Process Efficiency Improvement of Billet Saw and Digitalisation of Ingot Caster at EGA

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Abstract

The billet and ingot binding process, followed by the saw cutting complex and ingot stacking through robots at the EGA Cast House, plays a critical role in ensuring a seamless flow of production and customer requirements. This paper explores the identification of various types of process wastages, inefficiencies, and non-value-added activities in Billet Saw Complex. The amalgamation of this exploration will facilitate the seamless cutting of billets with a minimum 2000 mm cut length with an increase in process capability by approximately 25 % to 40 %.

Alongside, a new smart Missing Piece Detection System (MPDS) was introduced in ingot caster at EGA. The MPDS leverages digitalisation, advanced technologies, including smart sensors, sensor networks and pattern recognition. The integration of these technologies enables the real-time detection of missing ingots, thereby improving operational effectiveness and minimizing disruptions in the production process to enhance overall process efficiency.

The paper focuses on process optimisation, identification of various process wastages, system's architecture, anomaly detection algorithms, user interface and utilisation of advanced technologies aligning production demands to improve workflow efficiency by eliminating process depletion and adopting new digital smart system which support Industry 4.0 as well.

Keywords: Elimination of process wastage, Digitalisation and smart sensors, Process efficiency improvement, Reduced cycle time and rework, Flexibility in production planning.

1. Introduction

1.1 Billet Saw Complex at EGA Cast House

An aluminium billet saw is designed to cut long aluminium billets into shorter, precisely sized sections for downstream processes like extrusion, forging, or rolling. These saws are optimised for high precision, efficiency, and minimal material waste.

Functions of an aluminium billet saw complex include:

a) Billet loading
b) Positioning and clamping
c) Cutting to length
d) Cut length control
e) Chip removal and cooling
f) Billet discharge and handling
g) Safety and control.

1.2 Ingot Caster at EGA Cast House

The aluminium ingot casting process involves converting molten aluminium into solid ingots typically in various forms such as sows, T-bars, or smaller remelt ingots. The goal is to create a manageable, transportable, and re-meltable product for further processing.

Functions of an aluminium ingot casting system include:

h) Receiving and Filtering Molten Aluminium
i) Mould Filling (Casting)
j) Ingot Formation & Solidification
k) Ingot Removal
l) Weighing, Marking & Stacking
m) Cooling and Storage

2. Constraints and Transformational Opportunities for Billet Saw Complex

2.1 Current Limitations and Paths to Optimization for Billet Saw Complex

In Jebel Ali Cast House-2 molten aluminium is cast in billets through direct casters DC-4 and DC-5 and then transferred to continuous homogenizing furnaces Phase-3 and Phase-4. Homogenized billets are transferred to saw complex to prepare finished products as per customer requirements.

After homogenization process from Phase -3 complex, billets move through conveyors and then are transferred to Saw-E and Saw-F complex while in Phase-4 billets are moved to Saw-G and Saw-H complex for cutting of billets as per customer requirements. In Cast House-2, long billet cut length requirement varies from 2000 mm to 7500 mm.

In present condition, only two billet saws named Saw G and Saw H, following continuous homogenizing Phase 4 complex, are equipped to cut minimum 2000 mm length while billet Saw E and Saw F following continuous homogenizing Phase-3 complex are equipped to cut minimum 2200 mm length.

2.2 Improvement to Optimize the Overall Process Capability

Value stream is each single process step (value-added and non-value added) required to design, order and provide a specific product from concept to launch, order to delivery, and raw materials to finished product at the place where the customer needs it. Figure 1 shows value stream mapping flow chart.

Following value stream mapping analysis, there are 4 stages which need to be followed to identify various process wastages to work upon:

a. Current state
b. Wast identification
c. Ideal state
d. Future state.

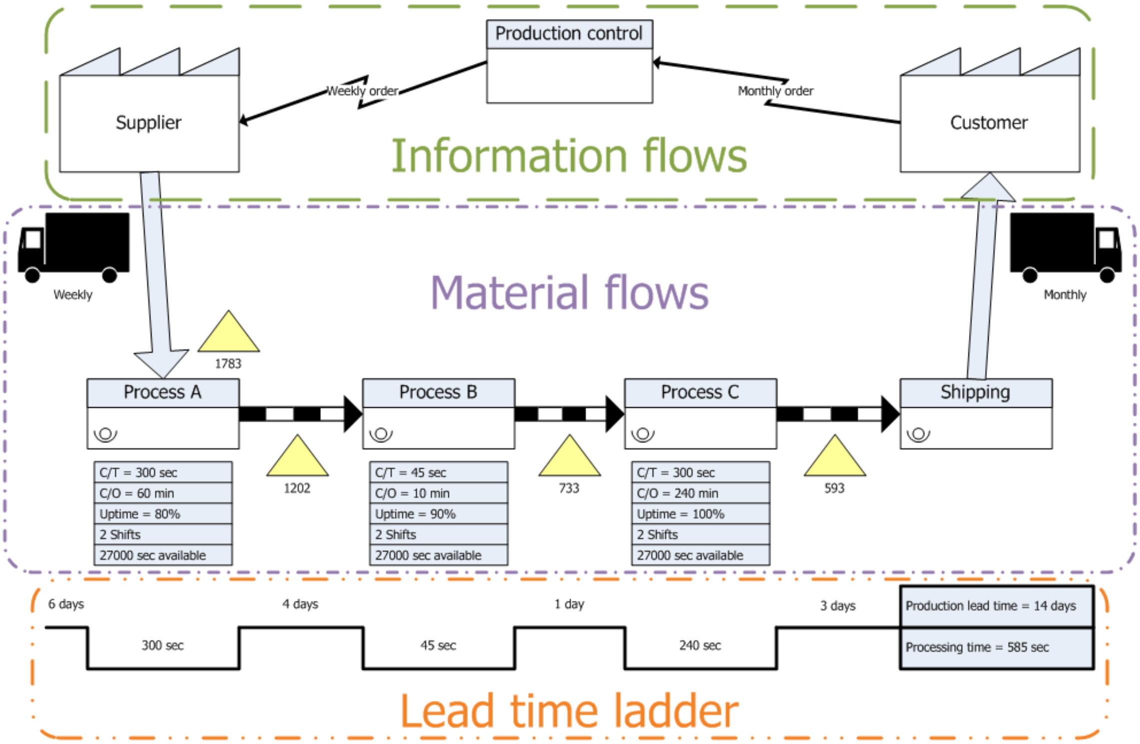

Figure 1. Value stream mapping flow chart – for sample reference only.

a. **Current state** to execute the process of 2000 mm cut length through Phase 3 route via billet saws G and H consumes enormous time. Various wastages in process are escalating the delay in billet cutting and binding process.

b. **Process Waste identification** to focus on recognizing all types of waste within the system, encompassing both value-added and non-value-added activities. The key processes identified as sources of waste or non-value-adding include:

- Transportation of billets to loading table and then to billet Saw-H.
- Time spent to search/arranging forklift
- Waiting time in Saw loading/unloading table for billet to make batch of 4 to 5 billets.
- Breakdown during the process – either due to skill or wrong practice.
- Re-work in case of breakdown.

c. **Ideal state** derived after removing all the wastages (value added and non-value-added) from the current state. Herewith ideal state was identified to evaluate further in terms of improving process efficiency.

Evaluating waste identification and ideal state, a deep dive analysis is required to be carried out to eliminate unwanted process waste. Following through root cause analysis, shown in fishbone analysis in Figure 2, a meticulous action plan was prepared to remove various process wastages identified through above methodology.

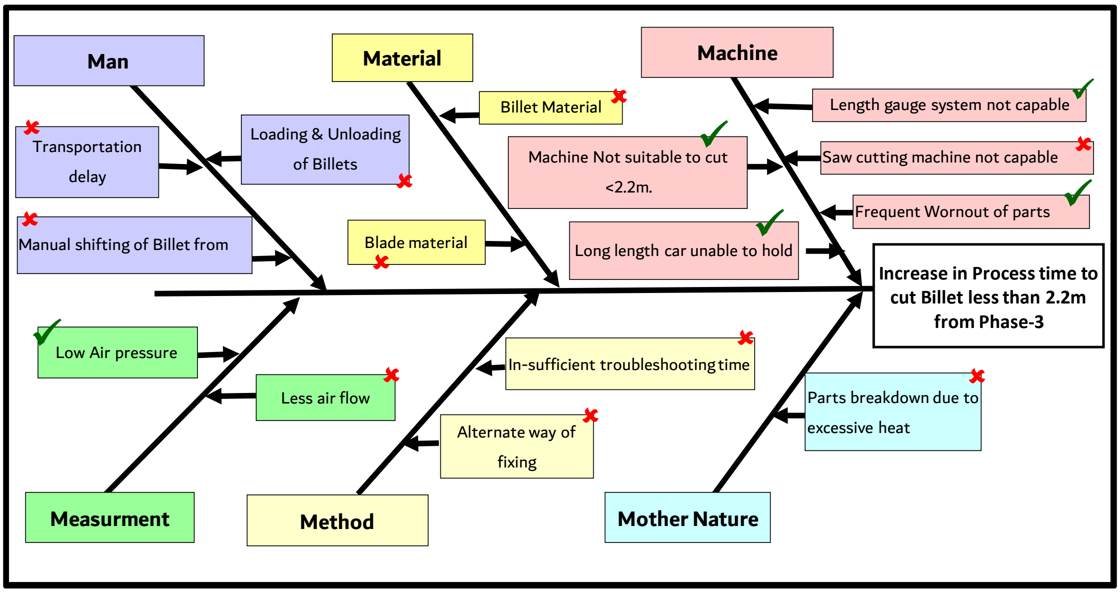

Figure 2. Fishbone analysis.

d. Future state of the value stream mapping methodology is very important where optimised process would get considered but it has to include some of non-value-added process which plays an important role to complete the whole billet cutting process. Existing billet saws E and F which follow Phase-3 complex, modified in such a way that they are themselves capable to cut minimum 2000 mm cut length while before, the minimum was 2200 mm cut length.

Ingenuity is incorporated in

- **Customized Modifications**: Implementing technical modifications for 2 m cut length.
- **Lean Methodologies**: Lean principles of value stream mapping, reducing total cycle time and eliminating waste, reflects creativity in optimizing the entire process flow to reduce downtime and rework.
- **Predictive Maintenance and Automation**: Integrating predictive maintenance and automation tools for saw machines can prevent unplanned downtime and maintain process consistency for 2-meter cutting and reduces potential breakdowns and increases machine utilization.

2.3 Benefits and Achievements

The following benefits were achieved:

1) Improved process efficiency (value added and non-value-added time), Figure 3

- Saving of 150 nonvalue-added minutes against 260 minutes for 100 billets processing, average batch size for processing is 100 billets.
- Total process duration reduced from 380 minutes to 227 minutes per 100 billets production. As a result of which 40 % additional billet handling capacity has been increased per shift.

2) Intangible benefits (reduced downtime and manual intervention)

- Reduction in waste time (non-value added) required for transportation of billets.
- Eliminate time spent to arrange forklifts for additional transportation.

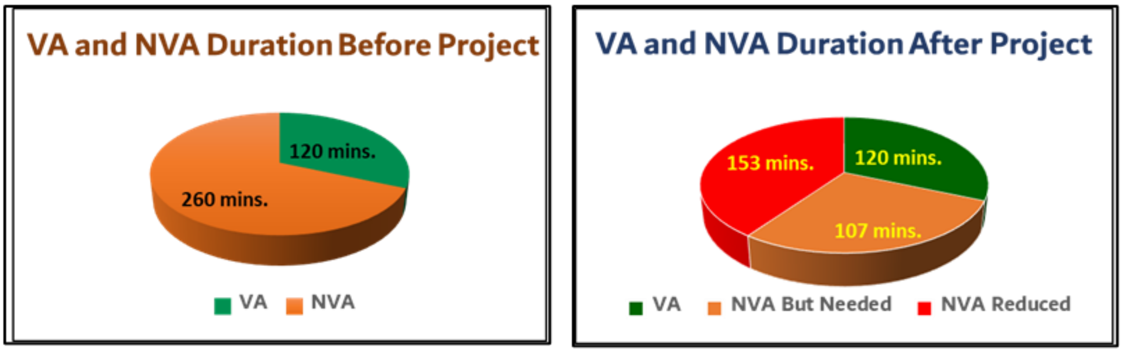

Figure 3. Value added (VA) and nonvalue-added (NVA) duration before and after the project.

3. Constraints and Transformational Opportunities for ingot caster outlet

3.1 Problem Statement

Automated Ingot Bundle Construction: Robotic manipulators automate the stacking and bundling of ingots. Each bundle must be complete to meet safety and quality standards. However, missing ingots during assembly occur sporadically due to sensor errors and process irregularities.

Impact of Missing Ingots: Missing pieces in a bundle undermine structural integrity and raise safety risks during handling and transportation. More critically, missing ingots lead to customer compliance issues, impacting contracts and EGA's reputation for quality.

Encoder Failures: Encoders provide positional feedback crucial for precise robotic and conveyor movements. Frequent failures arise from thermal expansion in the foundry environment, causing calibration drift and erroneous data.

Mechanical Collisions: Two major incidents occurred where robotic manipulators collided with moulds, uprooting assemblies and halting production. These failures reflect inadequacies in positional accuracy and collision avoidance.

3.2 Proposed Solution: Missing Piece Detection System (MPDS)

To address these challenges, the MPDS integrates real-time image processing and advanced PLC mathematical models to detect missing ingots during bundle construction with high precision. It involves:

1) Image Processing Technology
- High-resolution cameras capture the ingot bundles in real time.
- Custom algorithms analyse each image frame to detect the presence or absence of ingots.
- The system adapts to varying ingot shapes and sizes by training on multiple geometries.

2) PLC-Based Mathematical Modelling
- The PLC controller processes image data and correlates it with the robot operation cycle.
- Mathematical models predict bundle configurations, enabling rapid verification of ingot completeness.
- The system triggers alarms and halts operations if missing ingots are detected, preventing defective bundles from progressing downstream.

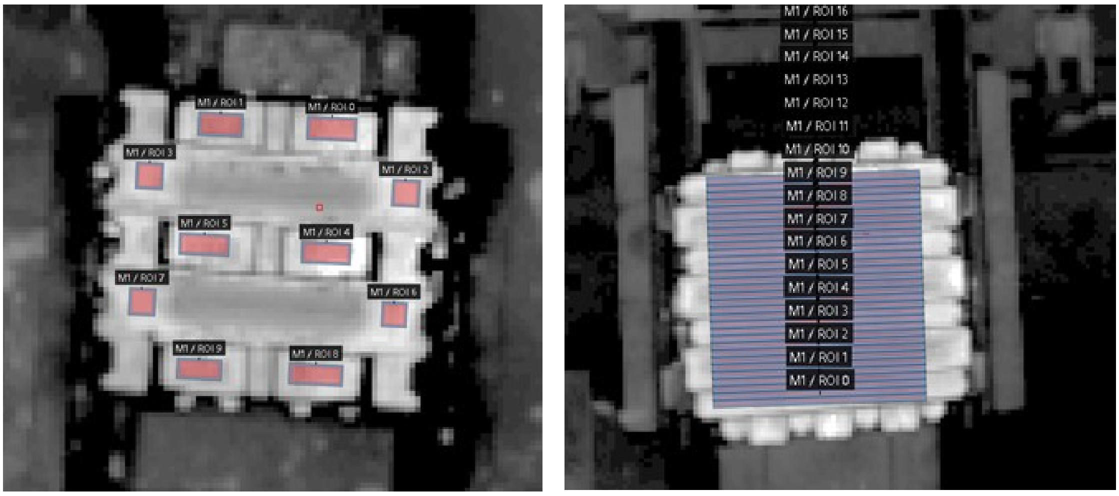

Figure 4. MPDS system identification of missing ingots.

3.3 Integration and Control System

The main characteristics of the system are:

1) a seamless integration
   - MPDS interfaces directly with existing robotic controllers, PLCs, and EGA's ERP system to ensure synchronised operation and traceability.

2) Conveyor and mould specifications
   - Each mould has a length of 1260 mm.
   - Moulds are placed with a tight gap of 10 mm, requiring precise conveyor positioning.
   - Each conveyor step corresponds to a 1270 mm move (mould length plus gap).

3) Absolute encoder implementation
   - An absolute encoder is deployed as the primary position measuring device, providing reliable and drift-resistant feedback even in high-temperature environments.
   - The encoder data informs the PLC to execute precise conveyor steps.
   - Chain Conveyor Control Mechanism,
   - The conveyor control system uses closed-loop feedback from the absolute encoder.
   - The control logic ensures that conveyor movements are accurate and repeatable, minimising misalignment risks.
   - Safety interlocks and emergency stop features are embedded to prevent collisions and equipment damage.

3.4 Results and Discussion

1) Improved Detection Accuracy: Initial deployment of the MPDS demonstrated near 100 % detection accuracy of missing ingots across different ingot types.

2) Reduced Equipment Failures: The use of absolute encoders and enhanced control algorithms decreased positional errors linked to thermal expansion, mitigating the frequency of encoder failures.

3) Incident Prevention: By providing real-time feedback and automated halts upon detecting anomalies, the system prevented further mechanical collisions and manipulator damage.

4. Conclusions

In Billet Saw complex, the process efficiency has been improved by reducing both value-added and non-value-added time. Non-value-added time was decreased by 150 minutes, from 260 to 110 minutes for every 100 billets processed. As a result, the overall process duration was reduced from 380 to 227 minutes per 100 billets produced. This reduction in processing time directly contributed to a 40 % increase in billet handling capacity per shift, demonstrating substantial improvements in operational efficiency. Along with, noteworthy intangible benefits were achieved through the reduction of downtime and manual intervention. The elimination of non-value-added time spent on billet transportation and the need to arrange forklifts for additional transportation has streamlined operations. This improvement not only reduced waste of time but also enhanced overall efficiency by minimizing manual tasks and optimizing resource allocation.

In Ingot Caster complex, the deployment of a new smart Missing Piece Detection System (MPDS) resulted in notable improvements across multiple aspects of the system performance. The detection accuracy for missing ingots reached near 100 %, covering various ingot types. The incorporation of absolute encoders and advanced control algorithms substantially reduced positional errors caused by thermal expansion, leading to a decrease in encoder failures. Additionally, the system's ability to provide real-time feedback and initiate automated halts upon detecting anomalies effectively prevented mechanical collisions and minimized manipulator damage, enhancing overall operational safety and reliability.