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Proposal for Continuous Improvement Strategies in the Metal Sheet Product Forming Process

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***Abstract*: In the metal sheet forming industry, discovering new and improved techniques to enhance efficiency, quality, and productivity is crucial to remain competitive in an ever-evolving market. Therefore, the implementation of continuous improvement techniques represents a key strategy to optimize manufacturing processes and meet market demands for profitability. The objective of this article is to propose a practical model for implementing continuous improvement techniques in metal sheet forming processes. The aim is to identify and analyze improvement opportunities at various stages of the process, from planning and design to production and quality control. Methodology: A thorough study was conducted on current information regarding continuous improvement techniques and metal sheet forming processes. Based on this, an implementation model was developed integrating Lean manufacturing tools such as 5S, TPM, and the 7 wastes. The proposed model was successfully applied in a company in the mechanical metal sector, where various improvements were identified and implemented in the sheet forming processes from start to finish. Significant improvements were recorded, including waste reduction, increased productivity, and enhanced final product quality. It is concluded that the implementation of Lean manufacturing continuous improvement techniques in metal sheet forming processes offers benefits such as improved operational efficiency, reduced production costs, decreased production times, and greater customer satisfaction. This project demonstrates the viability and importance of adopting a systematic and proactive approach to continuous improvement in the metal industry. Relevance: The results of this study have significant implications for companies in the metal sheet forming sector, serving as a guide to implementing continuous improvement strategies and achieving efficiency improvements in their production system to enhance competitiveness in the market.**

***Keywords*: continuous improvement techniques, metal sheet forming, lean manufacturing, efficiency enhancement, competitive market.**

1. Introduction

The concept of continuous improvement, epitomized by Lean manufacturing, originated at Toyota's production facility in Japan. It evolved from early 20th-century practices established by F.W. Taylor and Henry Ford, who formalized mass production techniques. Taylor pioneered scientific methods for organizing production processes, while Ford introduced assembly lines and standardized production methods [1].

In the 1990s, global industry embraced Lean production, a term coined by researchers at MIT, based on Toyota's production system. This system prioritized efficiency and waste reduction. The roots of Lean can be traced back to Sakichi Toyoda's invention in 1902, which improved productivity by integrating automation with human oversight.

Japan's industrial landscape faced a challenge in achieving productivity without relying solely on economies of scale. They studied American methods, including Ford's practices, statistical process control, and quality techniques by Deming and Juran [2].

In 1949, Toyota faced a crisis, leading engineers Eiji Toyoda and Taiicho Ohno to visit American automakers. They realized that American mass production methods were not suitable for Japan's needs, paving the way for Lean principles focusing on flexibility and variety [3].

The current project aims to implement continuous improvement techniques in sheet metal forming company. This includes adopting Lean Manufacturing and Total Productive Maintenance (TPM) to address issues like delayed deliveries and order cancellations.

The proposed improvements target:

- Enhancing product flow speed
- Reducing material waste
- Minimizing rework

The project scope is limited to the production line, encompassing maintenance, layout adjustments, specialized attachments, and operator training. Administrative and logistical aspects are excluded due to managerial opposition.

Budget constraints limit the project's resources, and not all departments will be involved.

The implementation plan involves:

Personnel training and project explanation. a) Layout changes in the production line b) Maintenance improvements c) Workstation enhancements

In summary, Lean manufacturing's evolution from Toyota's practices stemmed from a need to optimize productivity without relying on scale economies. The project at Hunter Douglas

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seeks to apply Lean principles to enhance efficiency and address production challenges, focusing on the production line's optimization through continuous improvement techniques. [4].

2. Methodology

In this section, the stages developed to achieve the objectives of this project are presented.

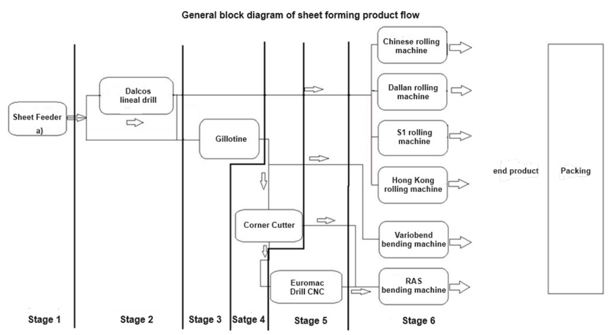

Fig. 1. General Process involving all the stages of the sheet forming in production line

First, the operations of the sheet metal forming production process, which are carried out in the company, are described. General block diagram of the flow and stages of the forming process at the Company are presented in figure 1. The diagram displayed in this figure, illustrates the overall process and the 6 stages of the sheet forming process for the architectural product production line at the organization. Next, the operations performed at each stage are described.

Stage 1: The feeder delivers the sheet coil to the process.

Stage 2: The Dallan perforator punches holes in the sheet; if the final design does not require it, the sheet is not perforated and proceeds directly to stage 3 or stage 6, the roller section.

Stage 3: The sheet is cut into sections on the guillotine; it is sent to stage 3, and if the design does not require it, the sheet proceeds directly to stage 6, the Variobend bender.

Stage 4: If the process dictates, the sheet goes through the notcher, where corners are cut from the sheet segments; if not, it moves to stage 6, the RAS bender.

Stage 5: The sheet segments are punched using the CNC machine.

Stage 6: Final processes such as rolling or bending are carried out here, according to the design requirements.

The sheet forming process at the establishment comprises three flow diagrams.

In Process 1, the flow offers two options: either passing through the linear Dallan perforator or not passing. If the design calls for plain sheet without perforation, the sheet proceeds to either of the rollers in Stage 6. The final product can be perforated or plain sheet, painted, or coated with texture, such as wood-like. Shapes include planks and gutters for interior ceilings, interior walls, and exterior facades, ranging from 1m to 8m in length and 0.5mm to 1mm in thickness.

In Process 2, perforated or plain sheet goes through the guillotine in Stage 3 and then to the Variobend bender in Stage 6. The final product features various shaped sheets, with finishes including paint or textured coating. Lengths range from 1m to 8m, with thicknesses from 0.6mm to 1mm.

In Process 3, after the notcher, the flow presents two options:

The sheet goes to the RAS bender in Stage 6, remaining plain without perforations.

The sheet proceeds to the CNC perforator to create perforation-based designs before passing through the CNC perforator. The final products are plain or perforated ceilings, ranging from 1m^2 to 2m^2, with finishes in paint or texture and thicknesses from 0.5mm to 1.2mm.

Explanation of the 6 main stages of the forming process: Stage 1: The sheet coil is mounted on the coil holder (loader), which then feeds the process, initiating it. Stage 2: The sheet passes through the linear perforator or mesh perforator, perforating the entire width of the sheet or only a section. The holes vary from 5 to 8mm in diameter, depending on the design. The Dalcos linear perforator generates a mesh-type perforation, equipped with a matrix capable of up to 100 punches, which work simultaneously in a single stroke. Stage 3: The guillotine cuts the sheet into sections of various lengths, according to the design. Stage 4: The notcher cuts the corners of the sheet sections, the cutting area varies depending on the design. Stage 5: The sheet sections are perforated in a CNC perforator, forming a combination of shapes, including squares, rectangles, or triangles of different sizes, creating a design on each sheet. The Euromac CNC perforator works with a multi-tool, a rotating mandrel that houses 8 punches of different shapes and sizes. Stage 6: This is where the sheet takes its final shape, whether it be a ceiling, plank, or rail, in the rollers or benders.

Rolling Machines: All of these machines pass the sheet between their rollers, with each section of rollers gradually deforming the sheet until it ends up with a specific shape. Each machine performs certain models or shapes and operates continuously, fed by a loader that unwinds a sheet coil.

Bending Machines: In these machines, the cut sheet sections are placed, and through bends made by their jaws, they give different shapes or designs to the sheets.

RAS Bender: This machine bends sheets up to a maximum of 5m in length, mainly used for ceiling tile manufacturing. It is a semi-automatic machine.

The products generated in these processes possess the following characteristics.

- Ceiling tiles or planks are manufactured for architectural designs of interior ceilings, facades, or interior wall decoration in buildings.
- Materials used are steel sheet with magnesium alloy or galvanized.
- The sheet is finished with a variety of colored paints.
- They are designed to resist corrosion and weathering.
- The sheet is used plain or perforated, with different designs and sizes.
- Some sheets feature designs or shapes based on folds.
- Sheet gauges range from 0.5mm to 1.2mm.
- Ceiling tiles measure from $0.5m^2$ to $5m^2$.
- Planks measure from 0.5m to 9m in length.

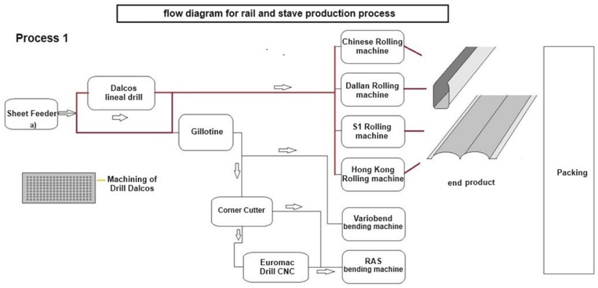

Fig. 2. Flow diagram to produce rails and staves

Figure 2 displays that in process 1, the flow has 2 options: 1) to pass through the Dallan linear punch, and 2) not to pass. In the case where the design involves smooth sheet metal without perforation, the sheet metal then goes to any of the rolling machines at stage 6.

The final product can take the form of perforated or smooth (non-perforated) sheet metal. It can also be painted or coated with a textured finish, for example, wood-like texture.

The shapes include planks and channels for interior ceilings, interior walls, and exterior facades. Lengths range from 1 m to 8 m, and thicknesses range from 0.5 mm to 1 mm.

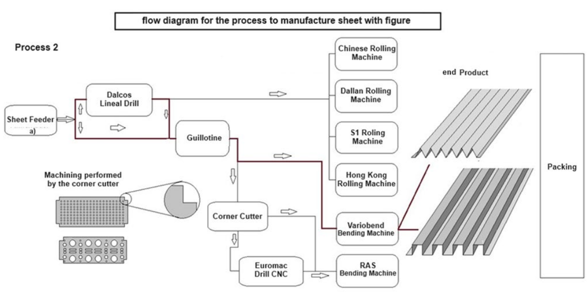

Fig. 3. Flow diagram to manufacture sheet with figure

Figure 3 shows that in Process 2, the perforated or smooth sheet metal moves to the guillotine in stage 3 and then goes to the Variobend bender in stage 6. The final product is sheet metal with various figures, and finishing touches are applied using painting techniques or textured coating.

Lengths range from 1 m to 8 m, with thicknesses from 0.6 mm to 1 mm.

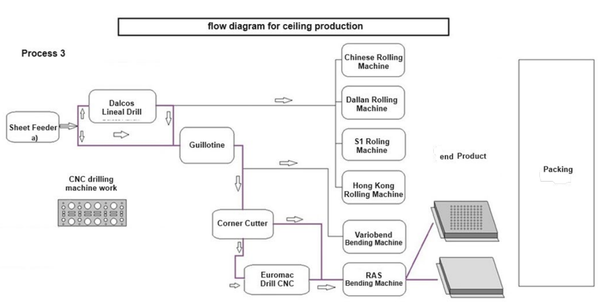

Fig. 4. Flow diagram for ceiling manufacture

Figure 4 illustrates that in Process 3, after the sheet metal is formed in the Notcher, the process flow has two options:

1) The sheet metal goes to the RAS bender in stage 6. In this condition, the sheet metal is smooth, without perforations.
2) The sheet metal goes to the CNC punch where designs are created based on perforations.

The final products are smooth or perforated ceiling panels, with dimensions ranging from 1m² to 2m². Finishes are achieved with painting or texturizing, and the thickness range varies from 0.5mm to 1.2mm.

3. Results

This section presents the results associated with the proposed implementation of industrial engineering techniques in the sheet metal forming process

The Proposed Layout where all the production process operations are shown is displayed in Figure 5.

Below, we present and describe each of the elements that make up the Layout.

A. Layout Description

1) Sheet feeder: This is where the process begins, delivering the coil.
2) DALCOS linear perforator: Performs mesh-type perforation on the sheet metal, maximum of 400 perforations in a single stroke.
3) Automatic shear: Cuts the sheet metal into sections, the length is variable and depends on the project.
4) Euromac CNC drill: Forms figures with the perforations, the perforations have different sizes and shapes, which can be combined as programmed.
5) Variovend bender: It is an automated machine and can form varied patterns with the folds.
6) RAS bender: Semi-automatic machine, used only for ceilings in the form of squares and rectangles.
7) S1 roller: It is used to form rails or slats, known as deflectors.
8) HONG KONG roller: It is used to form rails or slats, known as deflectors.
9) DALLAN roller: It is used to form rails or slats, known as deflectors.
10) CHINA roller: It is used to form rails or slats, known as deflectors.
11) Sheet straightener: Removes the curvature of the sheet when it is deformed.
12) Manual shear: Used for specific cuts.
13) Corner cutter: Cuts the edges of the sheets that are used to manufacture the ceiling or tray.
14) Hydraulic press: It is used to make special perforations for selected parts.
15) Crown roller: The sheet metal passes through this machine to give it curvature.
16) Table saw: It is used to cut cardboard that will be used in the packaging of the finished product.

B. Continuous Improvement Techniques Applied in Sheet Metal Forming

The following describes how each continuous improvement techniques are integrated into the sheet metal forming process.

With the integration of continuous improvement techniques in the sheet metal forming process, the potential benefits will be very significant, which will be reflected in significant improvements in efficiency, quality, and profitability. By implementing the key principles and tools described above, companies can improve efficiency, quality, profitability, and customer satisfaction.

Here are some key principles and tools to achieve successful integration:

1) *Identify the value stream:* The first step is to understand the entire value stream of the sheet metal forming process, from receiving raw materials to shipping the finished product. This involves identifying all activities that add value and those that do not (waste).
2) *1.1 Map the process:* Once the value stream is understood, a process map should be created that shows each step, along with the time it takes, and the resources used. This helps identify opportunities to improve efficiency and eliminate waste.
3) Layout modification or improvements [5].
4) Identify waste: This is very important to stop performing activities that do not add value and instead represent a loss [6].
5) Develop process sheets for each station: Create standard operating procedures (SOPs) that describe in detail how each task should be performed. This helps ensure consistency, quality, and efficiency [7].
6) Implement 5S: 5S is a set of five Japanese principles for workplace organization and cleanliness: Seiri (sort), Seiton (order), Seiso (clean), Seiketsu (standardize), and Shishin (sustain). Implementing 5S can help create a safer, more efficient, and more productive workplace [8].
7) Implement TPM, Preventive Maintenance, and Autonomous Maintenance. This helps improve equipment availability and reduce maintenance costs [9].
8) SMED: Improvements in tooling changeover are implemented during model changes [10].
9) Work cells: Work cells are designated areas in the workshop where all the steps necessary to complete a specific product or component are performed. This can help improve efficiency, quality, and communication between workers [11].
10) Involve employees: It is important to involve employees in the implementation of Lean Manufacturing. This can be done through continuous improvement groups, training, and recognition.

Here are the production indicators that can be measured, and which are also intended to be improved with the subsequent implementation of the methodological proposal of this work [12].

Production indicators:

$$\text{Productivity: } \frac{Finished\ product}{Production\ time}$$

Quality: Percentage of products that are manufactured without errors.

$$Costs{:}\frac{Total\ cost\ of\ production}{Total\ units\ produced.}$$

Time: Average time required to manufacture a product. Yield rate: Number of products that do not meet quality standards. A maximum of 10% scrap is allowed in each 800 m roll.

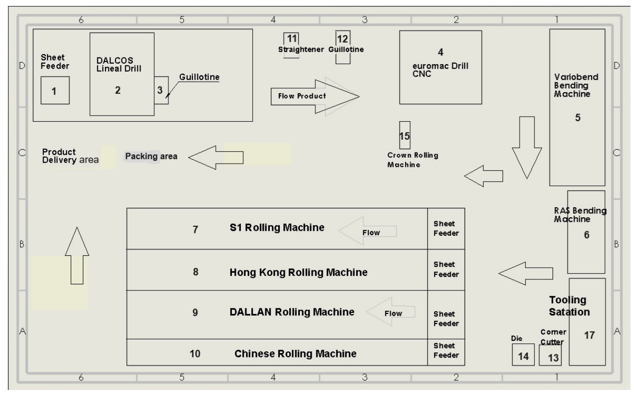

Fig. 5. Proposed layout for sheet metal forming process

C. *Description of the Implementation Sequence Diagram*

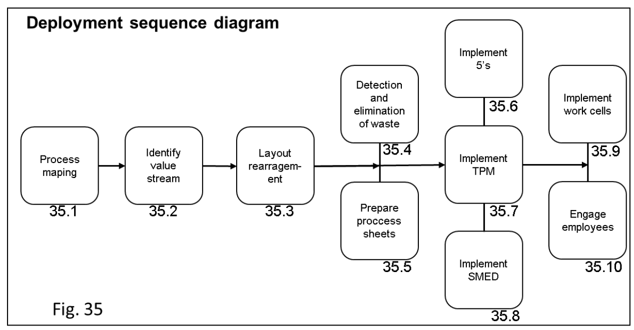

Fig. 6. Diagram of the implementation sequence of Industrial Engineering techniques

Figure 6 describes the sequence of implementation of industrial engineering techniques in the sheet metal forming process.

Important: The horizontal arrow indicates that a stage is performed only after the preceding stage indicated by the horizontal arrow has been completed. The stages connected by vertical lines are performed simultaneously. Thus, the sequence begins with stage 35.1 and ends with stages 35.9 and 35.10, which are performed simultaneously.

35.1 Process Mapping: This stage involves graphically representing all actions and responsible individuals in the workflow. Its purpose is to ensure that all involved parties have a better understanding of tasks, objectives, and stages to improve their performance and productivity. (Duran, H. (2022). Manual de Mapeo de Procesos Con Gestión Documental Y BPMN. Amazon Digital Services LLC - KDP Print US).

35.2 Identifying the Value Stream: Each step is analyzed to optimize the time and manner of delivery to the customer, identifying the steps that add value to the product.

35.3 Layout Rearrangement: This helps improve the product flow, enhances operator mobility, and reduces the risk of accidents.

35.4 Waste Identification: Wastes such as distance, waiting time, overproduction, and over-processing are identified. Strategies are then employed to eliminate them as they reduce process efficiency.

35.5 Process Sheets Preparation: Formal documents are created to detail the appropriate techniques for performing activities on the production line, ensuring consistent execution and quality.

35.6 Implementation of the 5S Technique: This generates an environment of order, cleanliness, and safety throughout the production area.

35.7 Implementing TPM: Total Productive Maintenance helps optimize machine work, resulting in zero production line stoppages due to machine failures.

35.8 Implementing SMED: Single-Minute Exchange of Die reduces tool changeover time for model changes, thereby improving production line efficiency.

35.9 Implementation of Work Cells: The production system is organized into individual, independent, and dynamic compartments, consisting of groups of people and machines performing a specific number of specialized operations. This allows each part of the value chain to address its own issues, helping to organize work better on the production line.

35.10 Employee Involvement: Involving employees in the entire improvement plan ensures they understand the objective, strategy, and commit to the entire plan.

The implementation process of Industrial Engineering techniques in sheet metal forming is detailed in the diagram shown in Figure 6.

4. Conclusion

By applying the specified industrial engineering techniques, the company under study is anticipated to enhance several key performance indicators (KPIs). Firstly, productivity is expected to increase significantly. Additionally, quality is projected to improve by 5 to 6%, and production costs are expected to decrease by the same range. Furthermore, manufacturing time for a product is projected to be reduced by up to 30%. Lastly, production yield, related to the number of products meeting quality standards, is expected to improve by approximately 5%.

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