Analysis of FMEA to Determine Failure Mode Priority on the TS Analyzer Machine

Welly Atikno
Master of Industrial Engineering Student
Faculty of Engineering
Universitas Mercu Buana Jakarta, Indonesia
wellbjbs2@gmail.com

Lien Herliani Kusumah
Master of Industrial Engineering Lecturer
Faculty of Engineering
Universitas Mercu Buana Jakarta, Indonesia
lien.herliani@mercubuana.ac. id

Abstract

The machine is a tool that is useful for converting force into energy, where the energy can be used by humans for various activities. The use of machines is believed to simplify and speed up all existing activities. In addition, the machine is also found to have problems that can interfere with work productivity. This can give a loss to the company so that an analysis is needed to find the priority of the failure mode. This study aims to determine the source of failure in the TS analyzer engine in the coal quality survey service industry. The priority of failure on the machine is determined by FMEA analysis. The results showed that the damage to the inner-outer tube was caused by changes in temperature too quickly, O2 gas specifications were not suitable, and the engine shutdown method was not appropriate. The three failures on the damage to the inner outer tube with a value of RPN 336. The damage to the silicon carbon tube comes from over heating, unstable electric current and inadequate operator skills. The three failures on silicon carbon tube damage with an RPN value of 336.

Keywords
Coal, FMEA, Inner-outer tube, Risk Priority Number, Silicon carbon tube

1. Introduction
A machine is a device whose way of working is based on changing two forms of energy in a particular system (Perdana & Santoso, 2019) (Hunusalela et al., 2019). The form of energy that is commonly converted in machines is mechanical energy or electrical energy. The purpose of energy changes in machines is to help make human work easier. The TZ Analyzer machine is one of the machines used in the Survey Service Industry. This machine is used to test coal content. The productivity of surveyors is strongly influenced by the available resources, both human resources, preparation equipment and sample testing equipment in the laboratory. During 2020, the downtime of this machine is very high. Downtime is very disruptive to activities and affects productivity. Downtime is wasted time, where the production process does not run, usually caused by machine breakdowns (Setiawan, 2021) (Alvira et al., 2015). Downtime for both preparation and laboratory equipment is shown in Figure 1.

The survey service industry is one of the quality and quantity survey service companies that is authorized to conduct verification or technical investigation on mineral and coal exports registered with the Ministry of Energy and Mineral Resources and the Ministry of Trade of the Republic of Indonesia. Mineral and coal laboratories at this company are spread across all branch offices located in Palembang, Banjarbaru, Muara Teweh, Samarinda, Berau and Kendari. Surveyor companies have competence in implementing the Quality Management Standard System, marked by obtaining an ISO 9001: 2008 Certificate and SNI ISO/IEC 17025:2017 ISO/IEC 17025:2017 accreditation in their respective branches as proof of competence as a testing laboratory for mineral and coal commodities. In addition, the

Company is appointed as a technical verifier by the Ministry of Energy and Mineral Resources and the Ministry of Trade and Industry.

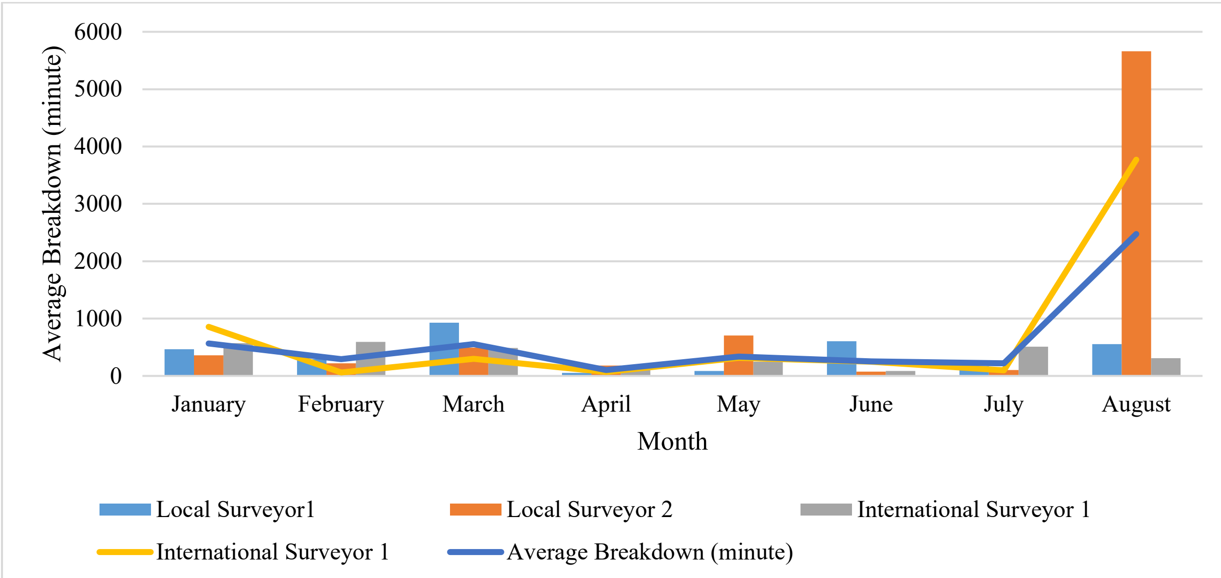

Figure 1. Downtime for both preparation and laboratory equipment

Based on the high value of downtime on the TS Analyzer Machine, it is necessary to analyze the determination of the causal factors. These factors need to be identified to determine the source of the low productivity (Er-Ratby & Mabrouki, 2018). The research of Liu et al. (2018) have identified the causative factors with the FMEA analysis method. His research determines the priority of the problem which is a factor causing the low value of the machine's effectiveness. In addition, the research of Anjalee et al. (2020) and Ramadhan & Widowati (2019)also apply FMEA as one of the methods to determine improvement priorities for low service delivery. Based on the references obtained, this study will use the FMEA method to determine the failure of the TS Analyzer Machine.

1.1 Objectives
This study aims to determine the source of failure on the TS analyzer engine. The failure priority is determined by FMEA analysis

2. Methods
The implementation stages of determining the largest failure on the TS Analyzer machine use the FMEA method (Akkarawatkhoosith et al., 2019). Here are the steps to determine the biggest failure mode (Stamatis, 1995).
a) Function definition of TZ Analyzer engine
Determination of the function of each component of the TS Analyzer machine that is damaged. The determination of this function is explained in the test process flow.

b) Determination of potential failure modes
Based on the results of the Focus Group Discussion (FGD) it can be seen the potential failure mode of each component that is damaged (Hendra et al., 2021) (Kurnia et al., 2021).

c) Determination of the effect of failure
Based on the known potential failure modes, determine the effect of the potential failure modes. Based on the effects, the severity level (S) is assessed on engine performance.

d) Determination of the cause of failure
The cause of potential failure is obtained from the drawing of the fishbone diagram that has been done. From the causes of failure, the occurrence value (O) will be determined.

e) Determination of detection of the cause of failure
Based on the known causes of failure, determine the detection value (D) of the cause of failure.

f) Value of Risk Priority Number (RPN)
The RPN value is used to determine the priority ratio of each component. RPN calculation using the following formula
RPN = S x O x D .... (1)

3. Data Collection

This chapter describes the flow of the coal testing process at the Surveyor Company. The stages of the sample testing process start from sampling (sampling), testing in the laboratory and finally the issuance of a report/certificate. Figure 2 is a technical verification process on coal quality.

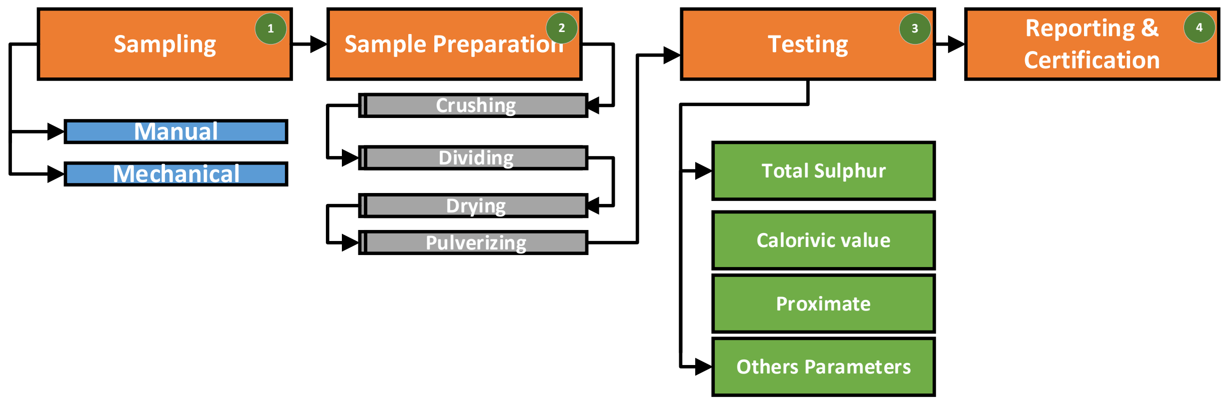

Figure 2. Coal sample testing process in the laboratory

The process of taking and testing coal samples in the laboratory goes through several stages. The first stage is Sampling, this stage is carried out in the field by manual method or mechanically at a location specified by the customer either at the mine, stockpile, jetty or on board. The second stage of preparation which is the stage of sample preparation in the laboratory before testing which includes the stages of crushing, dividing, drying and pulverizing. The third stage is testing samples to order from customers which includes various basic test parameters including Total Sulfur, Total Moisture, Proximate (moisture, ash, volatile matter), Calorific Value, as well as advanced tests such as Ultimate, Ash Analysis, and other tests. Each sample was tested twice (simplo and duplo). Then the fourth stage, the final product of the Surveyor company in the form of test results reports to customers and the government in the form of a Report of Analysis (ROA) or Certificate of Sampling and analysis (COA). Quantity measurement results are stated in the Draft Survey Report (DSR) and Certificate of Weight (COW). Meanwhile, the Survey Report (LS) is issued to customers to fulfill the requirements to the Ministry of Trade for processing export taxes and the Verification Result Report (LHV) is issued to customers to fulfill the requirements to the Ministry of Energy and Mineral Resources for processing royalties for mining materials.

4. Results and Discussion

The analysis of determining the factors causing failure on the TS Analyzer Machine is determined by the first stage through data breakdown losses. Based on the company's report data, the breakdown loss was caused by damage to several parts of the TS Analyzer. Breakdown loss recapitulation for the January – December 2020 period can be seen in Table 1.

Table 1. Breakdown loss January – December 2020

Part damage	Ammount of damage	*Break downtime total (minute)*	Percentage (%)	*Cumulative (%)*
Inner tube	5	3,960	36.87	36.87
Silicon Carbon tube	8	3,870	36.03	72.91

Outer tube	4	2,760	25.70	98.60
Electric Motor	1	90	0.84	99.44
Drying tube	2	60	0.56	100
Total	20	10,740	100	100

Based on Table 1, data processing and analysis were carried out using Pareto diagrams to determine the damage to parts of the TS Analyzer that dominated the breakdown time. The results of the Pareto can be seen in Figure 3.

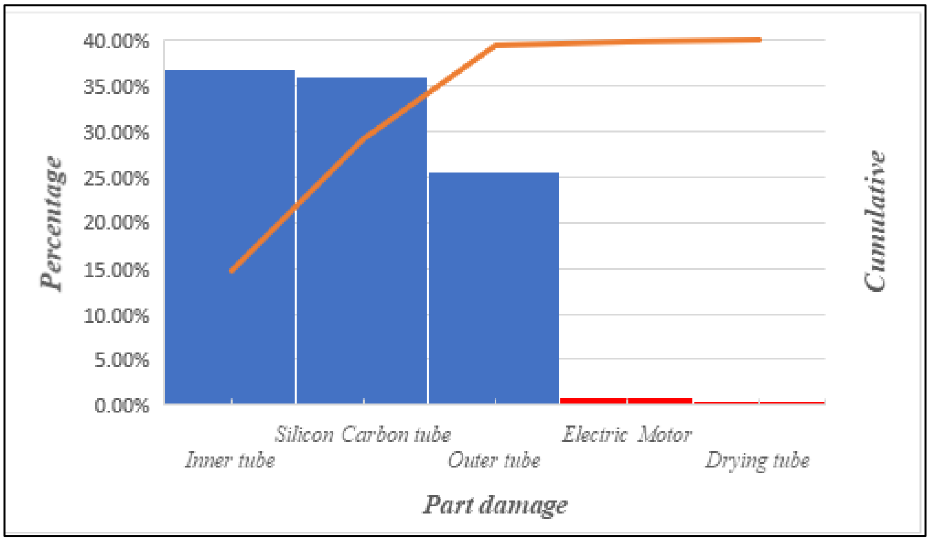

Figure 3. Pareto diagram breakdown time part damage

Based on Figure 4, it can be seen that three (3) types of damage to parts that dominate the breakdown time are Inner tube 36.87%, silicon carbon tube 36.03%, outer tube 25.70%, cumulative total 98.60%. Based on the three dominant factors, further analysis was carried out to find the root cause of the problem using fishbone.

4.1 Root Cause Analysis

Root Cause Analysis is a causal relationship to find the root cause of the problem that causes damage to the Inner Tube, Outer Tube and Silicon Carbon Tube on the TS Analyzer machine. Cause-and-effect analysis was carried out on each factor including humans, methods, machines, materials, and the environment.

RCA Inner tube dan Outer Tube with Fishbone

Based on Table 1, the largest breakdown time occurred in the Inner tube which reached 36.87% and the Outer tube by 25.70% which was the third highest dominant factor. The results of discussions with experts that the two parts have differences, namely function, and placement in the TS Anlayzer machine, while the workings and factors that cause damage are the same. Based on this, in analyzing the root of the problem combined the inner tube with the outer tube, hereinafter referred to as the inner outer tube. The causal analysis of the damage to the inner outer tube can be seen in Figure 4.

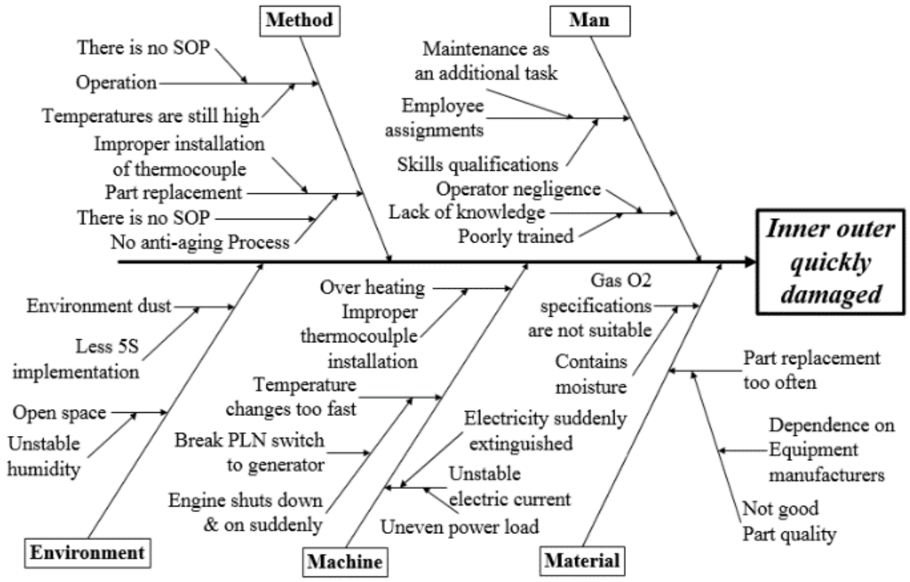

Figure 4. Fishbone diagram of inner outer

Based on the Fishbone diagram in Figure 4, the root of the problem is described using a table to make it easier to identify each of the factors that affect the frequent occurrence of damage to the Inner outer tube. The causal factors analyzed include humans, materials, machines, methods and the environment. The identification of each factor causing inner outer Tube which is often damaged can be seen in Table 2.

Table 2. Factors causing iner-outer tube

Cause 1	Cause 2	Cause 3	Causal factors
Employee Assignments	- Care as an additional task		Man
	- Quantification of expertise is not yet appropriate		
Operators don't understand Part replacement	- Operator negligence		
	- Poorly trained		
Part replacement too often	The quality of the part is less	Dependence on tool manufacturers	Material
Gas O2 specifications are unsuitable	Contains moisture		
Part replacement	Improper *installation of thermocouple*		
Electric current unstable	- Uneven power load		Machine
	-Public electricity outaged		
Over heating	*Thermocoulple* installation is not right		
Change in temperature too fast	Engines off & live suddenly	Break Public electricity switch to Generator set	Machine
Part replacement	Improper *installation of thermocouple*	Nothing SOP	Method
Operation	*Shutdown methode*	Temperatures are still high	

Cause 1	Cause 2	Cause 3	Causal factors
Unstable Humidity	Open space		Environment
Environmental Dust	Less 5S implementation		

RCA silicon carbon tube damage with fishbone
The second largest breakdown loss occurred in Silicon Carbon Tube which reached 36.03%. Cause and effect analysis of Silicon carbon tube damage can be seen in Figure 5.

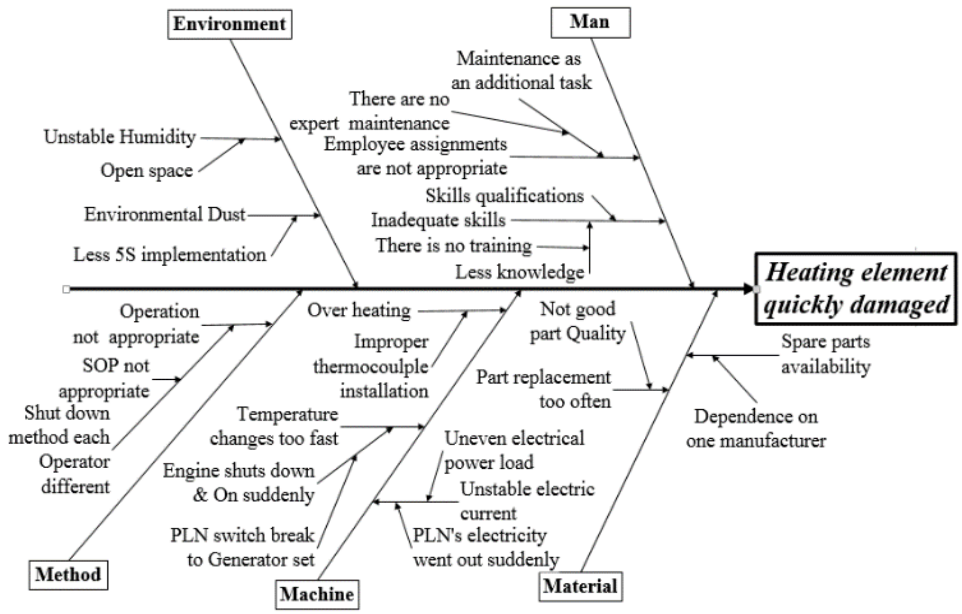

Figure 5. Fishbone diagram of heating

Based on the Fishbone diagram in Figure 5, the root of the problem is described using a table to make it easier to identify each of the factors that affect the frequent occurrence of damage to the Inner outer tube. The causal factors analyzed include humans, materials, machines, methods and the environment. The identification of each factor causing Silicon Carbon Tube which is often damaged can be seen in Table 3.

Table 3. Factors causing silicon carbon tube

Cause 1	Cause 2	Cause 3	Causal factors
Employee assignments are not appropriate	*Maintenance* as additional tasks	There are no officers. Special *maintenance*	Man
Inadequate skills	-Skill qualification		
	-Less knowledge	No training program	
Part replacement too often	The quality of the part is not good.	Dependence on tool manufacturers	
Unstable Humidity	Open space		Environment
Environmental Dust	Less 5S implementation		
Spare *parts availability*	Dependence on one manufacturer		
Part replacement too often	The quality of the part is not good.		Material

The electric current is unstable.	-Uneven power load -PUBLIC power outages suddenly		
Over heating	Improper *installation of thermocoulple*		
Temperature changes too fast	Engine shuts down & lives suddenly	Changeover break Public electricity to Generator set	Machine
The electric current is unstable.	- Uneven power load		
	PUBLIC power out of the blue suddenly		
Change in temperature too fast	-Engine off & live	Changeover break PUBLIC to Generator set	
Part replacement	- *Thermocouple* installation is not appropriate	- No SOP *thermocoulple* installation	Method
	-Not done *anti aging*	-No *anti aging SOP*	
Operation	*Shutdown methode*	Temperatures are still high	Method

4.2 Analysis FMEA

FMEA analysis is carried out by looking for the RPN value, in which the scoring of the Severity (Sev), Occurance (Occ) and Detection (Det) values is determined by the Experts through Focus Group Discussion (FGD). The experts involved in the FGDs include Senior technician from Sole agent, Head of branch, Laboratory Manager, Quality Assaurance, Laboratory Supervisor, Analyst and maintenance officer from the Company. FGD activities can be seen in Figure 6.

Figure 6. Focus Group Discusion (FGD)

FMEA analysis inner-outer tube

The failure mode analysis on the fast-damaging Inner tube outer tube using FMEA can be seen in Table 4. Calculation of the RPN value using Formula (1).

Table 4. FMEA Inner tube and outer tube

Cause	**Sav**	***Potential Failure Effects***	**Occ**	***Potential Cause of Failure***	***Det***	***RPN***	***Rank***
Temperature changes too fast	7	*Heating element*, *iner, outer tube* quickly breaks and breaks	7	Public electricity switch break to Generator set	7	343	1
Specifications of *Gas O2* not appropriate	7	*Iner outer quickly breaks*	7	O_2 gas contains moisture	7	343	1
Specifications of Gas $_{O2}$ not appropriate	7	*Iner outer* quickly breaks	7	O2 gas contains moisture	7	343	1
How to *shutdown* the tool is not yet appropriate	7	*Heating element*, *iner, outer tube* quickly breaks and breaks	7	Setting the temperature during *shutdown* is different after the operator	7	343	1
Over heating	6	*Heating element*, *iner, outer tube* quickly breaks and breaks	7	Improper *installation of thermocouple*	6	252	2
Operator lacks does not really understand the replacement of spare parts	6	Part-in-the-top error	6	Lack of training	7	252	3
The electric current is unstable.	6	Unstable temperature*, iner outer tube* ruptures	6	No stabilizer installed	6	216	4
Part replacement too often	6	Disrupting *the maintenance* and testing process	6	Low part quality	6	216	4
There are no maintenance officers.	5	Error of care	6	chemist has a dual duty as maintenance officer	6	180	5
Humidity is not stable	5	Contamination	6	Uncontrolled air circulation	4	120	6
Environmental Dust	4	Contamination	7	Uncontrolled air circulation	4	112	7

Based on Table 4, it is known that the highest RPN value is 343, namely the temperature change is too fast, the O2 gas specification is not suitable, and the shutdown method is not appropriate, so the three failures are the priority causes of the problem.

FMEA analysis silicon carbon tube
The failure mode analysis on Silicon Carbon Tube which breaks down quickly using FMEA can be seen in Table 5. Calculation of RPN value using Formula (1).

Table 5. FMEA silicon carbon tube (heating) tube

Cause 1	**S**ev	*Potential Failure Effects*	Occ	*Potential Cause of Failure*	*Det*	***RPN***	***Rank***
Over heating	7	*Heating element*, *iner, outer tube* quickly breaks and breaks	6	Improper *installation of thermocouple*	8	336	1
The electric current is unstable.	7	*Heating element* quickly breaks down, *controller* quickly breaks down	8	Surprise change in electrical power	6	336	1
Maintenance officer skills are less good	8	Maintenance and repair errors	7	*Maintenance officer* Lack of training	6	336	1
Temperature changes too fast	6	*Heating element*, *iner, outer tube* quickly breaks and breaks	7	Public electricity switch break to Generator set	7	294	2
How to *shutdown* the tool is not yet appropriate	8	*Heating element*, *iner, outer* quickly break and break	5	*Setting* the temperature at *shutdown* is different for each operator	7	280	3
Part replacement too often	6	Disrupting *the maintenance* and testing process	6	Low part quality	6	216	4
Employee assignments are not appropriate	5	Error of care	5	chemist has a dual duty as maintenance officer	6	180	5
Sparepart availability limited	5	Disrupting *the maintenance* and testing process	5	There is no inventory plan.	6	180	5
Unstable Humidity	5	Contamination	5	Uncontrolled air circulation	5	125	6
Environmental Dust	4	Contamination	5	Uncontrolled air circulation	6	120	7

Based on Table 5, it is known that the highest RPN values are 336 each consisting of over heating, unstable electric current, and inadequate operator skills, so that the three failures are the priority causes of the problem.

5. Conclusion

The purpose of this study is to determine the priority of failure on the TS Analyzer machine. Based on the analysis in the previous chapter, the damage to the inner and outer parts was found to be the highest source of failure on the method and engine factors with an RPN value of 343. The method factor of high temperature changes while the engine sourced from Specifications of Gas O2 was not appropriate. Damage to silicon carbon obtained the highest source of failure on machine and human factors with an RPN value of 336. Machine factors sourced from over heating and The electric current is unstable while human factors sourced from Maintenance officer skills are less good

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Biographies

Welly Atikno is a graduate student in Industrial Engineering at Universitas Mercu Buana, Jakarta. His research interests include Total Productive Maintenance, Performance Measurement, Quality Function Deployment etc. He graduated with a bachelor's degree from the Department of Management in 2002 from the Universitas Lambung Mangkurat, Banjarmasin.

Dr. Lien Herliani Kusumah is senior lecturer in Industrial Engineering Department and Management Department at Universitas Mercu Buana, Jakarta. Her research interest includes quality operations, management, productivity etc. She graduated in Management in 1988, M.T. from Institut Teknologi Bandung 1995, and obtained Doctor in 2006 from Institut Teknologi Bandung.