

iv) Gauge Control

c) The thickness, tension and speed measurement of the strips is taken from both the input and output side with the help of Speed gauge and Thickness gauge.

d) It is compared and tested with the set point which is fed to the GMG.

e) Here GMG controls the HGC thus adjusting the roll gap, to get the desired thickness of aluminum sheet.

f) Now after this process the strip is sent to the mill exit side. Flow chart of mill stand is shown in Figure. 8

III. Mill Exit Process

a) After the aluminium sheet undergoes appropriate thickness reduction, it is sent to the mill exit side

b) Here it checks if the sheets have uniform surface, else it is passed through levelling rolls.

c) Then again the thickness is measured using the gauges to check if it is that of expected.

d) Then it is sent to the deflection roll where it is passed to the re-coiler

e) There it is stored and produced in the conveyor belts for further processes like coating of surfaces or another round of thickness reduction. Flow chart of mill exit is shown in Figure. 9

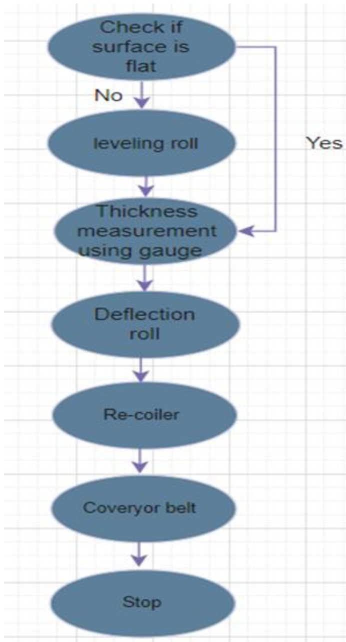

Fig. 9. ABB 800xA DCS

5. Simulation and Testing

Before full-scale implementation, the system is tested using simulations to validate control strategies and ensure reliable performance. This step helps identify potential issues and optimize system configuration.

G. Results

The implementation of ABB 800xA in aluminum rolling mills has yielded significant improvements in process efficiency, product quality, and operational reliability [2]. Key results include:

1. Increased Throughput: The automation

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 06 | June - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

system has optimized rolling schedules and reduced downtime, leading to higher production rates.

2. Improved Thickness Control: Advanced control algorithms have enhanced the precision of thickness measurements, resulting in more consistent product dimensions.
3. Enhanced Surface Quality: Automation has minimized defects and surface imperfections, improving the overall quality of the aluminum sheets and foils.
4. Energy Savings: Optimized process parameters have reduced energy consumption, lowering operational costs and environmental impact.
5. Reduced Maintenance Costs: Predictive maintenance capabilities have decreased the frequency and severity of equipment failures, reducing maintenance expenses.
6. Improved Product Quality: Precise control over thickness, tension, and speed leads to consistent and high-quality aluminum sheets.
7. Increased Production Efficiency: Automation streamlines the rolling process, and optimizes throughput [1]. Graph of Stress vs Strain is shown in Figure. 10

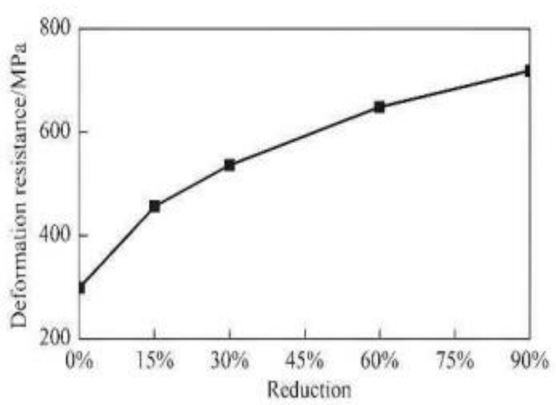

Fig. 10. Stress Vs Strain Curve of Strip

8. Reduced Scrap Rates: Consistent control minimizes variations and potential defects, leading to less scrap generation.
9. Enhanced Safety: Automated systems improve safety by reducing manual intervention in critical operations.
10. Real-time Data Acquisition and Analysis: The 800xA system provides real-time data on process parameters, enabling operators to make informed decisions and optimize rolling parameters.

H. Discussion

The implementation of ABB's 800xA automation system brings significant advancements to aluminum rolling mills. However, some points merit discussion:

1. Initial Investment: The initial investment for deploying the 800xA system can be substantial. However, the long-term benefits in terms of efficiency and product quality often outweigh the initial cost.
2. Technical Expertise: Integrating and maintaining a complex automation system requires skilled personnel with expertise in both rolling mill processes and the 800xA platform [8]. Table II shows the comparison between previous and proposed values.

TABLE II.

Sr No.	Comparison Table		
	Parameters	***Previous Values***	***Proposed Value***
1	Type of Forming	Cold Rolling	Multipass Cold Rolling
2	Lubrication	Based on material	Mixed Lubrication
3	Type of analysis	Flow Analysis	Fluid Flow Analysis
4	Stability of Mill	Unstable	Stand for support with hydrodynamic feed
5	No of Pass	Single-pass	Multi-pass
6	Use of ML	Not used	ML should be used

3. Customization: The automation system needs to be customized based on the specific mill configuration and rolling requirements.

I. Conclusion

ABB's 800xA DCS offers a powerful solution for automating aluminum rolling mills. It enhances process control, improves product quality, and boosts overall production efficiency.

The automation of aluminum rolling mills using ABB 800xA has demonstrated substantial benefits in terms of efficiency, quality, and cost-effectiveness. However, the implementation of such a sophisticated system requires careful planning, extensive testing, and continuous monitoring to ensure optimal performance [5]. Future research should focus on further enhancing control algorithms, improving system integration, and exploring new applications of automation in the aluminum rolling industry.

J. References

[1] Hani M. Mahfouz, "Aluminum Rolling: Processes, Principles & Applications," vol 20, 2021.

[2] George E. Totten (Ed.), "Aluminum Rolling: Advances in Modeling, Simulation, and Applications," vol 221, 2019.

[3] Yunbo Liu, Shuang Liu, Bin Zhang, "Development and Application of Roll Contour Configuration in Aluminum Cold FRolling," vol 6, 2022.

[4] Xingchen Liu, Jingwei Zhao, Zhiyuan Yan, "Surface Roughness Prediction in Aluminum Cold Rolling Process Based on Recurrent Neural Network," vol 56, 2020.

[5] Xiaodong Zhang, Changsheng Ma, Qingshan Chen, "An Integrated Approach for Modeling and Optimization of Aluminum Cold Rolling Processes," vol 14, 2019.

[6] Masayoshi Akiyama, Takeshi Uemura, Yasuhiro Ito, "Development of Rolling Oil with High Cleanliness for Aluminum Cold Rolling," vol 10, 2020.

[7] Honglin Wang, Yuzhi Wang, Hui Li, "Challenges and Solutions in Aluminum Hot Rolling Mills," vol 19, 2021.

[8] Nirajkumar Patel, Pratik Shah, Dhruti Shah, "Automation and Control of Aluminum Rolling Mill using PLC and SCADA," vol 12, 2019.

[9] Srinivasrao Paduchuri, V. M. Arunachalam, "Optimization of Rolling Parameters in Hot Rolling of Aluminum Strips using ABB 800xA Control System," vol 22, 2020.