ENHANCING AUTO STRAPPING MACHINE PERFORMANCE THROUGH SIX SIGMA: A TEXTILE INDUSTRY CASE STUDY

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Abstract

In modern industrial manufacturing, production efficiency and quality assurance are critical factors for maintaining competitiveness. One key element in this process is the auto strapping machine, which plays a vital role in packaging and securing products for distribution. However, frequent breakdowns and performance inefficiencies in these machines can disrupt operations, leading to increased downtime and production losses. This study applies the Six Sigma methodology, specifically the DMAIC (Define, Measure, Analyze, Improve, Control) approach, to optimize the performance of auto strapping machines in a textile industry case study. The research identifies major causes of inefficiencies, including mechanical failures, material inconsistencies, and human factors. Using tools such as Pareto charts and Why-Why analysis, the study pinpoints critical failure points, leading to targeted corrective actions such as enhanced maintenance schedules, operator training, and material quality control. The implementation of these improvements resulted in a significant reduction in defects per million opportunities (DPMO) from 794,288 to 517,281 and an improvement in the sigma level from -0.82 to -0.04. These findings highlight the effectiveness of the Six Sigma framework in identifying root causes of machine inefficiencies and implementing structured improvements. The study contributes valuable insights for industries looking to enhance machine reliability and overall operational efficiency. By standardizing best practices and fostering a culture of continuous improvement, manufacturers can reduce downtime, improve product quality, and enhance production sustainability.

Keywords*: Optimization, Auto Strapping Machines, Six Sigma, DMAIC, Process Improvement*

1. INTRODUCTION

In the increasingly competitive modern industrial era, production efficiency and quality have become key factors in maintaining a company's competitiveness [1]. One critical aspect of the production process is product packaging, where auto strapping machines play a vital role in ensuring that products are securely packed and ready for distribution [2]. However, like other industrial equipment, auto strapping machines are not immune to issues such as downtime, performance instability[3], and operational failures, which can disrupt the smooth flow of production.

The background of the problem lies in the frequent breakdowns of the fiberline machine, which have shown a tendency to increase. Based on field case studies, the highest contributor to this issue is Baler 3, accounting for 69% of the cases, with an average off-grade production of 1,184 kg per month. Additionally, the production time lost due to breakdowns on the baler machine amounts to 1,584 minutes over a year. Under these conditions, the sigma level is at -0.84, with a DPMO (Defects Per Million Opportunities) of 794,288.

To address these challenges, a systematic approach is required—one that not only identifies the root causes of problems but also provides effective and sustainable solutions. The Six Sigma methodology, known as a data-driven quality improvement framework, offers a comprehensive structure to achieve this goal [4]. By combining statistical tools and management principles, Six Sigma enables companies to reduce process variability, enhance efficiency, and achieve higher quality standards.

This paper aims to optimize the performance of auto strapping machines by applying the Six Sigma methodology, specifically through the DMAIC (Define, Measure, Analyze, Improve, Control) approach. By conducting an in-depth analysis of the factors affecting machine performance, it is expected that appropriate improvement steps can be identified to enable the machine to operate more efficiently, reduce downtime, and enhance overall productivity. Through this case study, it is hoped that the findings will contribute to improving production processes in the packaging industry and serve as a reference for implementing Six Sigma in similar contexts.

2. METHODS

21. Define Phase

The primary issue identified revolves around the frequent breakdowns and inefficiencies observed in the auto strapping machines, which have been disrupting production processes. To address this, the project aims to reduce downtime, enhance machine performance, and minimize off-grade production, thereby improving overall operational efficiency. Following this, statistical analysis is conducted using tools like Pareto charts and histograms to evaluate data trends and correlations, providing deeper insights into the problem [3]. Key stakeholders, including personnel and departments directly involved in the process, have been identified to ensure collaborative efforts in achieving these objectives.

2.2. Measure Phase

To address the issues with auto strapping machines, the first step involves collecting historical data on machine breakdowns, downtime, and production losses. This data serves as the foundation for identifying patterns and quantifying the extent of the problem. Key performance indicators (KPIs), such as Defects Per Million Opportunities (DPMO) [5], sigma level, and production efficiency, are then used to measure and evaluate machine performance. By establishing baseline measurements, the current performance levels of the auto strapping machines are documented, providing a clear starting point for improvement initiatives.

2.3. Analyze Phase

To uncover the root causes of machine breakdowns, analytical tools such as 5 Whys technique are employed [6]. These methods help systematically identify the underlying issues affecting the auto strapping machines. Through this process, the most critical factors contributing to machine inefficiency are pinpointed, enabling targeted and effective solutions to be developed.

2.4. Improve Phase

To address the identified issues, corrective actions are proposed, including the implementation of regular machine maintenance schedules, comprehensive operator training programs, and necessary process adjustments. These solutions are first tested on a small scale through pilot testing to assess their effectiveness and identify potential areas for improvement. Based on the results of the pilot tests, the solutions are further refined and optimized to ensure they deliver sustainable and long-term improvements in machine performance and operational efficiency.

2.5. Control Phase

Once the optimized solutions are implemented, the improved processes are standardized by documenting them and creating detailed standard operating procedures (SOPs). This ensures consistency and clarity in operations. To maintain sustained performance, monitoring and control mechanisms are established, such as control charts and regular audits, which help track progress and identify deviations early. Additionally, a culture of continuous improvement is fostered, encouraging ongoing evaluation and refinement of processes to adapt to changing conditions and further enhance efficiency over time. Figure 1 provides a visual representation of the specific research steps.

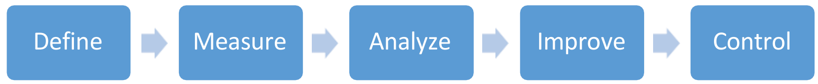

Figure 1*. Six Sigma flow methods*

2.6. Case Study Application

The case study is set within the textile industry in Purwakarta, west Java, Indoensia where auto strapping machines play a critical role in ensuring efficient and secure packaging of products. The implementation of the Six Sigma methodology involves a structured approach, including detailed steps such as problem identification, data analysis, solution development, and process optimization. Through this rigorous application, both quantitative and qualitative outcomes are achieved, including reduced downtime, improved machine performance, and enhanced overall productivity, demonstrating the effectiveness of Six Sigma in addressing industrial challenges.

3. RESULT AND DISCUSSION

3.1 Define

The production process of manmade fiber begins with the draw of creel, after which the material is transferred to the draw line area. In the draw line, the tow undergoes a heating process using steam to smoothen it, making it easier to shape using a crimper. This is followed by a cooling process using sprayed demineralized water, which hardens the tow, and the application of spin finish oil. The tow is then directed to a plate belt dryer for drying and is subsequently ready for the cutting process in the cutting unit, where it is transformed into synthetic fiber. The synthetic fiber from the cutting unit is fed into a baler equipped with automatic bale weight and automatic strapping for packaging.

In this phase, frequent issues in the draw line area will be identified using a Pareto chart [7], as shown in Figure 2. This figure illustrates the distribution of machine breakdown cases in 2021, analyzed using a Pareto chart. The chart highlights the most frequent issues, with the baler machine accounting for the highest percentage of breakdowns at 41%. This visualization helps prioritize problem areas for improvement efforts.

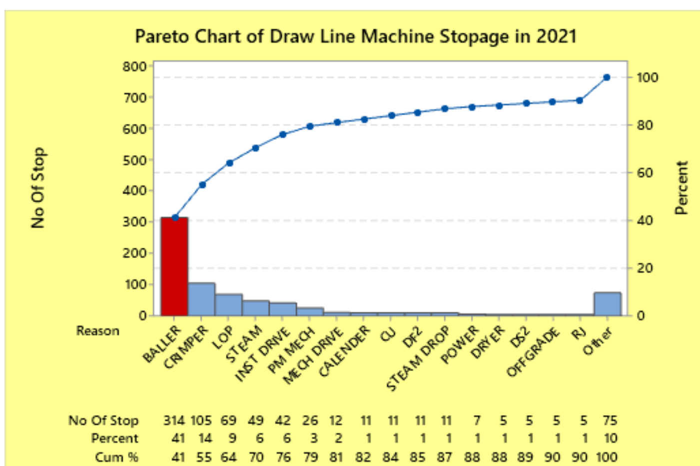

Figure 2. *Pareto Chart of Machine Breakdown Cases in 2021*

The baler machine consists of various components. To pinpoint the exact source of the problem, a Pareto chart was created to classify which parts were the primary cause of frequent breakdowns in the baler machine. After analyzing the Pareto chart, as shown in Figure 3 which presents a Pareto chart that classifies the problematic parts within the baler machine. The chart identifies the strapping machine as the primary contributor, responsible for 19% of the issues with 56 recorded stoppages. This analysis helps prioritize focus areas for troubleshooting and improvement efforts.

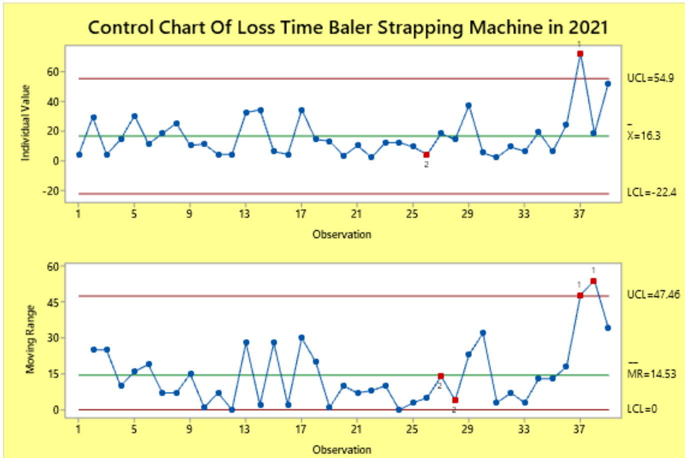

Figure 3. *Pareto Chart of Part Problem Classification*

3.2 Measure

The loss time caused by the baler strapping machine for the period January 2021 – December 2021 was analyzed using a control chart, as shown in Figure 4. From the individual value control chart, it is evident that the process is unstable, with Point 1 lying outside the control limits. The average value ($\bar{x}$) is 16.3, with an Upper Control Limit (UCL) [8] of 54.9 and a Lower Control Limit (LCL) of -22.4. Meanwhile, the moving range shows an average value ($\bar{x}$) of 14.53, with a UCL of 47.46 and an LCL of 0 as the target. Figure 4 explains the observation data from the chart of loss time of the baler strapping machine in 2021.

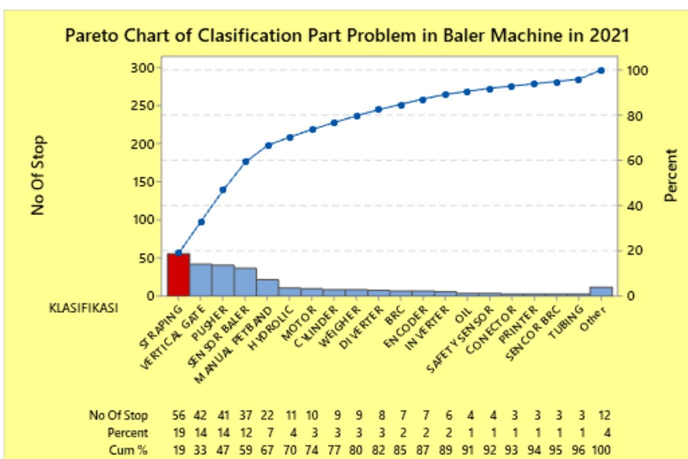

Figure 4. *Control Chart of Loss Time for Baler Strapping Machine in 2021*

From the capability analysis chart in Figure 5, the DPMO (Defects Per Million Opportunities) / PPM (Parts Per Million) value was found to be 794,288, and the sigma level was at -0.82. This indicates that the company is operating at a lower level and is not competitive. Therefore, significant improvements are required to enhance the sigma level and overall process performance.

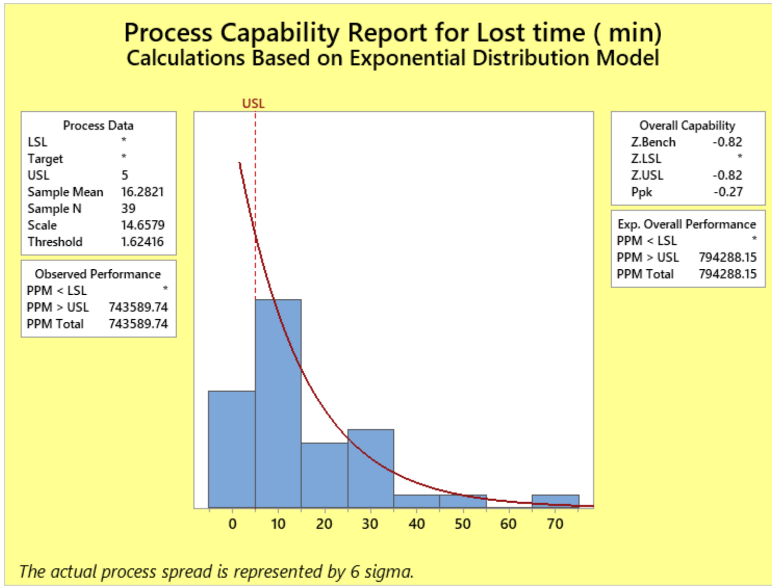

Figure 5. *Loss Time Capability Due to Machine Strapping in 2021*

3.3 Analyze

The analysis using the Pareto chart method revealed that 68% of the issues are concentrated in three major problem areas of the auto strapping machine: the welding system, PET band material, and sensors. As a result, the focus of the analysis will be narrowed down to these three components. Furthermore, the Why-Why Analysis identified several root causes, including the failure to follow the Standard Operating Procedure (SOP), inadequate maintenance control, and issues with the PET band material (such as failure or damage). These factors were found to be the primary triggers for breakdowns, leading to significant loss time. Figure 6 illustrates the process of conducting a Why-Why analysis.

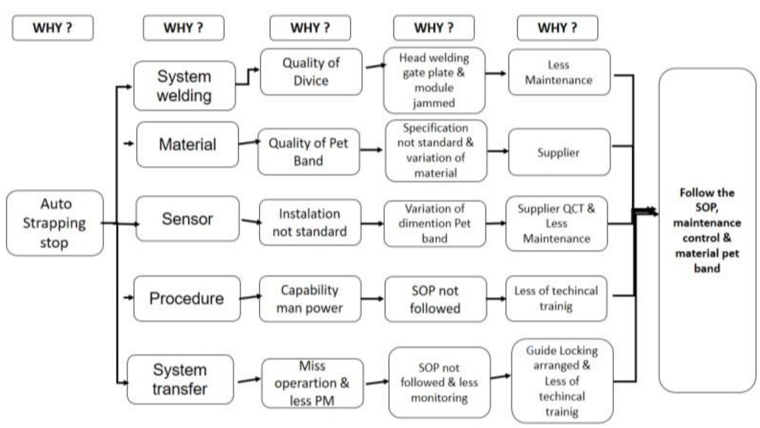

Figure 6*. Why Why Analysis Diagram*

Following Figure 6, Why-Why Analysis focused on identifying root causes of inefficiencies or breakdowns in an auto strapping machine system. Key areas of concern include material quality, sensor performance, adherence to procedures, and maintenance practices. By addressing these issues, the goal is to improve system reliability, reduce loss time, and enhance overall operational efficiency.

3.4 Improve

The next phase involves the improvement or repair stage, aimed at optimizing the performance of the auto strapping machine. This stage addresses three key factors: machine conditions, human factors, and material factors. Breakdowns often occur due to the safety barrier activating prematurely before the cycling process is complete, improper distribution or misalignment of the PET band during welding or strapping, and dirty welding plates that prevent proper material adhesion, leading to module jams. These issues are exacerbated by operator negligence, such as failing to clean the machine or check settings during operation.

To address these machine-related problems, proposed improvements include re-training operators on Standard Operating Procedures (SOPs) for machine operation and initial troubleshooting, increasing the frequency of preventive maintenance, and ensuring spare parts are readily available. Additionally, operator negligence, lack of accuracy, motivation, or responsibility significantly disrupts process efficiency. To mitigate this, it is essential to provide training programs, consider the employment status (contract vs. non-contract) of workers, and offer motivational support to foster a stronger sense of responsibility and improve performance.

Material-related issues arise from variations in PET band materials that fail to meet specifications, such as inconsistencies in shape, thickness, or thinness, which negatively impact the machine's performance. To resolve this, a comparison list of materials from different vendors should be created, evaluating their performance in the strapping process. Additionally, the Certificate of Analysis (CoA) for each material should be reviewed to identify which materials meet the required standards and which should be discontinued.

By implementing these improvements, the auto strapping machine's performance can be significantly enhanced, reducing breakdowns and improving overall operational efficiency.

After implementing the improvements, the control chart analysis comparing pre- and post-improvement data shows that the changes are not statistically significant, as the P-value remains greater than 0.05. This indicates that the observed differences may not be substantial enough to conclude a meaningful impact from the improvements (Figure 7).

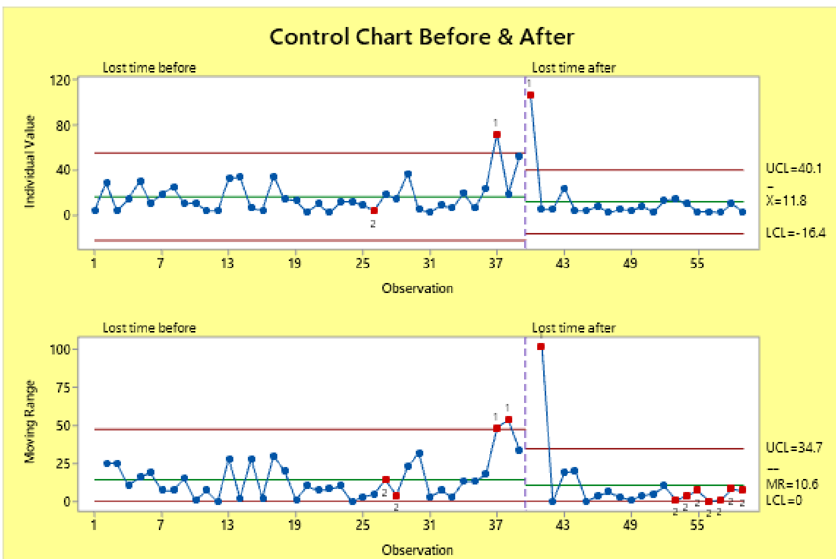

Figure 7. *Control Chart Comparison Before and After Improvement*

After implementing several improvements based on the findings from the analysis process, the process capability was recalculated to compare performance before and after the changes. The results showed a notable improvement: the DPMO (Defects Per Million Opportunities) value decreased from 794,288 to 517,281, and the sigma level improved from -0.82 to -0.04. This indicates a significant enhancement in process efficiency and quality (Figure 8 & 9).

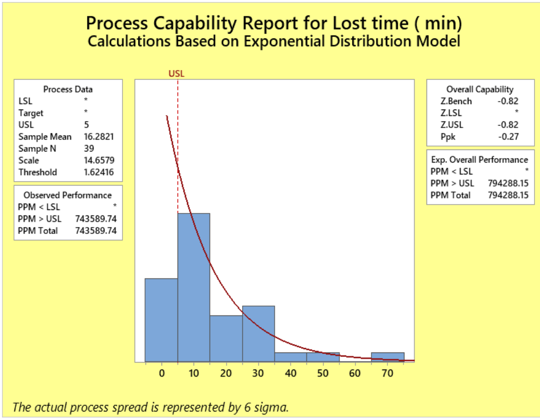

Figure 8. *Capability chart before improvement*

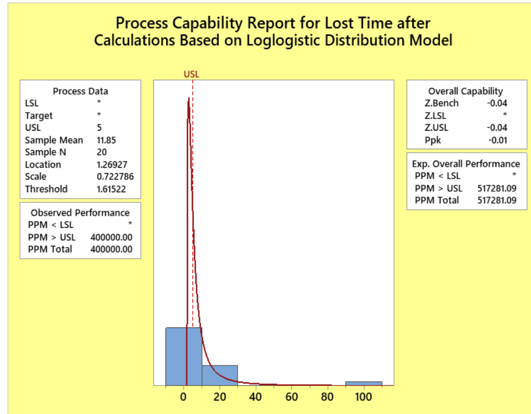

Figure 9 *Capability chart after improvement*

3.5 Control

After completing the previous four stages of data analysis and calculation, the final stage is the control or monitoring phase, which ensures the process operates as expected. The steps implemented during this stage include:

1. Training and Socialization [9]: Conducting monthly training sessions for each shift group to ensure workers understand the tasks and procedures outlined in the Standard Operating Procedures (SOPs).
2. Performance Monitoring [10]: Regularly supervising employee performance through CCTV surveillance and direct checks by area supervisors.
3. Preventive Maintenance [11]: Increasing the frequency of machine maintenance, particularly for those prone to breakdowns, from once a week to twice a week.
4. Interdepartmental Coordination [12]: Enhancing collaboration between the engineering and production departments to maintain machine stability. This includes daily meetings and maintaining logbooks to document activities and issues, ensuring all shifts and departments have access to activity histories.
5. Material Quality Control [13]: Inspecting materials received from vendors to ensure they meet required specifications. Additionally, maintaining adequate stock of PET band materials to avoid using unsuitable alternatives. This involves requesting a Certificate of Analysis (CoA) from vendors for each material shipment.

4. CONCLUSION

In an effort to enhance machine productivity, necessary improvements were implemented based on the analysis conducted using the Six Sigma methodology, specifically through the DMAIC (Define, Measure, Analyze, Improve, Control) framework. Initially, the loss time due to breakdowns on the auto strapping machine resulted in a DPMO (Defects Per Million Opportunities) of 794,288 and a sigma level of -0.82. After implementing several improvements and preventive measures, the DPMO decreased to 517,281, and the sigma level improved to -0.04. This shift in the sigma level demonstrates that the improvements and preventive actions effectively increased machine productivity. Therefore, the Six Sigma method proves to be a valuable approach for optimizing machines or other systems.

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