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Minimize Conveyor Belt Damage In Coal-Fired Power Plants Using SEM-PLS and FMEA Methods

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Abstract :
Coal is the largest source of 38% coal-fired power plants globally, the most growth in Asia. In Indonesia, coal-fired power plants dominate, with the total installed power reaching 48.43%. A Belt conveyor is leading equipment for transporting coal to the boiler. The phenomenon of conveyor belt damage such as tearing, peeling, and rupture is an event that occurs in many industries in the world. The purpose of this study was to determine the effects of belt damage, OEE values, and productivity using structural equation modeling (SEM) analysis methods, as well as identify and evaluate the causes of damage to belts, using failure mode and effect analysis (FMEA) methods. The results showed a significant influence between damaged belts with OEE, OEE productivity, and damaged belts on productivity through OEE. FMEA analysis three leading causes of belt damage based on the highest risk priority number (RPN).

Keywords: Belt Conveyor,FMEA, OEE, SEM PLS

1. INTRODUCTION

Coal-fired power plants are the world's leading source of electricity right now. Coal is the largest source of electricity, with a percentage of 38% of all coal-fired power plants in the world. Asian countries are the highest coal consumption, i.e., in China 81.67 Exajoule and India 18.62 Eexaloule (BP p.l.c., 2020). The abundant availability of coal and its low price make coal a top choice for providing cheap electricity. Coal-fired power plants dominate the total power generation capacity in Indonesia. Based on PLN statistics, the total installed capacity of power plants in Indonesia is
62.832.70 MW in 2019, with the most significant percentage being coal-fired power plants, amounting to 20.750.50 MW or 48.43% (PT PLN, 2020).

The leading equipment for transporting coal from the unloading area to the storage area is a conveyor belt at a coal-fired power plant. A Belt conveyor is commonly used as continuous transport equipment. It has a large delivery capacity with high efficiency, simple construction, and easy maintenance (Zhao & Lin, 2011), often damaged belts cause substantial economic losses for consumers (Fedorko et al., 2014), Conveyor belt damage phenomena such as crushing, breaking. Conveyor breakage is widespread occurrences in many of the world's coal-fired power generation industries. Therefore, this study attempts to determine the effect of damage to conveyor belts on the productivity of conveyor belts and analyze the causes of damage problems on conveyor belts.

2. LITERATURE REVIEW

Previous literature elaborated three tested variables of OEE representing availability, performance, and quality (Rimawan et al., 2018). These three indicators represent six significant losses: Equipment Failure (Damage), Preparation and Adjustment Loss, Small Idling and Stopping, Decreased Speed, Defects, which will affect productivity levels, decreased production costs, and profit performance of the company.

In addition (Supriyadi et al., 2017), the decrease in OEE value is due to the disruption of the torn belt due to the belt's friction with the back support when the belt is running.

Partial least square-structural equation modeling (PLS-SEM) is a multivariate analysis that combines factor analysis and regression, which can test the relationship between measured variables and latent variables. (Hair Jr et al., 2017), The PLS-SEM method can estimate the relationship between the path model and its latent variables (Sarstedt et al., 2020) PLS-SEM can address the lack of data, from modeling the available bands and the relationship of each variable, PLS-SEM has provided information with a relatively good level of importance and accuracy. (Rimawan et al., 2018). In PLS-SEM, there are two types of measurement models, namely measurement models with reflective indicators and measurement models with formative indicators (Asyraf & Afthanorhan, 2013).

The failure and impact analysis (FMEA) method was first developed in the late 1940s, and in 1940 reference was made to the FMEA manual. (Chang et al., 2013). FMEA is used to identify and analyze the failures of all parts of the system and their effects. In addition, the FMEA can also provide improvement recommendations to avoid losses or minimize the impact of failures. (S. Parsana & T. Patel, 2014). FMEA is a method that contains measures to identify possible process failures (Putra & Purba, 2018). FMEA is one method that can use to improve the quality, security of systems, products, processes, and reliability (Liu et al., 2019). One example is a modified FMEA approach that combines multiple criteria decision making, adding a cost component to the Risk Priority Number (RPN) calculation (Lo & Liou, 2018).

Based on the literature review above, the hypotheses presented in this study are: H1: Significant effect between the damaged belt and OEE

H2: Significant influence between OEE and productivity

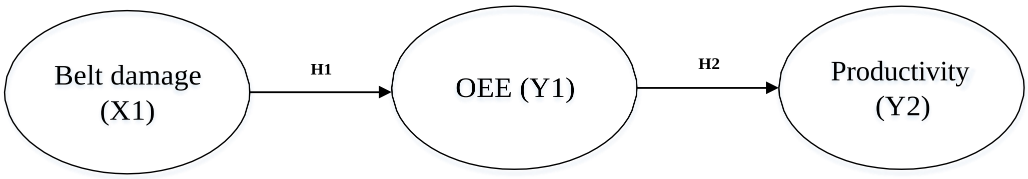


Figure 1: The proposed conceptual model

3. Methodology

Data collection for this study was conducted at large coal-fired power plants located in Banten, Indonesia. The data consist of monthly data recording between 2018-2020 coming from three conveyor belt samples. Other data are intermittent data caused by conveyor belt damage, overall equipment effectiveness (OEE), and conveyor belt production capability. They were extended with data analysis statistics using the Smart PLS application. The Smart PLS application determines a relationship between damaged belts, OEE, and productivity. Then find the cause of the problem with fishbone diagrams and priority improvements using the FMEA method.

Table 1. Variables, dimensions, and indicators

Variables	Dimension	Indicator	References
Belt damage	Downtime	X1	(Supriyadi ., et al 2017)
OEE	Availability, Performance, Quality	Y1	(Rimawan et al., 2018), (Sahrupi & Juriantoro, 2018)
Productivity	Production quantity	Y2	(Rimawan et al., 2018), (Zuniawan et al., 2020)

4. Result

In this study, performed testing, with the belt damage variable (X1) being the variable with reflective indicator, then the variable OEE (Y1) and Productivity (Y2) being the variable with formative indicator. Using CR)> 0.7, Indicator Reliability Value (using External Load)> 0.7, Convergent Validity Value (using AVE)> 0.5, and Discriminant Validity (using Former Larcker Criteria) The root value of AVE (diagonal matrix) must be greater than all good values to the left or down and for the formative model there are three levels of examination, namely Convergent Validity Values (using R-Square) 064-0.81, Colliniarity Issue Values (using VIF) <5, Significance and Relevance of Formative Indicators (using P-Values)) To see an essential indicator for measuring a variable, the P-Value of External Weight must be <(0.05) (Hair Jr et al., 2017). Figure 2 is an early-stage study model.

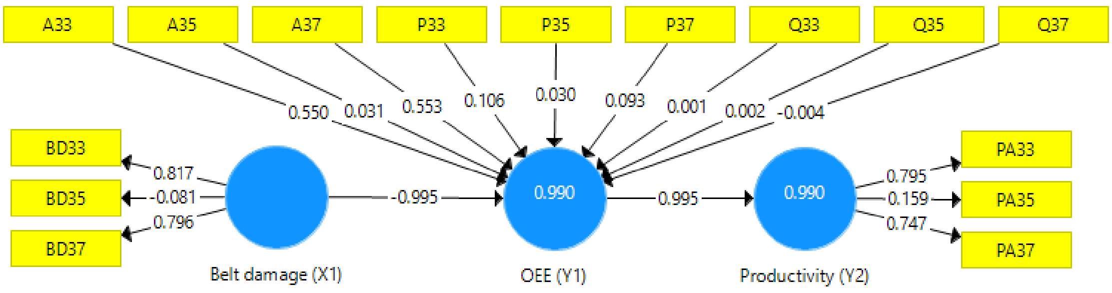


Figure 2. The early model of the outer model

Measurement Outer Model Final

In the initial testing of the external model, unqualified reflective and formative cues were eliminated. Figure 3 is the final stage outer model.

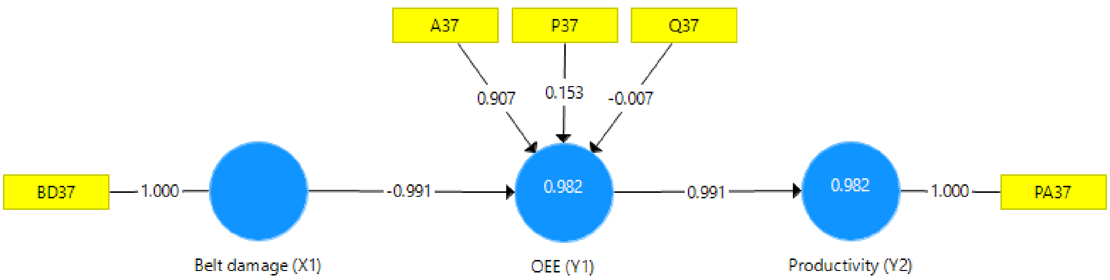


Figure 3. Outer model final

Table 2. Measurement of reflective indicators

Variables	Cronbach's alpha	rho_A	CR	AVE
Belt damage (X1)	1.000	1.000	1.000	1.000
Productivity (Y2)	1.000	1.000	1.000	1.000

Table 3. Measurement of formative indicators

Variable OEE	VIF
A37	1.572
P37	1.729
Q37	1.838

Based on table 2, reflective indicators were qualified with composite reliability values (CR), Cronbach alpha, and rho, above 0.7, and AVE values above 0.5. Table 3 all formative indicators were qualified with VIF values below 5 (Hair Jr et al., 2017). can then extend it by testing the inner model.

Testing Inner Model

Once all the variables meet the test conditions, the next step is to test the internal model to find out the results of the hypotheses. Figure 4 is the result of internal model testing using the bootstrap method.

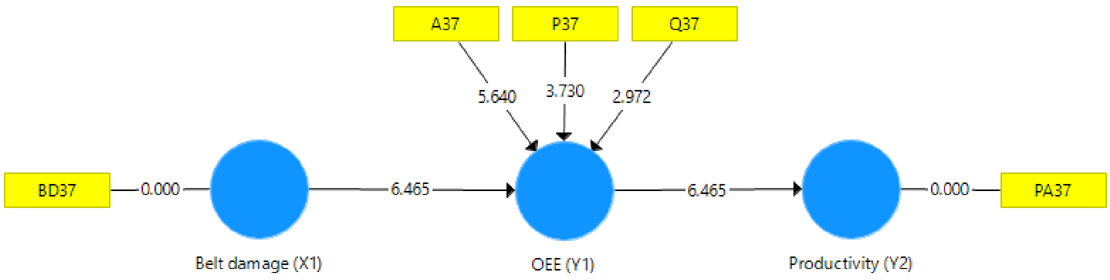


Figure 4. Inner model

From the results of testing the internal model, the next step is to test the hypothesis. If the value of P <(0.05), then the hypothesis has a significant relationship. If the P > (0.05) value is not significant, then the relationship is not significant or can be seen from the T-statistic value with > 1.96. the results of hypothesis testing are shown in table 4.

Table 4. Test the hypothesis of direct and indirect influence

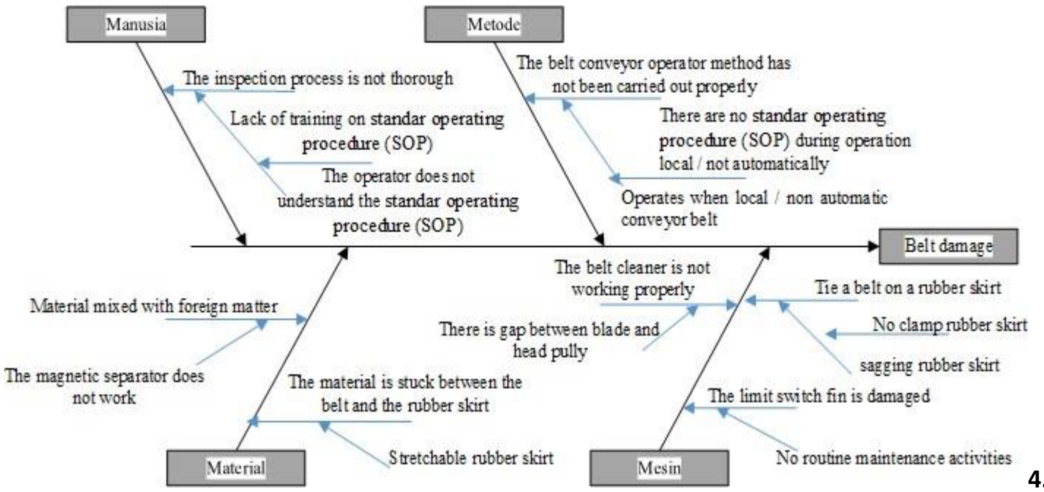
Hypothesis	Original sample	P-value	T-statistic	Remarks
Belt damage (X1) OEE (Y1)	- 0.991	0.000	6.465	Accepted
OEE (Y1) Productivity (Y2)	0.991	0.000	6.465	Accepted
Belt damage (X1) OEE (Y1) Productivity	- 0.982	0.000	98.856	Accepted

The next stage is to test the structural model with three steps, namely the measurement of the value of the coefficient of determination (R-square) R2 of 0.75, which is considered to have a significant budget accuracy, the value of R2 0.50 is deemed to be a simple budget accuracy. The value of R2
0.25 is considered to be poor forecast accuracy. Predictive relevance (Q2), a value of 0.02, is believed to have little forecast relevance, 0.15 has moderate forecast relevance, and 0.35 has high forecast relevance (Hair Jr et al., 2017). The coefficient determination calculation and predictive relevance are shown in table 5.

Table 5. Coefficient determination (R^2) and predictive relevance (Q^2)

Variables	R-Square	Q2
OEE (Y2)	0.982	0.473
Productivity (Y2)	0.982	0.934

Based on table 5, the value of the coefficient of determination (R-square) for OEE and productivity is above 0.75, which means that the variables OEE and productivity have significant estimation accuracy. The Predictive relevance value (Q2) for the variables OEE and productivity have values above 0.35, which means OEE and productivity have an excellent predictive correlation.



4.3

Figure 5. Fishbone diagram of conveyor belt damage

Failure Mode And Effect Analysis

In this study, a focus group discussion (FGD) was formed, consisting of maintenance, operations division, and teams from outside the company that specifically addressed conveyor belt damage, using root cause analysis using fishbone diagrams and determining repair priorities FMEA method. The results of the root cause analysis are presented in Figure 5.

Once the cause of the belt damage is at the next level, determining the priority of repair using the FMEA method, the analysis results using the FMEA method are presented in table 6.

Table 6. Risk identification and improvement using FMEA

Risk	Effect of risk	S	Causes of failure	O	Departemen control	D	RPN	Improvement
		8	Tie a belt on a rubber skirt	9	Operating team	8	576	Add rubber skirt clamps
Conveyor belt damage	The belt is peeling	8	There is a gap between the blade martin and drive pully	8	Operating team	7	448	Make adjustments to the blade
		8	The Material is stuck between the belt and the rubber skirt	7	Operating team	7	392	Make adjustments on a loose rubber skirt
		8	The limit switch fin is damaged	3	Maintenance team	4	96	Add a fin or belt to the limit switch
		8	Material mixed with foreign matter	6	Maintenance team	6	144	Repair damaged magnetic separator
		8	Lack of training on the standard operating procedure (SOP)	4	Operational team	2	64	Conduct training for operators on standard operating procedure

		8	Magnetic separator maintenance is not performed routinely	5	Maintenance team	2	80	Make a magnetic separator maintenance schedule every week.
		8	Lack of magnetic separator maintenance skills	5	Maintenance team	2	80	Conduct magnetic separator maintenance training

5. CONCLUSION

Statistical test results using Smart PLS, There is a significant effect between faulty belt on OEE with negative band coefficient value. Reducing the level of belt damage will increase the OEE value significantly. There is a significant effect between OEE on productivity with a positive path coefficient value so that increasing OEE will increase productivity value significantly. There is an indirect effect of a faulty belt on productivity through OEE with a negative band coefficient value. Reducing the damage to the belt will increase productivity significantly. Analysis using Failure mode and effect analysis (FMEA) method obtained three leading causes of belt damage based on the value of the highest risk priority number (RPN), namely Tying the belt to the rubber skirt, There is a gap between the blade and the pully head, and Material stuck between the straps waist and rubber skirt. Therefore, by fixing all the causes of belt damage, it can increase productivity significantly.

CONFLICT OF INTEREST

The author insists that there is no problem in stating this scholarly work.

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