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Precision in Production, Understanding the Ripple Effects of Minor Stops and Adaptive Speed Strategies

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Abstract

A major American timber company faced frequent minor stoppages on a veneer lamination press line, prompting an investigation by Northwestern State University's Department of Engineering Technology. The study, using data collection and statistical analysis, found these stoppages significantly impact production yield, contrary to initial assumptions. A recovery plan was developed, focusing on line speed adjustments and veneer quality, identifying key factors contributing to the stoppages. Recommendations were made to improve efficiency, leading to a potential management review for enhanced plant performance. This collaboration also fostered professional growth for the team members involved.

Keywords
Timberland Management, Production Yield, Minor Stoppages, Method Engineering, Veneer Quality.

1. Introduction

The timber industry plays a crucial role in the American economy, supplying essential materials for construction and manufacturing. However, a prominent timberland company based in Northern Louisiana has encountered significant challenges due to frequent minor stoppages in its Press department, which have led to decreased daily production rates. These unpredictable and frequent interruptions, particularly in the knockdown bays and layup area, have hindered the company's ability to increase production from 1.2 million to 1.8 million trusses daily. Additionally, the need to accommodate varying order sizes for I-beam bundle cuts, ranging from 20 to 60 feet, has introduced further downtime, compounding productivity losses.

This study investigates minor stoppages that occur during billet manufacturing, a process that is fundamentally continuous. These minor stops are defined as interruptions lasting less than 2 minutes. The production of billets involves assembling 10 to 15 veneers—thin sheets of wood—fed through a press machine, glued together, and cured at specific temperatures and durations. The veneers used in this process come in two thicknesses: 1/7 inch and 1/8 inch, while the final billets are produced in thicknesses of 1.25 inches, 1.5 inches, or 1.75 inches. Each veneer is graded as either Grade 1 or Grade 2, with Grade 1 representing superior quality. Notably, to maintain high-quality standards, the first and last veneers of each billet are always Grade 1.

The process starts with veneers being placed on a conveyor by one of the three bays at the beginning of the press line. Each bay is stocked with either Grade 1 or Grade 2 veneers, and a programmable robotic parallel horizontal bar equipped with suction cups transfers one veneer of a specific grade onto the conveyor from one of the bays. A fourth bay containing Grade 1 veneers is kept on standby to ensure production continuity, should any veneer be missed by the main feeders. Veneers may encounter quality issues such as splits, torn corners, waviness exceeding 3 inches, discoloration, or other visible damage, potentially compromising the billet's overall quality and strength. In such cases, these defective veneers are removed from the line, either semi-automatically or through manual intervention, depending on the situation.

These minor stoppages can impact production yield, and this study aims to quantify the resulting downtime and evaluate whether speeding up the line can help recover veneer loss. Additionally, it was observed that line speed varies based on the thickness of the billets; thinner billets allow for faster line speeds due to fewer layers and shorter curing times, whereas thicker billets require more layers and longer curing times, thus slowing down the production process. By identifying the underlying causes of these minor stoppages and exploring strategies to optimize production efficiency, this study seeks to enhance the company's operational performance and better meet market demands, ultimately leading to improved profitability. The findings will not only provide actionable insights for the company but also contribute to a broader understanding of efficiency challenges in the timber processing industry.

1.1 Objectives

The primary research objectives of this project are to systematically collect data on downtime occurrences across each unit, including their durations, and to provide a comprehensive overview of production inefficiencies. This data will be utilized to formulate a recovery plan aimed at enhancing daily production yield. Additionally, software tools such as Microsoft Excel and Python Pandas (Pandas development team 2023) will be employed to analyze the collected data. By achieving these objectives, the project seeks to identify actionable solutions that can significantly improve the company's overall productivity.

2. Literature Review

In the context of industrial production, engineering efforts are increasingly focused on implementing continuous improvement processes to enhance manufacturing efficiency and product quality (Bertocci et al. 2021). As the demand for sustainable and high-quality building materials such as plywood and joists continues to rise, manufacturers face mounting pressure to balance efficiency, quality, and waste reduction. This has led to the widespread adoption of Continuous Improvement (CI) strategies like Lean, Six Sigma, and Kaizen. These strategies not only help streamline operations but also improve the consistency and quality of the final product. Moreover, a global trend is emerging where artificial intelligence (AI) is being integrated into continuous improvement practices, playing a transformative role in optimizing production workflows across various industries, including manufacturing (Kronberger et al. 2020). In the production of wood-based composites, adhesive selection, and pressing techniques are pivotal in determining product quality. As highlighted by Wong et al. (2000), the choice of adhesives plays a significant role in enhancing the dimensional stability and mechanical properties of plywood, making it highly suitable for applications in furniture and construction. This insight underscores the importance of optimizing adhesive usage to maintain the quality and durability of the final product.

Automation is another critical element in improving veneer processing lines. As emphasized by Urbonas et al. (2020), automation helps to reduce human error and enhances precision, resulting in increased production efficiency. This is further supported by Freebush and Arent (2011), who found that automated systems significantly improve throughput, enabling manufacturers to fulfill orders more swiftly. The integration of automation not only boosts productivity but also minimizes waste, reduces operational costs, and optimizes resource allocation, leading to more efficient manufacturing processes. However, the presence of defects in wood veneers remains a common challenge in timberland manufacturing. According to Kamperidou et al. (2020), surface roughness is one of the most critical properties affecting the quality of wood and wood veneers, which in turn impacts their utilization. Defects such as splits, cracks, and uneven glue application can weaken the veneer, leading to interruptions in production. If defective veneer enters the manufacturing line, production must be halted to remove and replace the flawed piece, which results in delays, increased costs, and reduced efficiency.

A particularly crucial aspect of billet manufacturing is the downtime caused by issues in veneer feeding. Kumar et al. (2020) conducted an in-depth analysis of the veneer layup system in plywood production, demonstrating that interruptions in veneer feeding significantly contribute to inefficiencies. Their study underscores the importance of systematic modeling to enhance the reliability and efficiency of the manufacturing process, ultimately minimizing downtime and improving overall productivity. Additionally, the work by Dupleix et al. (2013) provides valuable insights into how the log heating temperature during the peeling process affects veneer quality. The study revealed that improper heating could cause high lathe check frequencies, leading to splits or waviness in the veneers. Properly controlling this process is therefore essential to minimize defects and ensure high-quality veneer layup during billet manufacturing.

To address these challenges effectively, applying systematic techniques to identify inefficiencies and optimize workflows is essential. As Niebel et al. (2020) suggest, these methods play a critical role in establishing productivity standards, thereby enhancing overall operational efficiency in manufacturing environments. Ultimately, the key to improving industrial production processes lies in the integration of continuous improvement strategies, automation, and systematic problem-solving techniques. This ensures that manufacturers can produce high-quality, sustainable materials such as plywood and joists while maintaining efficiency and minimizing waste.

3. Methods

In documenting this project, the team utilized a range of tools to ensure comprehensive data collection and effective organization, including Python Pandas, Microsoft Excel, and Microsoft Word, each fulfilling a vital role in our methodology.

Microsoft Excel was instrumental in managing and analyzing the data collected from the company. The team used Excel for data entry, storage, and complex processing. Its robust functions allowed us to manipulate large datasets, generate meaningful insights, and draw essential conclusions, providing a solid foundation for our results.

Additionally, Python Pandas was employed to produce the project's numerical and graphical outputs, including descriptive statistics for infeed delays, total time lost, and overall downtime at both the infeed and outfeed locations of the press line. The analysis conducted with Pandas clearly identified the locations facing the most significant challenges and quantified the total duration of time lost due to stoppages. This comprehensive visualization not only highlights critical bottlenecks in production but also aids in formulating targeted improvement strategies.

Finally, Microsoft Word was used to compile and present the project's findings in a cohesive and organized manner. This tool facilitated the creation of a structured report that integrated various sections, ensuring clarity and consistency in our presentation. Through these tools, the team systematically documented, analyzed, and communicated our project outcomes effectively.

4. Data Collection

For this study, data collection was conducted both manually and automatically. Manual data was collected in person to gain a deeper understanding of the process and its components by directly observing the workflow and speaking with on-site manufacturing engineers and operators. The team made several visits to the site, spending hours observing operations, interacting with operators, and taking detailed notes. After each visit, a Q&A session was held with plant officials. However, automatic data collection was obtained from the server, which captured machine operational and sensor data. For this study, a full month of production data across two shifts was analyzed. A sample of the collected data is presented in Table 1.

Table 1. Sample of downtime data

Event No.	Start Time	End Time	Minutes	Location	Fault	Shift	Grade1	Grade 2	Total Thickness (inch)
1	6/4/2024 10:22	6/4/2024 10:24	1.4333	Infeed	Feeder Delay	Day	8	5	1.5
2	6/4/2024 10:25	6/4/2024 10:25	0.2833	Infeed	Feeder Delay	Day	8	5	1.5
3	6/4/2024 10:25	6/4/2024 10:26	0.4167	Infeed	Stop Seq Main Console	Day	8	5	1.5
4	6/4/2024 10:28	6/4/2024 10:28	0.4167	Infeed	Feeder Delay	Day	8	5	1.5
5	6/4/2024 10:29	6/4/2024 10:29	0.0833	Infeed	Manual Coded Event	Day	8	5	1.5

In Table 1, a sample of downtime events, classified as minor stops, is presented. Grade 1 and Grade 2 represent the number of first-grade and second-grade veneer sheets used, respectively, while thickness refers to the billet thickness after the veneer exits the press at the outfeed section. The study focused on stops lasting less than 2 minutes, and only these events were analyzed.

5. Results and Discussion

Through detailed analysis, it was revealed that the assumption that minor stoppages had a negligible impact on production yield was incorrect; these disruptions significantly reduced overall output. A comprehensive assessment of downtime across individual units showed that frequent interruptions disrupted the production flow, leading to inefficiencies. Despite implementing a recovery plan, including adjustments to line speed, full restoration of production levels was not achieved. The persistence of minor stoppages highlights the complexity of the underlying issues, indicating the need for a more nuanced approach. A thorough examination of production processes, including equipment malfunctions and procedural inefficiencies, is essential. By adopting a holistic strategy incorporating advanced diagnostics, improved maintenance protocols, and process optimization, the team may reduce the frequency and impact of these stoppages, thereby improving production efficiency.

Our findings suggest that achieving complete recovery for Press and the in-line feed is unlikely. While the team developed a recovery plan to increase daily production yield, the team cannot guarantee a return to previous levels or an increase to meet new quotas. The high frequency of minor stoppages, coupled with the ambiguous nature of their causes, complicates resolution efforts. Data were analyzed using correlation analysis, regression, and logistic regression to determine if factors such as veneer quality or shift timing influenced the number of minor stops. However, none of these tests revealed statistical significance. The number of infeed delays was somewhat correlated with billet thickness and tended to be higher during the night shift, but these findings were not statistically significant. Apart from some exploratory analysis, discussed in the following subsections, the team primarily relied on direct observations and Q&A sessions with operators and engineers to develop their findings and recommendations.

5.1 Numerical Results

Pandas in Python was utilized to generate Table 2, which presents the total minutes lost and infeed delays for all types of downtime. As indicated, a total of 4,610 stoppages were recorded, with each stoppage having a minimum duration of 0.02 minutes. Furthermore, the mean downtime for these stoppages was calculated to be 3.13 minutes.

Table 2. Descriptive statistics of infeed delays and total minutes lost for all types of downtime

Description	Count	Mean	STD	Min	Max
Infeed Delay	4610	0.78	0.42	0.00	1.00
Down Time (min)	4610	3.13	149.19	0.02	10074.88

Table 3 illustrates the hourly infeed delays and the total minutes lost specifically attributed to minor stoppages. A total of 239 minor stoppages is recorded, with each stop averaging a minimum duration of 0.42 minutes. Additionally, the mean total time lost because of these minor stoppages is calculated to be 5.9 minutes.

Table 3. Descriptive statistics of hourly infeed delays and total minutes lost (minor stops only)

Description	Count	Mean	STD	Min	Max
Number of Infeed Delays	239	14.8	6.7	1.0	34.0
Total Minutes Lost (min)	239	5.9	3.0	0.42	15.8

5.2 Graphical Results

Figures 1-3 below provide graphical representations, in the form of bar graphs, illustrating the negative effects of minor stoppages on production yield. Each graph focuses on three key locations within ML Press 2: the Infeed, the Outfeed, and the overall machine performance.

Figure 1 illustrates the percentage of total stoppage time along with the total number of stops for each location, indicated by the numbers displayed above each bar. The data reveals that the highest percentage of stoppages occurred at the "ML Press 2 Infeed," where a total of 1,400 stops were recorded. This suggests that the infeed process at this location may be a significant bottleneck in the production line, contributing to considerable downtime even though only considering minor stops. It is also worth noting that the frequency of stops at this location could indicate recurring issues, such as improper veneer feeding or equipment malfunctions, which could be addressed to improve overall efficiency. Identifying and analyzing these patterns can be crucial for implementing targeted corrective actions and reducing stoppage-related downtime in the future.

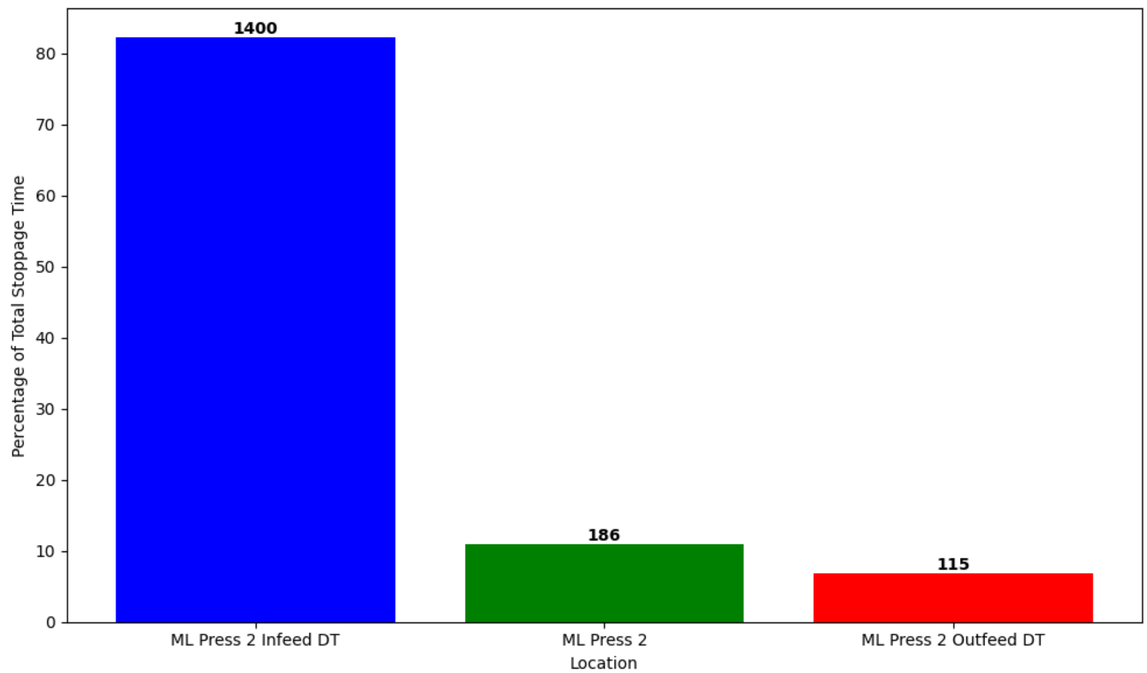

Figure 1. Percentage of total stoppage time at location

Figure 2 presents the total stoppage times (in minutes) for each location on ML Press 2. The data reveals that the most significant downtime occurred at the "Stop Seq Main Console," with a total of 740 minutes, indicating it as the primary

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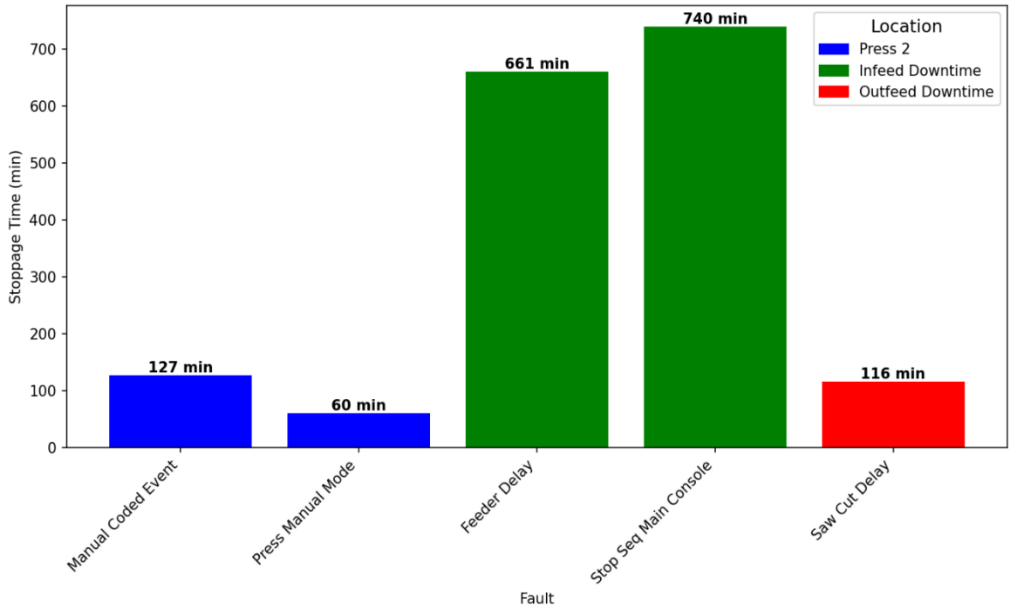

Figure 2. Total stoppage time (in min.) at location

source of inefficiency. The "Feeder Delay" followed closely behind with 661 minutes of stoppage, showing that issues with feeding processes contribute substantially to overall production delays. Additionally, the main press encountered delays, specifically in "Manual Code Event" and "Press Manual Mode," with recorded times of 127 minutes and 60 minutes, respectively. While these are notable, they pale in comparison to the feeder and main console delays. The "Saw Cut Delay," totaling 116 minutes, is another area of concern; however, this can be significantly reduced by optimizing the cutting process. Specifically, ensuring that billets are pre-cut to the sizes requested by customers could streamline the outfeed area, as smaller billets inherently require more cuts than their larger counterparts.

It is important to acknowledge that press delays, often caused by equipment issues such as chain snapping, motor burnout, and other infrequent, non-code events, resulted in approximately 3 hours of lost time over the nearly month-long observation period. Although this figure warrants attention, the current focus should be on addressing the more substantial delays, such as those at the feeder and main console, as resolving these will yield the most considerable improvement in overall efficiency. By prioritizing these high-impact areas, the production line stands to gain the most significant reduction in downtime.Figure 3 illustrates the hourly number of stops along with the total minutes lost during these interruptions. The data reveals a consistent pattern, with no significant fluctuations or anomalies that would typically warrant concern. To further investigate any potential trends, separate graphs were plotted to compare the hourly minutes lost due to minor stoppages during both day and night shifts, as well as the hourly number of minor stops for each shift.

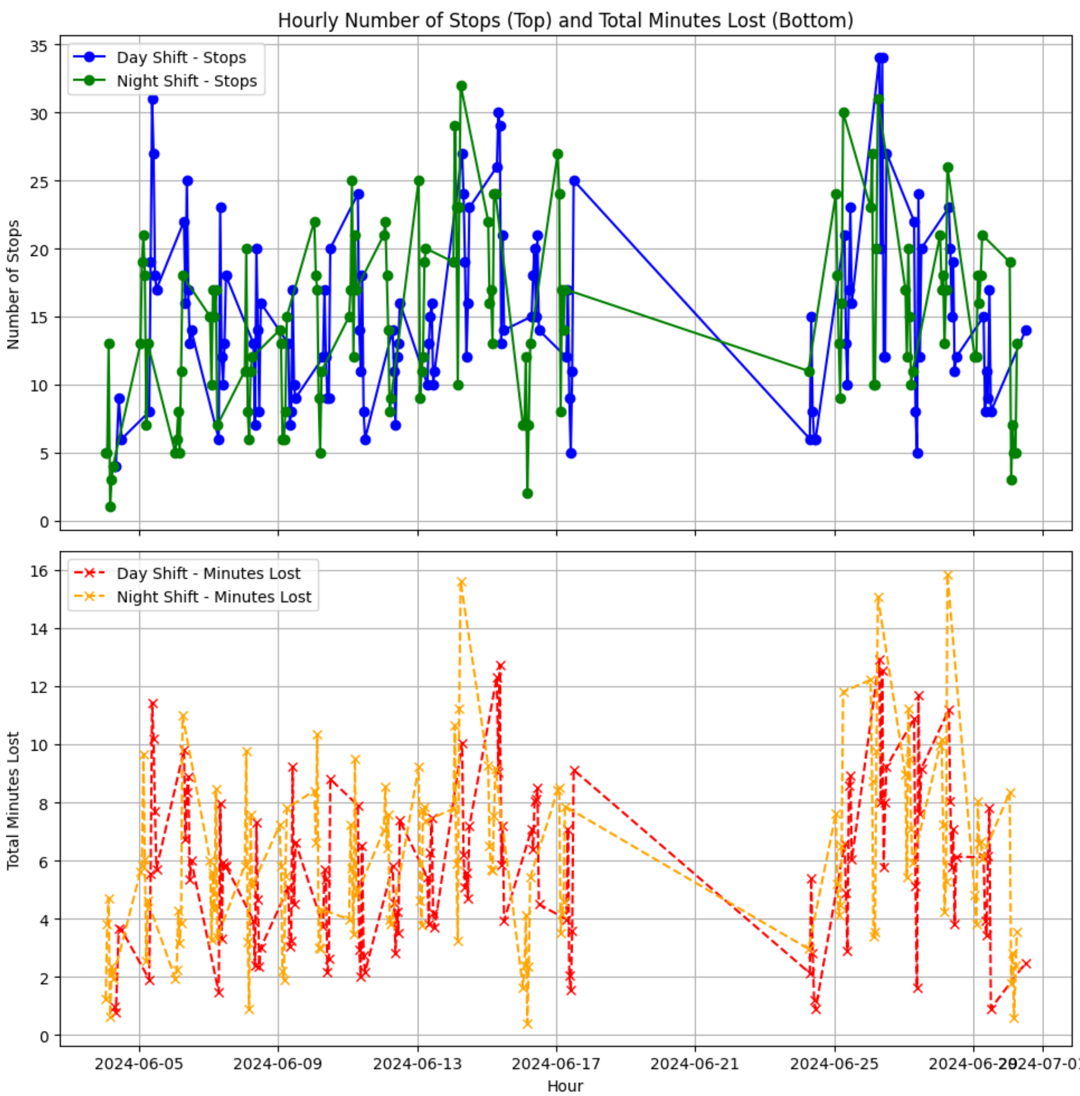

Figure 3. Hourly number of stops (top) and total minutes lost (bottom) per shift

The analysis showed no discernible or systematic patterns; the data appeared random, indicating that stoppages were distributed around mean value of 15. Additionally, the similarity in patterns between day and night shifts suggests that the issues causing these minor stops are not time specific. They are likely inherent to the overall production process. This lack of hourly or shift-based variation implies that the interruptions are not influenced by external factors such as worker fatigue or shift transitions but may be due to equipment-related inconsistencies or inherent process variations.

5.3 Proposed Improvements

Based on the results and discussion, the following recommendations are proposed for continuous improvement:

Addressing Veneer Quality Issues with the Vendor:

The veneer vendor should be informed about the specific quality issues that are impacting the infeed layup operation, as defects such as splits, torn corners, bent, and wavy veneers are contributing to frequent minor stoppages. Establishing a feedback loop with the vendor will ensure they are aware of the impact these defects have on production efficiency and can work towards improving the overall quality of the veneers supplied.

Implementing a Vendor Quality Screening Mechanism:

The vendor should implement a rigorous quality screening mechanism at their facility to detect and filter out defective veneers before they are shipped to the client site. Regular audits and quality assessments should be carried out to ensure adherence to the agreed quality standards, reducing the likelihood of defective veneers reaching the production line.

Detailed Communication of Physical Quality Requirements:
The company should provide the vendor with comprehensive specifications regarding the physical qualities that are acceptable and those that cause issues, such as the maximum allowable length of splits, acceptable levels of waviness, and criteria for rejecting torn or damaged corners. This will help the vendor better understand the client's expectations and requirements, leading to fewer disruptions in the layup process.

Redesigning the Suction Bar Geometry:
Consider redesigning the geometry of the suction bar that transfers veneers from the storage bay to the main conveyor. The implementation of a crossbar suction design could significantly improve the handling of torn and split veneers compared to the parallel bar suction system. Crossbar suction is known for its ability to distribute suction more evenly, reducing the chances of hang-ups, jams, and missed veneers. Testing different suction configurations in a controlled environment before full-scale implementation can help determine the most effective design for handling various veneer defects.

Enhancing the Veneer Feeding Mechanism:
Improving the speed and efficiency of the veneer feeding mechanism will allow the line to maintain continuous operation, even if one or two storage bays experience stoppages due to defective veneers. This recommendation includes evaluating the potential of adding an extra bay (a fourth bay) as a backup feeder to ensure uninterrupted feeding, even during downtime in other bays. Regularly maintaining and optimizing the feeding equipment can further enhance reliability and throughput.

Addressing Operator Overload in the Infeed Layup Area:
The current workload for operators in the infeed layup area may be excessive, leading to reduced attention to veneer orientation and quality issues. A comprehensive study should be conducted to quantify the losses and inefficiencies caused by this overload, justifying the need for additional personnel or task redistribution. For instance, assigning a dedicated operator solely to manage veneer alignment and orientation can prevent further downstream disruptions, thereby improving overall production efficiency.

Utilizing Data for CI:
Data collected from stoppages, veneer defects, and operator actions should be continuously monitored and analyzed to identify recurring issues and trends. Implementing an AI-based monitoring system can help predict potential stoppages, allowing proactive interventions before they occur. Such a system can also provide valuable insights into optimizing operator efficiency, machinery settings, and veneer handling processes.

Overall Recommendation:
To achieve maximum efficiency and minimize downtime, maintaining a dedicated operator in the infeed area is crucial. Implementing a faster, more efficient crossbar suction mechanism will greatly enhance the transfer of veneers from the bays to the conveyor, thereby reducing hang-ups and jams. Additionally, fostering a partnership with the veneer vendor to improve quality control based on current data analysis and observations will ensure that the manufacturing process is smoother and less prone to interruptions. By adopting these strategies, the company can significantly reduce minor stoppages, increase productivity, and maintain a consistent quality standard in billet production.

6. Conclusion

The project data suggests that eliminating minor stoppages on the timberland company’s press lines may be difficult with the current setup. While increasing machine speeds could reduce downtime temporarily, this method is unsustainable and could lead to equipment overheating and larger downtimes. Additionally, higher speeds may compromise billet curing quality.For a lasting solution, the facility should invest in upgraded equipment with advanced preventative measures, focusing on real-time automated detection, various AI technologies, improved veneer handling, and efficient feeding technology. Balancing short-term speed gains with these long-term upgrades will help reduce stoppages, boosting overall efficiency and productivity

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