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Análise de falhas com base no sistema de manutenção de máquinas do navio no navio de treinamento Bung Tomo

Failure analysis based on ship's machinery maintenance system in Bung Tomo training ship[1]

Análisis de fallas basado en el sistema de mantenimiento de maquinaria del barco en Bung Tomo training ship

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Resumo

O navio de treinamento Bung Tomo, com um peso de 12 S7 GT, um LWT de 899 toneladas e um LOA de 63 m, é o único navio de treinamento de propriedade da Surabaya Merchant Marine Polytechnic. Este navio foi fabricado em 2 017, com capacidade para 300 pessoas. A existência do navio é muito importante para o processo de aprendizagem na Politécnica da Marinha Mercante de Surabaya, porque

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é usada pelos cadetes para praticar velejados todos os sábados e domingos. Os danos às máquinas do navio podem ser causados por um planejamento e implementação deficientes e são conhecidos após o início da operação do navio. Para evitar maiores danos ou perturbações no navio de treinamento Bung Tomo, é necessária uma análise da falha do sistema de manutenção de máquinas. Esta pesquisa objetiva obter uma análise da falha de máquinas no navio de treinamento Bung Tomo usando a Análise de modo e efeitos de falha (FMEA), através da identificação das causas da falha, do impacto causado e das possíveis medidas corretivas para evitar maiores danos. Vários componentes com alto RPN merecem ser uma preocupação ou prioridade máxima na manutenção de máquinas do navio de treinamento Bung Tom o, a saber: bomba de água do mar, bomba de água doce, tubulação, OWS, refrigeração de água doce, bomba de refrigeração de água do mar e gerador de água doce.

Palavras-Chave: FMEA; RPN; Sistema de manutenção de máquinas do navio; Navio; Manutenção do navio.

Abstract

The Bung Tomo Training Ship with a weight of 12 S7 GT, a LWT of 899 tons and a LOA of 63 m, is the only training ship owned by Surabaya Merchant Marine Polytechnic. This ship was made in 2 017 with a capacity of 300 people. The existence of the ship is very important for the learning process at Surabaya Merchant Marine Polytechnic because it is used by cadets to sail practice every Saturday and Sunday. Damage to the ship's machinery can be caused by poor planning and implementation and is known after the ship has begun to operate. To prevent greater damage or disturbance to the Bung Tomo Training Ship, an analysis of the failure of the machinery maintenance system is needed. This research aims to obtain analysis of the failure of machinery on the Bung Tomo Training Ship by using the Failure Mode and Effects Analysis (FMEA) through identification of the causes of failure, the impact caused and possible remedial measures to prevent greater damage. Several components with high RPN are deserve to be a concern or top priority in machinery maintenance of the Bung Tom o Training Ship, namely: sea water pump, freshwater pump, pipeline, OWS, freshwater cooling, sea water cooling pump, and fresh water generator.

Keywords: FMEA; RPN; Ship’s machinery maintenance system; Ship; Ship maintence.

Resumen

El Bung Tomo Training Ship con un peso de 12 S7 GT, un LWT de 899 toneladas y un LOA de 63 m, es el único barco de entrenamiento propiedad de Surabaya Merchant Marine Polytechnic. Este barco se fabricó en 2017 con una capacidad de 300 personas. La existencia del barco es muy importante para el proceso de aprendizaje en el Politécnico de la Marina Mercante de Surabaya porque los cadetes lo usan para practicar vela todos los sábados y domingos. El daño a la maquinaria del barco puede ser causado por una mala planificación e implementación, y se sabe después de que el barco ha comenzado a operar. Para evitar mayores daños o perturbaciones en el Bung Tomo Training Ship, se necesita un análisis de la falla del sistema de mantenimiento de la maquinaria. Esta investigación tiene como objetivo obtener un análisis de la falla de la maquinaria en el Buque de entrenamiento Bung Tomo mediante el Análisis de modo y efectos de falla (FMEA) a través de la identificación de las causas de la falla, el impacto causado y las posibles medidas correctivas para evitar un mayor daño. Varios componentes con alto RPN merecen ser una preocupación o prioridad en el mantenimiento de maquinaria del Bung Tom o Training Ship, a saber: bomba de agua marina, bomba de agua dulce, tubería, OWS, enfriamiento de agua dulce, bomba de enfriamiento de agua marina y generador de agua dulce.

Palabras Llave: FMEA; RPN; Sistema de mantenimiento de maquinaria del buque; Embarcacion; Mantenimiento de la nave.

1. Introduction

The Bung Tomo Training Ship with a weight of 12 S7 GT, a LWT of 899 tons and a LOA of 63 m, is the only training ship owned by Surabaya Merchant Marine Polytechnic. This ship was made in 2 017 with a capacity of 300 people. The existence of the ship is very important for the learning process at Surabaya Merchant Marine Polytechnic because it is used by cadets to sailpractice every Saturday and Sunday. Disturbance or damage that occurs on the Bung Tomo Training Ship will affect the sailing practice activities so that the cadets learning targets will be difficult to achieve. In order to keep the Bung Tomo Training Ship always in a good condition and ready to be used for sailing practice, and to extend the life time ofthe ship's machinery, a good machinery maintenance system isneeded.

Damage to the ship due to lack of attention in the maintenance of the ship's machinery can be caused by an inadequate planning so that in its implementation there are many problems or obstacles. Maintenance planning based on risk assessment minimizes the probability of system failures and its consequences (Cicek, Turan, Topcu, & Searslan, 2010) One method for assessing the risks that will occur from ship machinery maintenance system is failure mode and effect analysis (FMEA). In this paper, FMEA is used to identify the causes of failure, the impact caused and possible remedial measures to prevent greater damage on the Bung Tomo Training Ship.

Failure Mode and Effect Analysis (FMEA)

Failure Mode and Effects Analysis or FMEA was first introduced by U.S Amy after World War II as a process of control. FMEA was quickly used by industry as a quality management tool in 1980 and later developed with the SIX SIGMA in the early 1990s. With this FMEA can minimize the risks that may arise in industrial processes(Faturachman, Mustafa, Octaviany, & Novita, 2014). In the next development FMEA was then widely adopted in the marine sector of machinery system on the ships, and also the gas and oil industry (Pillay, A. and Wang, 2003).

AEA is a tool used to identify and assess each potential failure (Zhang & Chu, 2011). FMEA is a procedure used to assess potentialfailuresthat arise in a system to minimize any disruption (error) by looking at the cause (“The application of FMEA in the oil industry in Iran: The case of four litre oil canning process of Sepahan Oil Company,” 2011). FMEA is an analysis of a system by examining Iow-level components to high-level components to obtain the failure rate that is likely to be achieved by a system (Kusuma, 2015). FMEA is a systematic procedure on a system to identify any potential failures, causes and impacts that affect system performance (Sayareh & Ahouei, 2013).

FMEA analyze the impact of failures on the system by considering failures that can arise from the smallest components so that it can be analyzed the likelihood of the greatest failure. The use of FMEA has two hinds, namely functional and hardware. In functional use, FMEA discusses how these failures can occur. In the use of hard ware, it discusses the smallest components that can cause system failure.

In using FMEA to assess the failure of a smallest component in a system both in products, services and processes, there are several stages that must be passed, namely (Sayareh &Ahouei, 2013): define the components to be analyzed, define each component function to be analyzed, identify potential failures that might occur in each component, determine the causes of each failure mode, identify each effect of potential failures of each component without any control on the system, identify the controls that must be performed on each potential component failure, determine appropriate actions to deal with each potential failures and recommendations that need to be done based on a risk analysis.

To facilitate the use of FMEA in managing the risk of failure, block diagram can be made to recognize each potential failure in sequence. After obtaining all the potential failures, their causes and also their impacts, a ranking of each potential that emergesand the largest to smallest risk impacts is made using the Risk Priority Number (RPN) which is the result of the interaction between the severity of failures (S), the possibility of occurrence (0), and at so the probability of detection (D). The RPN formulais as follows (Feili, Akar, Lotfizadeh, Bairampour, & Nasiri, 2013)

$$RPN = S \times O \times D$$

Severity of failures (S) is an assessment of the potential impact of failures on the system, Possibility of occurrence (0) is an assessment of the frequency of possible failure, detection (D) is an assessment of the probability of detecting parameters that can cause failure or damage (Cicek & Celik, 2013).

(Authors, it is inelegant to end a topic only with the opinion of others. Write a final paragraph with your opinion: do you agree with what others have said, disagree or what? Set it right, thank you).

Ship’s Machinery Maintenance System

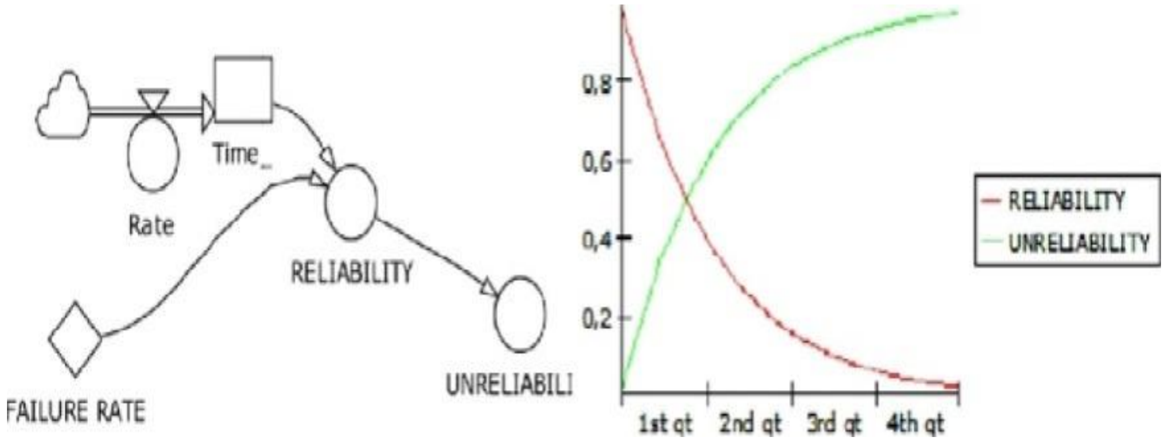
Machinery maintenance and repair is an activity to maintain and repair all of technical objects in order to keep the materials can be used and functioning properly and always meet the requirements of International Standards. Ship engines maintenance and repair aims to: optimize the power and yield of materials according to their functions and benefits; prevent severe and sudden damage; prevent the loss of efficiency; reduce time unemployment means adding ship’s working days; reduce the number of repairs and repair times when the annual docks ship; increase the knowledge of the crew and educate them so that they have work responsibilities. Maintenance and repair can be conducted periodically (planned maintenance system) be it daily, three daily, weekly, monthly, quarterly, six months, and so on or based on machinery working hours, and incidentally (outside the arranged schedule) when there is damage or not optimal parts of the machinery.

Ship machinery maintenance includes, among others: main machines maintenance; diesel generator maintenance; auxiliary machines maintenance; pipeline maintenance; propeller shaft maintenance; deck machines maintenance. Main machines maintenance is adjustedto the number of material working hours andmaintenance method, maintenance treatment, inspection, measurement, repair, or replacement of materials according to working hours. From physical checking, decisions can be taken on material that is maintained, repaired, or replaced even though working hours have not been met/not yet time. While diesel generator maintenance in general the same as the mainengine maintenance, especially the replacement of the filter and lubricant oil. The auxiliary machines maintenance involves the maintenance of all machinery appliances, propulsion appliances, equipment in the system that functions to support the operation of the ship, namely: run air compressors, seawater pump and main engine cooler, purifier, OWS. Pipeline maintenance covers the condition of pipes that have become rusty and must be replaced or welded to prevent leaking, connection conditions must use packing according to the types of pipes, and the pipe must also be painted so it is not easy to rust with the color of the pipe paint according to I MO standard. Procedure of propeller shaft maintenance: intermediate shaft (successor bearing shaft) must be cooled sufficiently or normally by using lubricating oil or grease etc., bolts for shaft successor bearings are checked and tightened periodically, cooling water pipes in the stern tube are checked to work properly. The deck machine maintenance includes: cargo crane/engine control, windlass a rich or machine, and mooring winch.

2. Method

This research type is explanatory research within used the qualitative approach. This research is an experimental research to get the variables that affect the reliability and failure of the machinery system on the Bung Tomo Training Ship. This study uses reliability analysis to prevent system failures as the following chart:

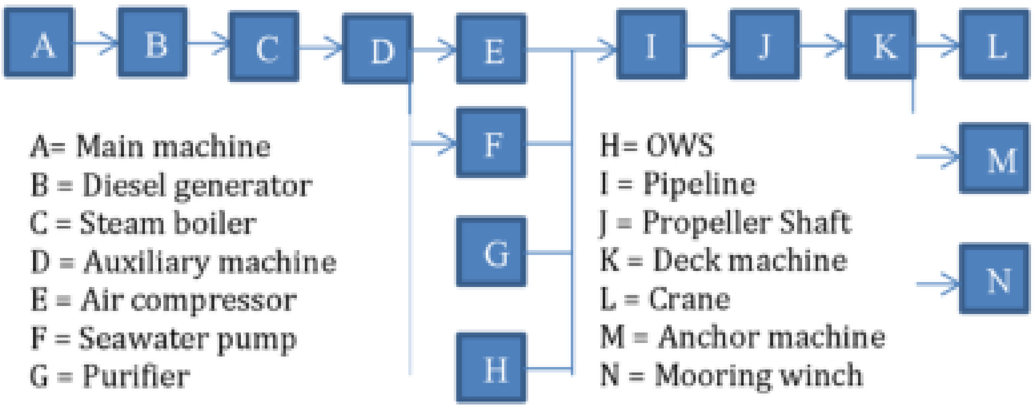
Figure 1: Modelling dynamics of system reliability.



Source: authors.

The research instrument used was an Android-based FMEA application and also an assessment form for the machinery conditions of the Bung Tomo Training Ship. Data collection is using interviews and paperless questionnaires that use the Android-based FMEA application. Research data used are primary data and secondary data. Primary data includes data obtained directly in the field, namely periodic maintenance of the Bung Tomo Training Ship's machinery document and also direct interview with the engine crews of the Bung Tomo Training Ship. The secondary data used is the supporting document regarding the Bung Tomo Training Ship. The machinery components analyzed in this research in accordance with the machinery sequence of the Bung Tomo Training Ship as follows.

Figure 2: Order of the Bung Tomo Training Ship's machineries.



Source: Authors.

Stages for using FMEA toassess the failure of a smallest component in a system, such as:

1) Define components to be analyzed in the maintenance and machinery of the Bung Tomo Training Ship; 2) Define each component function to be analyzed in the maintenance and machinery of the Bung Tomo Training Ship; 3) Identify potential failures that might arise each maintenance and machinery components of the Bung Tomo Training Ship; 4) Determine the cause of each failure mode in the maintenance and machinery of the Bung Tomo Training S hip; 5) Identify every effect of potential failure of each component without any control on the maintenance and machinery system of the Bung Tomo Training Ship; 6) Identify the controls that must be performed on each potential failure of the maintenance and machinery components of the Bung Tomo Training Ship; 7) Determine appropriate actions to deal with any potential failures and recommendations needed to be based on a risk analysis.

In dealing with the risk of failure, block diagrams can be draw to recognize each potential failure in sequence. To rank the potential failures, the Risk Priority Number (RPN) is calculated by using the formula: RPN = S x 0 x D (Feili et al., 2013).

3. Findings and Discussions

A. Risk Analysis Form Data

The risk analysis form data the most important part of FMEA. This form contains the type of equipment used in the engine room and outside the engine room. Each machinery component is outlined in function, damage and cause, initial symptoms, damage impact (small, large, and final impact), failure detection, and impact on the main engine.

B. Formation of the FMEA Team

The assessment of the Risk Analysis Form cannot be done alone by the researchers, but must be carried out jointly by involving officers and crew members of the Bung Tomo Training Ship. The FMEA team involved several experts including chief engineer, engineer 1, engineer 2, and discussion was carried out on the Bung Tomo Training Ship.

C. Discussion for FMEA Analysis

The discussion includes several analyzes of ship machinery components, the functions of each component, various potential damages and their causes. The discussion on the initial symptoms seen from the damage, the impact caused (small, large, and final impact), how to detect failure or damage that appears.

Further discuss ion on critical assessment covers:

- Severity is the impactcaused as a result of damage to the ship's machinery component Components is a tool or applianceused in the ship machinery which includes all machineries used on the Bung Tomo Training Ship.
- Occurrence is the number of events or frequency of damage or problems in each component in the machinery of the Bung Tomo Training Ship.
- Detection is the extent to which the crew can find out or detect problems that arise from each component in the machinery of the Bung Tomo Training Ship.

By knowing the critical value of each of the analysis variables above, we will get the Risk Priority Number (RPN) calculation results as a reference for assessing the extent of risk that will arise from each component and which will be the main priority in handling it so that the impact is not too broad and have effects on components or other machinery parts of the ship. Table 1 explains the results of discussions on the risk analysis of the Bung Tomo Training Ship.

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Table 1: Risk analysis results of the Bung Tomo Training Ship.

No	Componenet	Function	Damage & Cause	Initial Symptoms	Damage Impact			Failure Detection	Does It Affect the Main Engine?	
					Small Impact	Large Impact	Final Impact		Yes	No
1	Storage tank	Fuel storage	Leakage	Reduced oil supply	Fuel costs increase	Fire hazard	Explosion & fire	Direct observation	-	No
			Blockage	Reduced oil supply				Direct observation		
2	Generator	Electric power supply	Blackout	Reduced oil supply	Lighting on the ship is interrupted	Ship activities cannot operate	Ship activities cannot operate	Direct observation	Yes	-
			Fuel does not flow to the engine	Fuel pump does not work						
3	Transfer pump	To move liquids from one place to another	Pump leak	Reduced oil supply	Machine operation is interrupted	The machine cannot operate	Ship activities are disrupted	Direct observation	Yes	-
			Oil seal is damage							
4	Settling tank	Fuel storage	Leakage	Reduced oil supply	Fuel costs increase	Fire hazard	Explosion & fire	Direct observation	-	No
			Blockage	Reduced oil supply						
5	Purifier LO	To separate oil from dirt	Leakage	Reduced lubricant supply	Lubricant costs increase	Waste of operational costs	Waste of operational costs	Direct observation	-	No
			Oil seal is damage	Reduced lubricant supply						
6	Service tank	Fuel storage	Leakage	Reduced oil supply	Fuel costs increase	Fire hazard	Explosion & fire	Direct observation	Yes	-
			Blockage	Reduced oil supply						
7	Aerator chamber	N/A	-	-	-	-	-	-	-	-
		freshwater reservoirs		supply	water stock	cooling water is lacking	for ships is disrupted			
			Corrosion							
14	Boiler	-	-	-	-	-	-	-	-	-
15	Engine control room	To monitor machines appliance operating in the engine room	Error occurred in the Control tool	Out of sync between the monitor at ACER and the operating appliance	Less optimal supervision of appliance operating	Damage to the machine due to lack of monitor	Operation of the ship can be interrupted	Indirect observation	Yes	-
16	Sea water pump	To transfer sea water from one place to another	Pump leak	Reduced sea water supply	Engine coolant temperature rises	Damage to the engine/ excessive heat	The machine cannot operate	Direct observation	Yes	-
			Damage to the mechanical seal							
17	Freshwater pump	To transfer freshwater from one place to another	Pump leak	Reduced freshwater supply	Engine coolant temperature rises	Damage to the engine/ excessive heat	The machine cannot operate	Direct observation	Yes	-
			Damage to the mechanical seal							
18	Pipeline	A device that is passed by	Leak	Liquid substances cannot flow	The pump cannot operate	Danger of engine sinking	Flooding in the engine room	Direct observation	-	No

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No	Componenet	Function	Damage & Cause	Initial Symptoms	Damage Impact			Failure Detection	Does It Affect the Main Engine?	
					Small Impact	Large Impact	Final Impact		Yes	No
23	Bilge pump	To rid of waste water from ships	The pump does not suck	The pump cannot suck	Waste water dumping occurs	Danger the engine is under water	Engine appliance cannot be operated	Direct observation	-	No
			Return valve does not function properly			Waste water in the engine room				
24	Air compressor	To produce air for the air tube	The air bottle cannot be filled	Air pressure cannot be supplied to air bottle	No air in the air bottle	Safety device cannot function	Safety device cannot function	Direct observation	-	No
			Damage to the pressure valve							
25	Air bottle	To store high pressure air	Air pressure cannot be stable in the bottle	Air pressure always decreases in the bottle	No air in the air bottle	Safety device cannot function	Safety device cannot function	Direct observation	-	No
			Air bottle leaks							
26	Exhaust gas boiler	N/A	-	-	-	-	-	-	-	-
27	Freshwater generator	To convert sea water into	Blockage	Water quality is not good	Freshwater needs not met	Freshwater needs not met	Freshwater needs not met	Indirect observation	-	No

Source: Own study.

Based on the risk analysis results of the Bung Tomo Training Ship above, it can be calculated the critical values for each component involved in the operation of the main engine, so that we know the weight of each critical value that includes the seriousness of the effect of the potential failure to the system (severity), the frequency of the specific failure cause is projected to occur (occurrence), and the probability that operating parameters monitoring system will detect a cause or mode of failure before the component/system is damaged and stopped (Cicek & Celik, 2013).

The Risk Priority Number (RPN) in this study is calculated using an ordinal scale of 5 which indicates very dangerous to1 which is not dangerous. Based on each of these critical values, the Risk Priority Number (RPN) calculation results as shown in the Table 2.

Table 2: Results of severity, occurrence and detection.

No	Item	Severity	Occurrence	Detection	RPN
1	Sea water pump	5	5	4	100
2	Freshwater pump	5	5	4	100
3	Pipeline	5	5	4	100
4	OWS	3	4	7	84
5	Freshwater cooling	5	5	3	75
6	Sea water cooling pump	5	5	3	75
7	Freshwater generator	3	2	7	42
8	Filter DO	6	2	3	36
9	Bilge pump	3	3	4	36
10	Transfer pump	8	1	4	32
11	Aerator chamber	5	1	5	25
12	Supply pump	5	1	5	25
13	Batteray (accu)	5	5	1	25
14	Distribution Main Board	5	1	5	25
15	Boiler	3	1	7	21
16	Sewage plant/tank	3	1	7	21
17	Purifier LO	4	1	5	20
18	Engine control room	5	1	4	20
19	Fuel oil pump	5	1	4	20
20	Fuel oil separator	4	1	5	20
21	Oil pump	5	1	3	15
22	Air compressor	3	1	5	15
23	Exhaust gas boiler	3	1	4	12
24	Distribution Box	3	1	4	12
25	Water tank	3	3	1	9
26	Settling tank	7	1	1	7
27	Service tank	7	1	1	7
28	Storage Tank	5	1	1	5
29	Drain Tank	5	1	1	5

Source: Own study.

Table 2 shows several components with higher RPN value. Sea water pump, freshwater pump, and pipeline are the components that have the highest RPN among the components identified, followed by OWS, freshwater cooling, sea water cooling pump, and freshwater generator. Therefore, these 7 components must receive more attention in the machinery maintenance system of the Bung Tomo Training Ship.

4. Conclusion and Suggestions

A Failure Mode and Effect Analysis (FMEA) have been carried out on the Bung Tomo Training Ship by forming a FMEA Team that discussed the risk analysis of the ship's machinery components. The several components directly affect the main system, especially on the main engine including transfer pump, service tank, supply pump, battery (accu), DO filter, water tank, boiler, engine control room, sea water pump, freshwater pump, freshwater cooling, sea water cooling pump, oil pump, fuel oil pump.

Risk Print Number (RPN) calculation results based on critical analysis on the level of impact (severity), the level of occurrence and the level of detection or ease in detecting problems that arise in each component shows some components that deserve to be a concern or top priority in machinery maintenance of the Bung Tomo's Training Ship, namely: sea water pump, freshwater pump, pipeline, OWS, freshwater cooling, sea water cooling pump, and freshwater generator.

A Failure Mode and Effect Analysis (FMEA) have been carried out on the Bung Tomo Training Ship by forming a FMEA Team that discussed the risk analysis of the ship's machinery components. The researcher suggests for future researches to prevent the Failure Mode and Effect Analysis (FMEA)

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