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Application of FMEA and RCM in Developing a Standard Operating Procedure (SOP) for Belt Conveyor Splicing

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ABSTRACT

Belt conveyors are the most widely used material transportation systems in various industries because they are capable of continuously moving goods efficiently and consistently. This system consists of a belt driven by pulleys and a motor, enabling the transfer of large quantities of material in a relatively short time. Its reliability is highly influenced by the quality of the belt joint, making maintenance and splicing procedures crucial aspects. This study discusses the application of Failure Mode and Effect Analysis (FMEA) and Reliability Centered Maintenance (RCM) methods in developing a Standard Operating Procedure (SOP) for belt conveyor splicing. The study was conducted at PT. Indonesia Belting Solution during the period of June 1 – July 31, 2025, through field observations, technical interviews, documentation, and data analysis. The results of the identification show that the dominant failures occur at the belt joints in the form of breakage, tearing, and brittleness. FMEA analysis indicates that joint failure due to inaccurate splicing processes is the top priority with the highest Risk Priority Number (RPN). Through the RCM approach, a Condition Directed Maintenance strategy was established as the primary action, and an SOP for splicing using the finger splice and hot press methods was developed to improve joint quality. In addition to providing a structured evaluation of potential failures, this study emphasizes that the integration of FMEA and RCM can serve as a systematic basis for preparing standard procedures. The proposed SOP implementation is expected to enhance joint strength, extend belt service life, and reduce production downtime, thereby improving conveyor system reliability and overall operational efficiency.

Keywords: Belt conveyor, FMEA, RCM, SOP, Splicing

1. INTRODUCTION

A belt conveyor is one of the most widely used material handling systems in modern industries due to its efficiency and ability to transport materials continuously (Konieczna-Fuławka, 2025). This system plays a crucial role in maintaining smooth production processes, particularly in the food, beverage, and manufacturing sectors (Anjas Saputra et al., 2024). However, belt conveyors are also prone to various technical issues, especially in the joint section. Failures such as torn belts, broken splices, or hardened belts can cause significant downtime and reduce overall productivity (Bajda & Hardygóra, 2021). To minimize the risk of such failures, a comprehensive evaluation of the existing splicing procedures is required, including adjustments to operational standards and industry best practices (Badan Standardisasi Nasional, 2015). One analytical approach commonly used is the Failure Mode and Effect Analysis (FMEA) method, which helps identify potential failure modes and assess their risk levels through the calculation of the Risk Priority Number (RPN) (Kurniawan & Rizqi, 2025). Using this method, companies can determine which components are most critical and require greater attention. In addition, the implementation of Reliability

Centered Maintenance (RCM) is essential, as it helps formulate appropriate maintenance strategies for each identified failure mode. These strategies may include Condition Directed (CD), Time Directed (TD), Finding Failure (FF), or Run to Failure (RF) approaches, ensuring that maintenance activities are more targeted and efficient (Hakim et al., 2021). The combination of FMEA and RCM methods enables companies to enhance the effectiveness of their maintenance programs and reduce downtime risks caused by belt conveyor failures. This research was conducted at PT. Indonesia Belting Solution, a company specializing in belt conveyor splicing services and industrial belt supply (Indonesia Belting Solution, 2025). The study focuses on evaluating the existing splicing procedures and developing recommendations for a new, more systematic Standard Operating Procedure (SOP). The findings are expected to improve conveyor system reliability and support optimal production continui

2. METHOD

The research utilized both primary and secondary data as the main sources of information. Primary data were obtained through direct field observations, interviews with technicians and operators, and documentation of the belt conveyor splicing process to understand actual conditions, splicing procedures, and common types of damage. Meanwhile, secondary data were collected from company archives, including maintenance reports, damage records, and relevant literature on Failure Mode and Effect Analysis (FMEA) and Reliability Centered Maintenance (RCM), which were used to support and validate the field findings.

The research on the belt conveyor system was then conducted systematically through several stages. It began with determining the research topic and scope, focusing on updating the conveyor splicing SOP based on FMEA and RCM methods. A literature and field study was carried out to review relevant theories and observe actual conditions in the company. Data were collected through observations, interviews, and documentation to identify existing issues.

Next, a Functional Block Diagram (FBD) was developed to illustrate the relationship between conveyor components such as the motor, pulley, roller, and belt. The FMEA method was applied to identify potential failure modes and calculate risk priority values based on severity, occurrence, and detection. Based on these results, appropriate maintenance strategies were selected using the RCM approach, including Condition Directed, Time Directed, Finding Failure, or Run to Failure.

Finally, a new Standard Operating Procedure (SOP) was developed to improve inspection, maintenance, and operational processes. The proposed SOP was analyzed and compared with FMEA and RCM findings to ensure its relevance and effectiveness. The research concluded with a finalized SOP document ready for implementation to enhance the reliability and maintenance performance of the belt conveyor system.

3. RESULT AND DISCUSSION

3.1. Data Collection

After conducting research at PT. Indonesia Belting Solution, various types of belt conveyor failures were identified based on repair and maintenance activities observed during the period from June 1, 2025, to July 31, 2025. The collected data summarize 15 cases of belt conveyor damage from different companies that underwent repair or maintenance, as presented in the table below.

Table 1. Belt Conveyor Failures in Several Industries

No.	Date	Company	Type of Damage	Cause
1	June 1, 2025	PT. Garudafood	Torn belt	Worn-out roller bearing
2	June 5, 2025	PT. Garudafood	Broken splice	Uneven or misaligned belt joint
3	June 6, 2025	PT. UBM Waru Biscuit	Hardened and cracked belt	Over-tightened adjuster
4	June 9, 2025	CV. Sejahtera	Rapid wear on belt top layer	High abrasive or dusty environment
5	June 10, 2025	PT. Prasad Seeds	Worn belt, potential breakage	Uneven or misaligned belt joint
6	June 15, 2025	PT. Nissin Biscuit	Edge wear, poor tracking, potential tearing	Misalignment of belt, pulley, or roller
7	June 17, 2025	PT. Sepanjang Pangan Jaya	Minor damage with potential major failure	Lack of regular inspection
8	June 21, 2025	PT. Garudafood	Carryback and material buildup, potential tearing	Infrequent cleaning maintenance
9	June 25, 2025	PT. Garudafood	Belt wear and slippage	Overload (exceeding capacity)
10	July 18, 2025	PT. Prasad Seeds	Torn belt	Material trapped in roller
11	July 22, 2025	PT. Surya Pangan Lestari	Uneven surface causing wear and slippage	Worn or rusty pulley/roller
12	July 23, 2025	PT. Prasad Seeds	Hardened or cracked belt	Excessive heat exposure
13	July 25, 2025	CV. Sejahtera	Excessive elongation	Incorrect belt thickness or type
14	July 27, 2025	PT. Nissin Biscuit	Belt surface wear	Scraper too tight
15	July 31, 2025	CV. Sejahtera	Rapid wear on belt cover and roller	High abrasive or dusty environment

3.2. Failure Mode and Effect Analysis (FMEA)

In the next stage, a Failure Mode and Effect Analysis (FMEA) was conducted to identify potential system failures. One of the key elements in implementing FMEA is the calculation of the Risk Priority Number (RPN). This value is used to determine the priority level for addressing each failure mode based on the associated risk. The formula for calculating the RPN is shown below (Fabis-Domagala et al., 2021):

$$RPN = Severity\ x\ Occurance\ x\ Detection$$

Table 2. Failure Mode and Effect Analysis (FMEA)

No	**Company**	**Failure Mode**	**Failure Effect**	**Main Cause**
1	PT. Garudafood	Torn Belt	Material spillage, extensive damage, downtime	Infrequent cleaning
2	PT. Sepanjang Pangan Jaya	Minor Continuous Damage	Operational and quality impact	Lack of routine inspection
3	PT. Nissin Biscuit	Torn Belt	Material spillage, extensive damage, downtime	Misalignment (belt/pulley/roller)
4	PT. Garudafood	Splice Failure	Complete belt break, high downtime, safety risk	Uneven or imprecise belt joint
5	CV. Sejahtera	Belt Wear	Shorter belt life, increased replacement cost	Abrasive and dusty environment
6	CV. Sejahtera	Belt Wear	Shorter belt life, increased replacement cost	Abrasive and dusty environment
7	PT. Garudafood	Torn Belt	Material spillage, extensive damage, downtime	Worn roller bearing
8	PT. Prasad Seeds	Torn Belt	Material spillage, extensive damage, downtime	Material stuck on roller
9	PT. Prasad Seeds	Belt Wear	Shorter belt life, increased replacement cost	Uneven belt joint
10	PT. Garudafood	Belt Wear	Shorter belt life, increased replacement cost	Overload (exceeding capacity)
11	PT. Surya Pangan Lestari	Slip	Loss of traction, reduced throughput	Worn or rusty pulley/roller
12	CV. Sejahtera	Excessive Elongation	Belt slack, slip, take-up stroke fully extended	Improper belt thickness/type
13	PT. UBM Waru Biscuit	Brittle/Cracked Belt	Unexpected failure, tearing risk	Overtightened adjuster
14	PT. Prasad Seeds	Brittle/Cracked Belt	Unexpected failure, tearing risk	Excessive heat exposure
15	PT. Nissin Biscuit	Belt Wear	Shorter belt life, increased replacement cost	Scraper too tight

Table 3. Failure Data

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3	PT. Nissin Biscuit	Torn Belt	Material spillage, extensive damage, downtime	Misalignment (belt/pulley/roller)
4	PT. Garudafood	Splice Failure	Complete belt break, high downtime, safety risk	Uneven or imprecise belt joint
5	CV. Sejahtera	Belt Wear	Shorter belt life, increased replacement cost	Abrasive and dusty environment
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Table 4. FMEA Rating

No	Severity (S)	Occurrence (O)	Detection (D)	RPN
1	9	6	7	378
2	5	8	9	360
3	9	6	6	324
4	10	5	6	300
5	6	7	6	252
6	6	7	6	252
7	9	5	5	225
8	9	5	5	225
9	6	5	6	180
10	6	6	5	180
11	6	5	5	150
12	6	4	6	144
13	7	4	5	140
14	7	4	5	140
15	6	4	5	120

The FMEA table above shows that each failure mode in the belt conveyor system has a Risk Priority Number (RPN) value calculated by multiplying the Severity, Occurrence, and Detection scores. The assessment was conducted objectively through interviews with operators and maintenance technicians to evaluate component failures and their resulting impacts.
The analysis identified six failure modes with the highest RPN values, as follows:

1. Torn belt (PT. Garudafood) with an RPN of 378, causing material spillage and production downtime.
2. Operational and quality disturbances (PT. Sepanjang Pangan Jaya) with an RPN of 360, resulting from a lack of regular inspection.
3. Torn belt (PT. Nissin Biscuit) with an RPN of 324, caused by frequent misalignment issues.
4. Splice failure (PT. Garudafood) with an RPN of 300, potentially leading to a complete belt break.
5. Belt wear (CV. Sejahtera) with an RPN of 252, due to an abrasive working environment.
6. Torn belt caused by worn roller bearings (PT. Garudafood) with an RPN of 225, which still requires attention.

These six failure modes are identified as priority focuses in determining maintenance strategies and developing an updated Standard Operating Procedure (SOP) for belt conveyor reliability improvement.

3.3. RCM Action Analysis

The Reliability Centered Maintenance (RCM) analysis was carried out to determine the most appropriate maintenance strategy for each failure mode identified through the FMEA process. RCM classifies maintenance actions into four categories: Condition Directed (CD), Time Directed (TD), Finding Failure (FF), and Run to Failure (RF) (Hakim et al., 2021).

Table 5. RCM Action Analysis

Failure Mode	Main Cause	Failure Effect	RPN	RCM Action	Type
Belt Tear/Rip	Infrequent cleaning maintenance	Material spillage, high downtime	378	Regular inspection and cleaning, upgrade scraper and skirting, improve housekeeping	CD
Lack of Inspection	No routine inspection	Minor damage undetected → major failure	360	Scheduled inspection program, checklist and audit, safety protection test	FF + CD
Belt Tear/Rip	Misalignment (belt/pulley/roller misaligned)	Edge damage → tear → downtime	324	Laser alignment, use self-aligning idler, frame adjustment	CD
Splice Failure	Uneven or imprecise splicing	Complete belt break, safety risk	300	Standardize vulcanizing procedure, certify splice technicians, splice inspection	TD + CD
Wear/Abrasion	Abrasive or dusty environment	Short belt lifespan, increased cost	252	Use anti-abrasive cover, apply sealing and dust control, thickness inspection	TD + CD
Belt Tear/Rip	Worn bearing/idler	Material spillage, extended damage	225	Idler preventive maintenance (greasing), vibration/temperature monitoring, proactive replacement	TD + CD
Belt Tear/Rip	Material trapped in roller	Local belt damage or tear	225	Redesign chute, install anti-jam guarding, inspect transfer point	CD
Wear/Abrasion	Overload (excessive load)	Slippage/fast wear, reduced throughput	180	Feed rate control, load interlock system, review motor capacity	TD + CD
Slip (Pulley/Roller)	Worn and corroded pulley/roller	Loss of traction, reduced throughput	150	Pulley relagging, roller replacement, corrosion inspection	TD + CD
Excessive Elongation	Incorrect belt type/thickness	Slack belt, take-up stroke limit reached	144	Re-specify belt according to duty, verify OEM specs, reset take-up tension	TD + CD
Belt Cracking/Brittleness	Adjuster or scraper too tight	Unexpected failure, tear risk	140	Adjust pressure according to OEM, train maintenance personnel	TD + CD
Belt Cracking/Brittleness	Excessive heat exposure	Belt material degradation	140	Use heat-resistant belt, improve ventilation or insulation	TD + CD

The analysis presented in the table above shows that most failure modes can be effectively managed through the Condition Directed (CD) strategy, particularly for issues such as misalignment, material jamming, and carryback caused by insufficient cleaning. Meanwhile, wear-related failures are more appropriately addressed using a Time Directed (TD) approach, while hidden potential failures require a Finding Failure (FF) strategy. The Run to Failure (RF) method is not recommended, as most components have a direct impact on production continuity (Hakim et al., 2021).

3.4. Development of a New SOP

Based on the results of the FMEA and RCM analyses, a new Standard Operating Procedure (SOP) for belt conveyor splicing was developed. The SOP is designed to be more structured and to minimize the potential for joint failure, which had previously been identified as a critical point. The new SOP includes technical procedures for splicing using the finger splice and hot press methods, which were chosen for their superior joint strength and precision. In addition, the SOP incorporates detailed instructions for periodic inspections, workplace cleanliness standards, belt condition monitoring, and guidelines for both preventive and corrective maintenance (Apridiansyah et al., 2024). With the implementation of this updated SOP, maintenance activities can be conducted more consistently and systematically. This improvement is expected to enhance conveyor system reliability, extend belt lifespan, and reduce production downtime caused by splicing failures.

4. CONCLUSION

Based on the results of the study on updating the Standard Operating Procedure (SOP) for belt conveyor splicing using the FMEA and RCM approaches, several conclusions can be drawn as follows: The FMEA analysis successfully identified the main failure modes in the belt conveyor system, including belt tearing, splice failure, wear, and inspection-related issues. The Risk Priority Number (RPN) values indicated that the splice joint is the most critical component requiring priority attention. Through the application of the RCM method, appropriate maintenance strategies were established, primarily dominated by Condition Directed (CD) and Time Directed (TD) strategies, supported by Finding Failure (FF) for hidden or undetected failures. The results of these analyses formed the foundation for developing a more structured and targeted new SOP, which includes detailed procedures for finger splice and hot press methods, regular inspection schedules, and preventive as well as corrective maintenance guidelines. The implementation of this updated SOP is expected to enhance the overall reliability of the conveyor system, extend belt service life, and significantly reduce production downtime caused by splicing failures.

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