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Reliability and Risk Analysis of Lubrication System on Sabuk Nusantara 43

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ABSTRACT

This study aims to present a systematic approach to evaluating the reliability of the lubrication system on the Sabuk Nusantara 43. The methods used in conducting risk assessments are quantitative methods and qualitative methods or semi-quantitative methods. In the quantitative method, the approach taken is more to the value (number) approach. Meanwhile, in the semi-quantitative method, the approach used is a qualitative approach and a quantitative approach. This method can identify potential events that not only cause disruption to pipeline operations but also events related to safety and the environment. The results showed that the biggest risk in the installation of Sabuk Nusantara 43 lubricant was found in the filter section with damage levels reaching five times in one year with risk matrix plotting in the major category (Not Acceptable) and risk control options (recommendation). Selection of filter components that are better and fulfill standards of existing rules, regular maintenance and checking, and avoiding the use of lubricating oil that is too old and used.

Keywords: *Risk assessment, reliability, Lubrication System, mitigation recommendations*.

1. INTRODUCTION

To support connectivity between islands in Indonesia, it is very necessary to have a cheap and affordable mode of transportation for the community. The Indonesian government through the Ministry of Transportation has made 63 shipping routes for pioneer ships with a total fleet of 32 pioneer ships and 35 cargo ships [1]. One type of pioneer ship fleet is the Sabuk Nusantara 43, a ship with IMO number 9734044 which was built in 2014 and has shipping routes including Waingapu, Salura, Raijua, Sabu, Ndao, Rote, Kupang, Wulandoni, and Larantuka [2,3].

Sabuk Nusantara 43 in one route from the port of Waingapu to return to Waingapu again takes 8 days [4] which of course must be supported by the level of resistance of the engine and its support systems such as the fuel system, engine lubricant, and cooling system. Failure in support systems such as the fuel system, cooling, or lubrication system can cause the system not to operate optimally which can cause the failure of the main engine. It can be concluded that the initial engine damage generally starts from damage to the support system. For the ship's lubrication system, it starts from the storage tank then goes through valves, filters, valves, hand pumps, and valves and continues to enter the main engine and generator.

The main function of the lubrication system is to reduce the friction that occurs from moving and interacting machine parts. Meanwhile, other functions of the lubrication system are as an engine coolant, as a cleaner, to prevent corrosion and as a medium to check the condition or damage that occurs to the engine [5]. Meanwhile, anticipating component failures in this system can be done by means of reliability analysis or evaluation of the reliability of this lubrication system. A study in Japan was conducted to determine the reliability level of a hydrogen pipe supply installation while it was still in the design stage with the aim of identifying critical risks and preventive measures that must be taken [6]. research related to pipeline difficulties has also been carried out to determine the risk of accidents that may occur due to seismic activity [7] and further research, namely by calculating the possible risks that occur and implementing a routine service inspection strategy allows fatigue life and cracks in pressure vessel piping to be prevented [8].

As with other pipes, Sabuk Nusantara 43 ship also has complex pipe installations and this must be anticipated so that failure of the main engine lubrication system does not occur. Meanwhile, the risk is the possibility of something happening that will have undesirable impacts while the risk assessment itself is divided into three, namely risk identification, risk analysis, and risk evaluation [9] as a preventive measure against these matters required an assessment of the risk or risk assessment. Risk analysis consists of three main components, namely risk assessment, risk management, and risk communication. Risk assessment is an assessment of the risk of a system or component so that if things happen that could possibly lead to a hazard, preventive measures can be taken immediately. Preventive actions or commonly known as mitigation actions are included in risk management. After a risky system or

component is arranged in such a way as to prevent a hazard from occurring, the risk assessment and handling actions must be conveyed to related parties such as staff, workers, and local residents. This action is called risk communication.

Risk assessment is carried out on an object by identifying events that may occur and assigning a hazard value on a certain scale. The object referred to in this study is Sabuk Nusantara 43 lubrication system. The identification of the causative factors of each event is also carried out, where there are several types of factors that may occur. From the identification of consequences and the calculation of the frequency, a risk matrix can be made which shows the position of the risks that may occur to the object, and whether the risk is acceptable or not.

Studies on risk analysis have actually been carried out a lot, including by using the FTA and ETA methods. researchers analyzed the impact of the occurrence of covid 19 on the economic level of the Surabaya coastal community [10][11] other studies also used the Fault Tree Analysis method to test the repair of autonomous ship propulsion [12] subsequent research was also carried out research on the level of danger in the LNG supply pipeline Floating Storage Regasification Unit (FSRU) and predicting the frequency of occurrence and consequence analysis, as well as the appropriate form of mitigation to do [13] and others, are conducting research that is still the same on gas pipeline installations which are carried out to determine the effect of delays in the construction process of distribution pipelines that are able to suppress gas distribution delay [14].

2. METHODOLOGY

The object of the ship used in this study is Sabuk Nusantara 43 whose main size data refers to the data available in the BKI register [2].

Length Overall (LOA)	= 68.50 m
Breadth (B)	= 14.00 m
Depth (H)	= 6.20 m
Drafts (T)	= 2.89 m
Ship builders	= PT. Daya Radar Utama (2014)

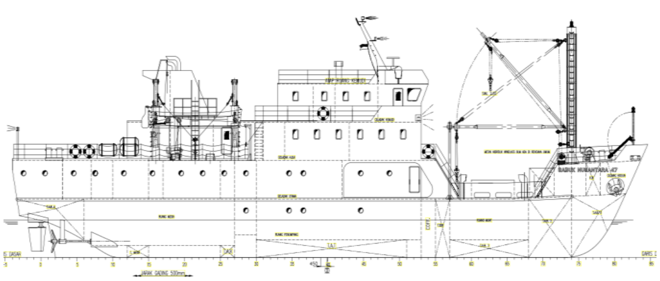

Figure 1. General Arrangement of Sabuk Nusantara 43

The next work step is to carry out a risk assessment, the risk must be kept as small as possible (in the green zone), meaning that after risk reduction has been carried out, it must also be considered in terms of costs. It has endeavored that the risk remains acceptable and then followed by the lowest possible cost. The calculation of the reduced frequency must take priority before the calculation of the reduced consequences. Various kinds of research related to risk analysis have been carried out such as

The process of risk analysis consists of four basic steps, including [13].

1. Identification of Hazards
2. Estimated Frequency
3. Forecasting Consequences
4. Risk Evaluation

2.1 Standards/ Rules/ Code

In the calculation of risk assessment as well as in other fields of engineering, it takes a rule that regulates clearly, be it definitions, procedures, or technical aspects of a field with the hope that it can achieve the desired goals without violating the applicable rules. Rules are very closely related to health, safety, and the environment so that unwanted things such as accidents or disasters can be avoided as early as possible.

In the maritime world, the International Maritime Organization (IMO) as the parent of the world's maritime organizations, issues many rules based on historical experiences. For safety, IMO issued rules like International Regulations for Preventing Collisions at Sea (COLREG) [15] the safety of Life at Sea (SOLAS) [16], and Marine Pollution (MARPOL) [17]. IACS (The International Association of Classification Societies also issues many rules, including the classification bodies that are members of it, such as DNV (Det Norske Veritas). Not to forget the statutory/flag state also has its own rules regarding safety.

2.2 Hazard Identification

Hazard is a situation that is qualitative in nature that has an influence on the frequency of possible losses or the number of losses that may occur. Meanwhile, hazard identification is the process of identifying hazards that may occur regardless of what is acceptable or unacceptable. Usually, this activity is carried out by people who are experts or very experienced and are also based on existing literature data. [18].

2.3 Frequency analysis

Frequency estimation begins with conducting a literature study on previous research and existing data. From the literature study, it will be analyzed how many frequencies will occur in each event. Furthermore, the frequency is obtained by performing calculations based on existing scenarios. Scenarios are made based on logical assumptions so that the possibility of a risk event occurring is acceptable and the frequency values obtained can also be used to make decisions on the outcome.

2.4 Consequence Analysis

As with frequency, consequence estimation is also started by conducting a literature study on previous research and historical data. These consequences can be measured by the number of fatalities/loss of life, costs, and other parameters in an asset.

2.5 Risk Assessment

A risk assessment or risk assessment after going through the stages of hazard identification, frequency analysis, and consequence analysis. At this stage, we will find out whether a system or asset that we are calculating the risk of is in an acceptable, tolerable, or unacceptable area.

An unacceptable risk is a situation where mitigation must be carried out with the consequence that an accident or disaster will occur which is difficult to avoid with the existing system, not only having an impact on the system but also having an impact on the surrounding environment. Acceptable risk is a situation where an asset or system has an acceptable risk level. In other words, the assets and the surrounding environment are in a safe condition in their operations. Meanwhile, areas that can be tolerated or ALARP (As Low As Reasonably Practicable) areas are areas where assets are in a fairly safe condition but it is highly recommended to carry out mitigation whenever possible. This is very closely related to cost-benefit analysis. Simply put, it can be seen in Figure 2.

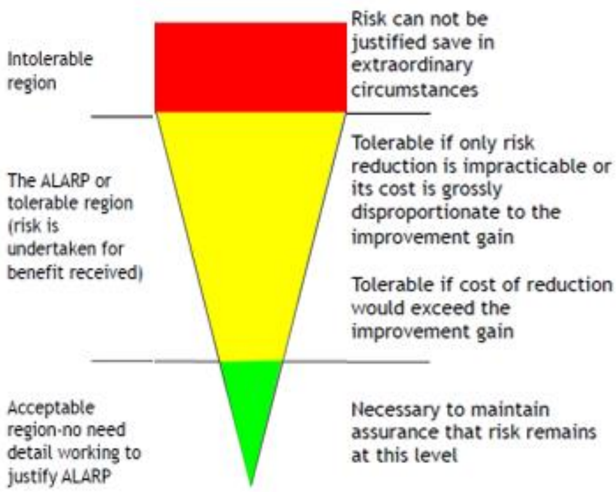

Figure 2. Risk acceptance criteria

Risk assessment is usually described in a matrix of the relationship between consequences and frequency as shown in Table 1

Table 1. Risk matrix

Frequent	Risk Level 4	Risk Level 5	Risk Level 6	Risk Level 7
Reasonably Probable	Risk Level 3	Risk Level 4	Risk Level 5	Risk Level 6
Remote	Risk Level 2	Risk Level 3	Risk Level 4	Risk Level 5
Extremely Remote	Risk Level 1	Risk Level 2	Risk Level 3	Risk Level 4
	Insignificant	Minor	Major	Catastrophic

Levels 1-2 (green) indicate that the low risk means acceptable region, levels 3-4 (yellow) medium risk means the ALARP region, and levels 5-7 (red) indicate that the High risk means unacceptable region.

2.6 Risk Control Options

After conducting a risk assessment, several hazards are included in the unacceptable risk category in the region of the risk matrix. Several methods can then become options for asset maintenance so that they can continue to operate in areas where the risk is acceptable.

In general, avoidance, mitigation, transfer, and acceptance methods can be carried out at this stage by considering several aspects, and of course studies, and cost analysis is needed to determine the method used. As for the method in question, in simple terms, it can be interpreted as defined below.

1. **avoidance**: This is a business that is done by avoiding or stopping an event that can pose a big risk.
2. **Mitigation**: The method of reducing the impact of risks that can arise by reducing the frequency and consequences of an event through a strategic step.
3. **Transfer**: Involve third parties in asset maintenance. In this case, the insurer.
4. **acceptance**: Choosing to accept a risk even though theoretically, the risk is in the unacceptable risk area with consequences that can be fatal.

3. RESULT AND DISCUSSION

For a description of the ship's lubrication system, see Figure 3.

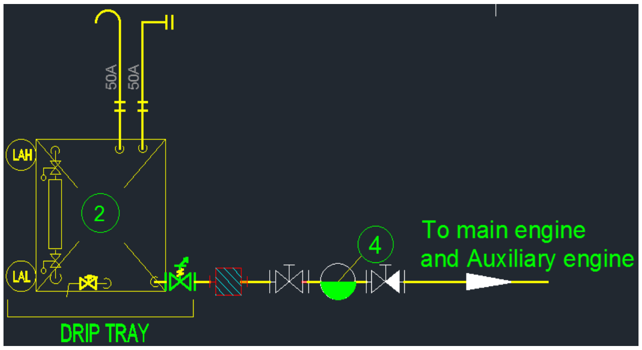

Figure 3. Lubrication installation system on ships

Figure 2 shows that each component in the ship's lubrication system is connected in series, while the more components connected in series, the lower the reliability of the system, and vice versa, the more components connected in parallel, the higher the reliability index. high too.

In total there are 6 identified hazards/risks that might occur in the ship's lubrication system, namely:

1. Lube tank leak (LO Tank Leak)
2. The inability of the emergency shut-off valve to open or close emergency Shut-off Valve Fail to Regulate)
3. Filter failure (Filter Failure)
4. Failure of the hand pump (Hand Pump Failure)
5. Globe valve inability to open or close globe Valve Fail to Regulate)
6. Failure on the SDNR valve (SDNR Valve Failure)

The next step is to carry out a frequency and consequence analysis using historical data. After that, all risks are tabulated in the HAZID worksheet for descriptions of causes, impacts, and risk levels as explained in the next section. The MTTF and MTTR values can be seen in table 2. Meanwhile, the λ (failure rate) values are obtained from the Offshore Reliability Data (OREDA) Handbook 4th Edition [19].

Table 2. MTTF and MTTR values

Items	λ (Failure rate)	µ (Repair)	MTTF (1/λ)	MTTR (1/µ)
LO tank leak	2.3 x 10-6	24	43.5 x 104	0.042
LO failure alarm level*	3.2 x 10-6	-	4.8 x 10-6	-
Emergency Shut-off valve (fail to regulate)	12 x 10-6 (Oreda)	25.3	83.3 x 103	0.04
Emergency Shut-off valve (fail to close on damand)	73 x 10-6 (Oreda)	0.5	13.7 x 103	2
filter failure*)	1.3 x 10-6	-	7.7 x 105	-
Hand pump failed	1.5 x 10-6	12	6.7 x 105	0.083
Globe valve (fail to regulate)	1.24 x 10-6 (Oreda)	25.3	8 x 104	0.04
Globe valve (fail to open damand)	73 x 10-6 (Oreda)	0.5	13.7 x 103	2
SDNR valve Failure	1.1 x 10-7	0.5	9.1 x 106	2

*Non-repairable system

Table 3. Reliability value

Items	λ (Failure rate)	Operational Time	Reliability Value (R=e-λt)
LO tank leak	2.3 x 10-6	10000	0.977
LO failure alarm level*	3.2 x 10-6	10000	0969
Emergency Shut-off valve (fail to regulate)	12 x 10-6 (Oreda)	10000	0887
Emergency Shut-off valve (fail to close on damand)	73 x 10-6 (Oreda)	10000	0.482
filter failure*)	1.3 x 10-6	10000	0987
Hand pump failed	1.5 x 10-6	10000	0.985
Globe valve (fail to regulate)	1.24 x 10-6 (Oreda)	10000	0.884
Globe valve (fail to open damand)	73 x 10-6 (Oreda)	10000	0.482
SDNR valve Failure	1.1 x 10-7	10000	0.999

3.1 Frequency Analysis

Below is a table of frequency groupings based on the number of system LO failure events per year, with detailed descriptions and definitions.

Table 4. Bands of frequency

Description	definition	Per –Year*
frequent (F)	It may occur continuously per year	equal or more than 10/year
Reasonably probable (RP)	It may occur annually with an intensity that is not as frequent as at the Frequent level	5/year
Remotes (R)	It will only happen if there are unknown things with very low intensity	2/year
Extremely Remote (ER)	It's very rare to even say it won't happen in a year	equal or more than 1/ year

3.2 Consequence Analysis

The following table will be used as a reference in determining the level of consequences with the parameters used as a reference being the impact of damage and overheating on the main and auxiliary engines of the ship.

Table 5. Bands of consequence

Description	Definition
Catastrophic	Losses incurred can cause main and auxiliary engine damage if the LO system failure frequency occurs at least once a month
Majors	LO system failure occurs at least once in 2 months
Minor	LO system failure occurs at least 3 times a year
Insignificant	LO system failure is considered not too influential on the ship's engine

3.3 Risk Matrix

After classifying the frequency and consequence levels, historical data is entered as the cause of the failure previously mentioned. Then the following data is obtained:

Table 6. Bands of Frequency & Consequency LO System

Failures	frequency	Consequence
Oil tank leak (LO Tank Leak)	2 times/5 years	1
Inability of the emergency shut-off valve to open or close (Emergency Shut-off Valve Fail to Regulate)	2 times/1 year	2
Failure on the filter (Filter Failure)	5 times/1 year	3
Failure of the hand pump (Hand Pump Failure)	1 time/1 year	1
Globe valve inability to open or close (Globe Valve Fail to Regulate)	2 times/1 year	2
Failure on the SDNR valve (SDNR Valve Failure)	2 times/1 year	2

Based on the data in Table 5, each type of failure can be plotted in the risk matrix table. Here are the results:

Table 7. Risk matrix

frequent				
Reasonably Probable			3	
Remote	1,4	2,5,6		
Extremely Remote				
	Insignificants (1)	Minors (2)	Majors (3)	Catastrophic (4)

(red)	Not Acceptable
(yellow)	ALARP Region
(green)	Acceptable

3.4 Risk Control Options (Recommendations)

Based on the results of data processing on the risk matrix, there is one event that is included in the Unacceptable Risk category.

Table 8. Unacceptable Risk table

Failures	Categories	Recommendations
LO Tank Leaks	Insignificant	Keep checking and maintaining regularly
Emergency Shut-off Valve Fail to Regulate	Minor	Keep checking and maintaining regularly
Failure Filters	Majors	Selection of filter components that are better and meet the standards of existing rules.
		Periodic maintenance and checking.
		Avoid using lubricating oil that is too old and used.
Hand Pump Failure	Insignificant	Keep checking and maintaining regularly
Globe Valve Fail to Regulate	Minor	Keep checking and maintaining regularly
SDNR Valve Failure	Minor	Keep checking and maintaining regularly

4. CONCLUSIONS

The results of an analysis of the components of the main and auxiliary engine lubrication system for the Sabuk Nusantara 43 ship which is considered to have a high level of vulnerability and risk lies in the filter where the failure rate reaches almost five times a year so it is necessary to anticipate and maintain periodically so that it can support the work of the main engine lubrication system and help the ship.

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