FAILURE MODE AND EFFECTS ANALYSIS OF DIESEL ENGINE FOR SHIP NAVIGATION SYSTEM IMPROVEMENT

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Abstract

Indonesia is the world's largest archipelago, 2/3 of the country is covered by sea. But due to many factors a lot of ship accidents occurred every year, and claiming a large number of casualties. Efforts have been done to improve the safety of domestic sea transportation, as the result to be fully compliance to the SOLAS (Safety Of Live At Sea) regulations regarding to the IMO (International Maritime Organization) convention, worsen by varying sea and cargo characteristic, and low educated passengers, they are very vulnerable to accidents. There are so many accidents in sea transportation in Indonesia, especially in 2005-2010 is due to human errors and only a few caused by natural factors and others. Most of the accidents occur due to the low awareness of the aspects of security and safety. Equipment's and system on board ship, will not remain safe or reliable if they are not maintained. Failure Mode and Effects Analysis (FMEA) approach is chosen as a risk assessment methodology in this paper to synthesize the potential failure modes and their associated causes for product design, especially in ship diesel engine. In this paper, the study proposes the fuel oil system in the ship diesel engine. Fuel oil system is extremely important system on a ship which is designed to supply clean fuel oil to main engine, diesel generators and emergency diesel generators. FMEA is an effective tool or technique used for identifying possible failures and mitigating their effects. In various life cycle phase of diesel engine, FMEA activities are executed, and detailed FMEA documents are usually used as reference. Design changes can be executed according to the existing FMEA documents, especially for the most dangerous failure modes with high prevention difficulty.

***Keywords**:* FMEA, Diesel Engine, Indonesia

1. Introduction

The lack of the ship as a means of transport caused by unplanned maintenance system resulted in a decrease of existing equipment performance on his boat in particular motor carrier. Treatment cannot be regarded as excluded because when in the process performance of a motor carrier does not do care, then the motor carriers will decline slowly but surely. A motor carrier in ship usually called diesel engines. A diesel engines are well known for their operational robustness and efficient performance. These attributes make them a leading choice for prime movers in critical industrial, and mobility applications. Despite the diesel engine's known reliability, there are some operational issues that justify monitoring critical engine components and subsystems in order to increase the overall availability and readiness of diesel-powered systems. Moreover, engines typically constitute a significant fraction (1/10-1/5) of the acquisition cost and a comparable fraction of the life cycle cost for mobility applications, thereby providing the motivation for engine condition monitoring on the basis of reducing life cycle costs. Review of the available literature indicates that the fuel injection and cooling subsystems are among the most problematic on diesel engines contributing to reduced readiness and increased maintenance costs. These faults can be addressed and studied using scaled testing to build the necessary knowledge base to quickly transition the methods to full-scale, more costly diesel engines (Banks, et al 2001).

Diesel engines play major roles in automotive and stationary applications (Nunney, 1998). The life cycle cost of diesel engine is largely determined by the design phase, and its inherent reliability is also heavily influenced by this phase. In order to improve the reliability of the engine, similar diesel engine which have detailed FMEA (Failure Mode and Effects Analysis) documents are usually used as references for priority identification and risk estimation of failures model in FMEA.

FMEA is a methodology designed to identify potential failure modes for the product, to assess the risk associated with those failure modes, to rank the issues in term of importance, and to carry out corrective actions to address the most serious failure modes. Failure modes may be introduced in design, manufacture, and/or usage, and can be potential or actual. Effects analysis refers to studying the consequences of those failures. FMEA is widely used in the manufacturing industry in whole life cycle of a product (Bowles & Bonnell, 1998).

In diesel engine design and manufacturing, it is common to perform FMEA. The aim of diesel engine FMEA is to find potential failure modes and implement design changes, to eliminate critical failure modes, and to decrease the maintenance cost when the engine is put into use.

2. Problem Statement

Analysed of the caused of accidents involving complex technological systems clearly indicates that a small percentage of the major accidents are caused by failures of the systems (something less than 20%). Rather, the accidents that caused by unanticipated actions of people have undesirable outcomes (something more than 80 %). These an unanticipated actions and outcomes can have root source in design, construction, operation, and maintenance.

Perrow (1999) states that the error inducing character of the system in shipping lies in the social organization of the personnel on board, economic pressure, the structure of industry and insurance and difficulties in international regulation. This review examines the current status of safety in the maritime industry and the human factors that may contribute to the causal chain in shipping accidents. There is a particular combination of demand characteristic of the maritime industry such as fatigue, stress, work pressure, communication, environmental factors, and long periods of time away from home, which could be potential contributors. Exemplifying that in shipping "there are a number of workplace dangers in combination, something rare in other industries" (Mc Namara, et al, 2000).

Maintenance, repair, and overhaul of complex industrial and marine systems have received considerable attention in the last decades, due to the high amounts of capital invested and the high availability rates requested. Especially to prevent the risky situations and to increase systems reliability on board ships, the prestigious marine engine manufacturers and ship operators have continuously evidence gathered from the past experiences.

Current methods used to assess system reliability are focused primarily on the hardware component of the system. At one end of the spectrum are the qualitative methods that use historical and experimental hardware fail data to predict future failure rates and how various hardware can fail by using Failure Modes and Effects Analysis (FMEA). By using FMEA we could identify where and how it might fail human factor tabulation data, assessing the relative impact of different failures, and identifying the parts of the process most in need of improvement with factor analysis. We can make the worksheet data after determining the failure mode with the validation matrix.

In this paper, the ship has an important role in the shipping industry, and need to do an analysis of engine system service. This is done to prevent the failure of components within the system that could cause a failure of the punitive damage portion of the ship's functions will ultimately lead to decreased safety level and can endanger passengers and cargo transported even ships nearby. Bad fuel distribution system on a ship caused a breakdown in the fuel to the main engines. This resulted in a delay in the ship's anchor, necessitating regular care and held continue on the fuel distribution system. A technique used to identify, prioritize and eliminate potential failure in systems used for reviewing a process or operation in which systematically acquainted with FMEA. FMEA is used as a risk assessment technique which synthesizes failure modes in order to identify early response and to take appropriate actions into account. As a case application, crucial troubles in fuel oil systems on board ship are investigated deeply to adopt an effective preventive maintenance strategy for fuel oil system in marine diesel engine.

3. Ship Accident In Indonesia

Indonesia is the maritime area that has a unique-features in terms of its transport system, especially the technical and economic aspects, that should be examined more deeply because the age of the current fleet are mostly old, this can cause damage that is not entirely unexpected and it may also affect safety of other ships.

From the report of Trend Analysis of Sea Accident by PT. Trans Asia Konsultan in year 2009, it states that the vessel must meet the requirements of the materials, the construction of buildings, machinery, and the electrification, governance, stability and structure of radio equipment/ship's electronics, accredited by a certificate, that is obviously required after the inspection and testing. Vessels whose condition is excellent, and in accordance with the legal provisions, and declared fit to sail, would be safe to take people and goods, otherwise the ship which is in questionable when the condition is likely to find resistance from maritime transport authority. If the ship was damaged during the trip, it will require additional costs, such as the exploitation of costs due to delay. It is certainly not an easy thing to maintain. The State of the vessel which complies with the requirements and security, the prevention of pollution, control of cargo, the health and well-being of the crew, all of these require additional capital. In addition, companies in business from cruise ships also require full cooperation and assistance of the shipyards, while the current conditions of the shipyards are also faced with lethargy. Therefore, the Government has a rule to play in devising desirable policy, particularly the aspects of the capital and the creation of a favourable business climate, so that transport and shipbuilding company implement rehabilitation, replacement and expansion of the current fleet.

Accidents occurring in sea, rivers, lakes, and crossing that reached Marine Court in 2005-2010 was mostly due to human error (65%), and only a few accidents in the waters caused by natural factors (Danny & Shariman, 2011). Given the reasons mentioned above, all accidents can be minimized if prevention efforts are seriously performed by all parties so as not to stumble on the same stone. Water transport accidents occur mainly due to overcrowding and navigation system, which is characterized by a large number of passengers and goods compared to the draft Commission. For passengers who do not have the expertise and skills in emergency situations, it is important to note that users of the waterway in the category of vulnerable population groups. Efforts to ensure the safety of passengers and crew must be considered as a serious issue, including this trivial security equipment such as buoys. Current conditions, many ships that do not have safety equipment should be able to buoy passengers and crew when the vessel having accident. Most of the accidents occur due to the low awareness on the aspects of security and safety of the crew. The figures differ from the manifest of passengers and number of passengers on the ground become common place. Transportation is the lifeblood of society and the economy in Indonesia. Transportation development activities in Indonesia are out of various dimensions (marine transport and others) and increasing. This is an impacts of economic activity and socio-cultural activities and community. In addition, the process of regulatory reform in the field of national transportation deregulation has also triggered an increase in transport activity. To understand fully that human consciousness towards the preservation of the environment are increasingly high, so that sea transportation accidents which can cause damage to the environment (pollution) should be a significant consideration. In order to further integrate transport infrastructure and facilities that meet the requirements of security and safety of transport, it is necessary to make a standardization of regulation system and procedures, as well as human resource professionals to realize the service organization of the transport and works in order to hold everything intact. Then it is necessary to have a system of good governance, where Governments have function in the transportation services which include coaching in the aspects of setting up, monitoring and controlling the system (PT. Trans Asia Konsultan, 2009).

3.1 Indonesian Ship Accident Data (2005-2010)

The accident happened on a river, lake, and river crossings that are up to the Marine Court over voyage caused by human error, and just a little accident in the waters caused by natural factors. Tracing the reason mentioned above should all the events of the accident can be minimized while there are preventive efforts from all parties so as not to stumble on the same stone. As the image comparison between amphibious insertions accidents caused by human error and natural factors can be seen in Figure 1.

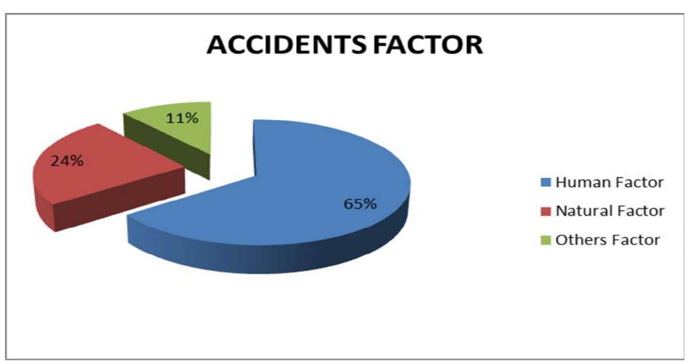

Figure 1: Ship Accidents Factor

A lot of ship accidents occurred every year on Indonesia water, described in Table 1.

Table 1: Number of Ship Accident According to Marine Court Decision 2005-2010

No	Description	Quantity	2005	2006	2007	2008	2009	2010
	Accidents Type							
1	Sunk	Accidents	7	12	9	13	11	4
2	Collision	Accidents	10	9	4	15	9	2
3	Grounded	Accidents	5	5	5	2	3	6
4	Fired	Accidents	5	6	9	4	5	5
5	Others	Accidents	2	6	5	1	5	2
	Total		29	38	32	35	33	19

Source: Marine Court, Secretary General, Ministry of Transportation (2011)

4. Safety of the Ship

4.1 Formal Safety Assessment (FSA) of the Ship

Current models of Formal Safety Assessment (FSA) is a model widely used to analyse accidents at sea where the safety assessment is based on the model risk. Formal Safety Assessment (FSA) was developed by the UK Marine Safety Agency (1992). The concept of the FSA adopted by IMO in the form Guidelines to Formal Safety Assessment (FSA) through memorandum MSC/Circ. 1023-MEPC/Circ. 392 (IMO, 2002) and updated through 2006 included an evaluation of FSA Guidelines risk criteria. The FSA is basically put their risk factors, in which the process is systematically using the scientific method approach.

International Maritime Organization (IMO), Maritime Safety Committee (MSC) in 1995 decided to adopt the concept of FSA. This was done in the hope of improving the IMO rule-making process, and thus further enhancing the safety of shipping. As stated by Wang (2001), it is considered that ‘‘Marine safety may be significantly improved by introducing a formal ‘goal-setting’ safety assessment approach so that the challenge of new technologies and their application to ship design and operation may be dealt with properly’’. For a more specific discussion on the expected benefits of the FSA as a regulatory tool, and as a potential framework for safety assurance in shipping companies, the reader is referred to MSA (1993),Wang (2001) and Peachey (2002). Following the development and introduction of the FSA method, interim guidelines for FSA application were issued by IMO (1997a) to describe and explain the new method and to support its application and further development in practice. Since that time, several FSA trial applications and case studies have been carried out in various IMO member states around the world. Some of the studies have been issued in direct support for the formulation of new IMO safety regulations (e.g. DNV (Det Norke Veritas), 1997a; IMO, 1997b, 2000a,b), while in some other studies the objective has been to provide the justification for rule amendments or provisions allowing deviation/exemptions from a particular rule (e.g. DNV, 1997b). For a further discussion on ways of FSA applications, see Wang (2001).

Formal Safety Assessment (FSA) is a rational and systematic process for the proactive management of safety based on principles of hazard identification, risk analysis and cost-effectiveness evaluation of the efforts in controlling the risks. FSA can be used as a tool to help in the development of new safety regulations or in analysing an existing set of regulations, and thus achieve a balance between various technical and operational issues, including human element and costs. The characterization of hazards and risks should be both qualitative and quantitative, consistent with the available data, and should be broad enough to include the range of options for reduction of risks. A typical FSA exercise in a ship type according to the IMO Guideline would proceed as follows:

Problem definition:

The problem under analysis and its boundaries should be carefully defined. While defining the problem, the following parameters may be considered relevant;

a) Ship category (e.g. type, length or gross tonnage, new or existing)
b) Ship systems (e.g. type layout, subdivision, propulsion,)
c) Ship operation (e.g. in ports and/or during navigation)
d) Accident category (e.g. collision, explosion, fire)
e) Risk category (e.g. injuries and/or fatalities to passengers and crew, environmental impact, damage to ship or port).

By considering the characteristic of the ship, a formal safety assessment of the ship is described in detail in this chapter regarding by IMO. FSA is a structured and systematic methodology, aimed at enhancing maritime safety, including protection of life, health, the marine environment and property, by using risk analysis and cost benefit assessment. FSA can be used as a tool to help in the evaluation of new regulations for maritime safety and protection of the marine environment or in making a comparison between existing and possibly improved regulations, with a view to achieving a balance between the various technical and operational issues, including the human element, and between maritime safety or protection of the marine environment and costs.

FSA consists of five steps:

1. Identification of hazards (a list of all relevant accident scenarios with potential causes and outcomes);
2. Assessment of risks (evaluation of risk factors);
3. Risk control options (devising regulatory measures to control and reduce the identified risks);
4. Cost benefit assessment (determining cost effectiveness of each risk control option); and
5. Recommendations for decision-making (information about the hazards, their associated risks and the cost effectiveness of alternative risk control options is provided).

In simple terms, these steps can be reduced to:

1. What might go wrong? = identification of hazards (a list of all relevant accident scenarios with potential causes and outcomes)
2. How bad and how likely? = assessment of risks (evaluation of risk factors);
3. Can matters be improved? = risk control options (devising regulatory measures to control and reduce the identified risks)
4. What would it cost and how much better would it be? = cost benefit assessment (determining cost effectiveness of each risk control option);
5. What actions should be taken? = recommendations for decision-making (information about the hazards, their associated risks and the cost effectiveness of alternative risk control options is provided).

It is equally admitted however, that the application of absolute numerical risk criteria may not always be appropriate as the whole process of risk assessment involves uncertainties. Furthermore, opinions on acceptable numerical risk criteria may differentiate between individuals and societies with different cultures, experience and mentalities.

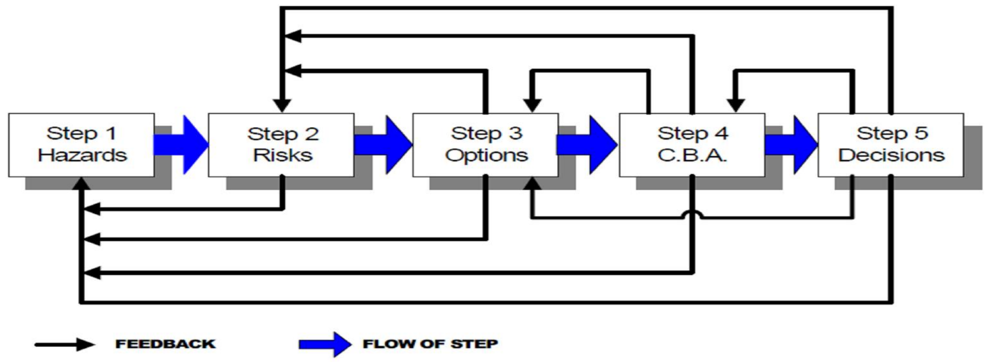

Figure 2: Information Flow in FSA Process

Source: Interim Report of Collaborative FSA Studies between Indian Register of Shipping, China Classification Society, Korean Register of Shipping and Class NK., 2002

Prior to application of the FSA steps additional information would require to be compiled on the following:

a) Identification of existing design concepts and review of existing rules/regulations
b) Identification of existing operational procedures/concepts
c) Compilation of materials under consideration and their properties.
d) Identification of involved parties responsible/liable for safety.

In general, the problem under consideration should be characterized by a number of functions. Where the problem refers to a type of ship, these functions include carriage of payload, emergency response, communication, manoeuvrability etc. Where the problem relates to a type of hazard, for instance Fire, the functions include prevention, detection, alarm, containment, escape, suppression etc. It is imperative that a comprehensive view is taken of the ship 'hardware' (i.e. technical & engineering system) dynamically integrated to the 'software' (i.e. human behaviour governed by organization & management infrastructure).

4.2 FMEA Analysis

Initially used by the U.S military after World War II as a process tool, FMEA gradually spread into industry. It became widely known within the quality community as a total quality management tool in the 1980s and as a Six Sigma tool in the 1990s. A team should apply FMEA to perform risk assessment to see what the customer will experience if a key process input (X) were to fail. The team should then take action to minimize risk and document processes and improvement activities. FMEA is living document that should be reviewed and updated whenever the process is changed (Jogger, 2002). It can be used in the define phase of the define, measure, analyse improve and control strategy as a voice of the customer input, but is more commonly created in the measure phase, updated in the analyse and improve phases and is a vital element of the control phase. FMEA is one of the most efficient low-risk tools for prevention of problems and for identification of more efficacious solutions, in cost terms, in order to prevent such problems.

To develop the FMEA, initially was done a survey on the functions of each component, as well as on its failure modes and effects. Were been used, as support for the analysis, the system textual description, contained in the technical operation instructions, the fault registers in the abnormality cards (service orders for maintenance) of the plant, the maintenance plans currently used and the instrumentation descriptions of the equipment and components. It was also performed a brainstorming in a join into the plant operators, so that it was possible to get with more details about the description of the possible failures of each component.

For the analysis, the data was taken from the field data, from the ship KM (Kapal Motor) Karisma in Table 2 the specification data from the ship and main engine specification.

Table 2: Data Spec and Main Engine of KM Karisma

Principal Dimension	Description
Gross Tonnage	2059 GT
LWT (Light Weigh Tonnage)	1329 Ton
LOA / LPP (Length of All) / (Length Between Perpendicular)	88,636 / 81,50 m
Breadth	13 m
Draft	5,409 m
Velocity	10 Knot
Main Engine	MAN B&W 6S26MC
HP / Kw / R.P.M	2382 PS / 1752 / 250
Crews	21 peoples
Year Making- Country Made	1990 – South Korea

Main Engine Spec

1	No. Of Set	:	1 Set
2	Type	:	Marine Use, Vertical In-Line Two (2) Stroke Single Acting, Direct Reversible Crosshead Diesel Engine With Exhaust Turbocharger
3	Model	:	MAN B&W 6 S26MC
4	Rating	:	MCR : 2400 BHP at 250 RPM CSR : 2160 BHP at 241,4 RPM OR : 2648 BHP at 258 RPM
5	Direction of Rotation	:	Clock Wise Viewed From After
6	Starting	:	Compresed air max 30 Kg/cm^2
7	Using Of Fuel Oil	:	HFO
8	Fuel Oil Consumption	:	130g/BHP.hr

Table 3: FMEA of Effect of Main Engine

System	**: Main Engine Suporting System**
Indenture Level	**: Fuel Oil System**
Reference Drawing	**: Schematic Piping Diagram KM.Karisma**
Mission	**: Fuel Oil System Failure**

Identification No.	Item/Functional Identification (Nomenclature)	Function	Failure Modes and Causes	Mission Phase/ Operational Mode	Failure Effects			Failure Detection Method	Effect For M/E Critical	
					Local effects	Next Higher Effects	End effects			
1	Storage Tank	Fuel oil storage	Leakage	Fuel oil supply less	Fuel losses	Fire hazard	Danger of explosion	Direct observation		No
			Clogged	Fuel oil supply less	Excess charge	Fire hazard	Danger of explosion	Direct observation		
2	Transfer Pump	Drain the fuel oil from service tank to main engine Raise the pressure low of fuel oil	Less pressure and the resulting lack of capacity.*(Low output) (OREDA 2002)*	Fuel oil supply less	Reduce the fuel flow and the flow become small	The supply of fuel to another sub-system disturbed	Main engine performance decrease	Pressure indicator	Yes	
			Noise and vibration on pump *(Vibration and Noise) (OREDA 2002)*	Fuel oil supply less	Damaged pumping fast	The supply of fuel to the main engine disturbed	Main engine performance decreased	Direct observation		
			Leakage on pump seal *(Leakage) (OREDA 2002)*	Fuel oil supply less	Damaged pumping fast	The supply of fuel to the main engine disturbed	Main engine performance decreased	Direct observation		
			Pump cannot spin *(Breakdown) (OREDA 2002)*	Fuel oil supply less	Damaged pumping fast	The fuel supply is cut off.	Main engine cannot operating	Direct observation		
3	Settling Tank	Shelter early and heating fuel oil	Leakage	Fuel oil supply less	Fuel losses	Fire hazard	Danger of explosion	Direct observation		No
4	Purifier	Separate the fuel oilfrom water and dirt	Purifier cleaning is bad	Fuel oil viscosity is not enough	Purity levels of fuel does not qualify	Viscosity ineligible	Main engine burning not perfect	Water transducer Direct observation	Yes	
5	De-Aerator chamber	Regulating the flow of fuel oil to the main engine	The seal has corrosion and leakage	Seal tight decreased	The unit cannot be spinning as well as the presence of fluid out of the seal unit	Increasing the pressure on the pipe leading to the main engine	Low fuel quality as well as a decline in performance of main engine	Direct observation	Yes	
6	Service Tank	A place of shelter fuel advanced that ready to use	Leakage	Fuel oil supply less	Fuel losses	Fire hazard	Danger of explosion	Direct observation		No
			Leakage	Fuel oil supply less	Excess charge	Fire hazard	Danger of explosion	Direct observation		
7	Supply Pump	Flow the fuel from service tank to main engine Raise the pressure flow of fuel oil	Impeller get corrosion and erosion Cavitation happened Pump leakage *(OREDA 2002)*	Less pressure	Fuel supply become small, Overheat pump, Speed up the wear of pump	Fuel supply to another system disturbed	Fuel oil supply to main engine stopped	Pressure indicator	Yes	
			Section and discharge clogged Electric supply less Electric voltage unstable	Less pressure	May cause damage on pump Bearing will quickly to wear	Lack of fuel discharge for main engine	Fuel oil supply to main engine stopped	Flow indicator, Voltmeter		

			Driving the pump get overload *(OREDA 2002)*							
			The pump vibrates and the sound which is very noisy*(Vibration and Noise)* *(OREDA 2002)*	The particles enter into a pump, Cavitation happened. Pump foundation is not good	Damaged pumping fast	Fuel supply to main engine disturbed	Fuel oil supply to main engine stopped	Direct observation		
			The pump is spinning and suddenly stopped *(Breakdown)* *(OREDA 2002)*	The presence of impurities which enters into a pump, Deformation occurs due to the heat so that the impeller was broken	Damaged pumping fast	Fuel supply terminated	Fuel oil supply to main engine stopped	Direct observation		
8	Filter 1 Filter 2	To filter the impurities in fuel oil	Filter clogged by the dirt	Any dirt that cannot be cleaned	Damaged filter	The fuel oil can not flow	Fuel oil supply to main engine stopped	Viscometer Flow meter	Yes	
			The filter not maximum	Any dirt that cannot be cleaned	Dirty fuel oil	Damaged pump	Fuel supply to main engine stopped	Viscometer Flow meter		
9	Drain Tank	Holding excess fuel oil from the main engine	Leakage	Plate corrosion	Fuel losses	Fire hazard	Danger of explosion	Direct observation		No

Table 4: FMEA Severity Class of Fuel Oil System

System : **General Service System Of Main Engine**
Indenture Level : **Sub System**
Mission : **Fuel Oil System Failure**

Identification No.	Item/Functional Identification (Nomenclature)	Function	Failure Modes and Causes	Mission Phase/ Operational Mode	Failure Effects			Failure Detection Method	Compensating Provisions	Severity Class
					Local effects	Next Higher Effects	End effects			
FO-01	Storage Tank	Fuel oil storage	Leakage	Fuel Oil supply less	Fuel oil losses	Fire hazard	Danger of explosion	Direct observation	Patching the leaking plate	Catastrophic
			Clogged	Fuel Oil supply less	Excess charge	Fire hazard	Danger of explosion	Direct observation	Patching the leaking plate	
FO-02	Transfer Pump	Drain fuel oil from service tank to main engine Raise the pressure flow of fuel oil	Less pressure and the resulting lack of capacity	Fuel Oil supply less	The flow of fuel oil decreased, Overheat pump, Speed up the wearing of a pump	The supply of fuel oil to another sub-system disturbed	Main engine performance decrease	Pressure indicator	Changing the impeller, Opening suction valve, Checking and fixing the part contained air to go in, Treatment fuel oil in order to have the right viscosity, Setting again flow regulating valve	Critical
			The pump vibrates and the sound is very noisy	Fuel Oil supply less	Damage pumping fast	The supply of fuel oil to main engine disturbed	Main engine performance decrease	Direct observation	Cleaning the suction valve and discharge, Adjusting the power enters to the pump needs, Repairing the pump foundation, tighten the bolt fastener, Add the bearing on the foundation of the pump,	

									Changing the Impeller	
			The pump cannot spin	Fuel Oil supply not enough	Damage pumping fast	The supply of fuel oil cut by system failure	Main engine failed to operate	Direct observation	Repairing if the damage of the pump minor, changing if major	
FO-03	Settling Tank	Shelter early and heating fuel oil	Leakage	Fuel Oil supply not enough	Fuel oil losses	Fire hazard	Danger of explosion	Direct observation	Patching the leaking plate	Catastrophic
	Purifier	Separate fuel oil from water and dirt	Bad cleaning	Temperature controllers not functioning properly, Viscosity fuel not meet	Fuel oil purity levels are not eligible	Viscosity does not eligible	Main engine burner imperfect	Direct observation	Checking the temperature controller. Checking the flow rate of the pump, Checking the valve	Critical
FO-05	De-Aerator Chamber	Regulating the flow of fuel oil to main engine	Rust Seal leakage	Impermeability down	Unit difficult or cannot be rotated, The presence of fluid out of the seal unit	Pressure pipe to the engine increase	Slow start, Fuel quality is not good, Knock misfiring, Poor Idle performance engine	Direct observation	Cleaning the rust, Painting, Changing the broken seal	Marginal
FO-06	Service Tank	A place of shelter fuel oil and prepared for use	Leakage	Fuel Oil supply less	Fuel oil losses	Fire hazard	Danger of explosion	Direct observation	Patching the leaking plate	Catastrophic
			Outlet clogged	Fuel Oil supply less	Excess charge	Fire hazard	Danger of explosion	Direct observation	Cleaning the output line	
FO-07	Supply Pump	Flow the fuel oil from service tank to main engine Raise the pressure flow of fuel oil	Impeller get the corrosion and erosion, There is the air into the pump, Suction valve closed, Fuel oil viscosity is too high, Cavitation happened, The pump leakage	Less pressure	The flow of fuel oil decreased, Overheat pump, Accelerate the wear and tear of the pump, Interface in separator is changed	Fuel oil supply to another sub system disturbed	Fuel oil supply to main engine stopped	Pressure indicator	Changing the impeller, Opening the suction valve, Checking and repairing part contained air to go in, Fuel oil treatment for the right of viscosity, Setting again flow regulating valve	Critical
			Section and discharge channel clogged, The supply voltage is reduced, Electric voltage is not stable, Pump does not meet the capacity specification, Driving the pump get overload	Less pressure	Can cause damage on a pump, Bearing will be broken	Debit fuel oil to main engine not match	Fuel oil supply to main engine stopped	Flow indicator, Voltmeter	Opening and cleaning the inlet and outlet valve, Cleaning the filter regularly Stabilizing supply voltage so that the pump's power needs are met	

			The pump vibrates and the sound which is very noisy	The existence of objects which enter into the pump, Resources used exceeded the maximum, Cavitation happened, The pump foundation is not good.	Damaged pumping fast	Fuel oil supply to main engine disturbed	Fuel oil supply to main engine stopped	Direct observation	Cleaning the suction valve and discharge, Adjusting the power enters to the pump needs, Repairing the pump foundation, tighten the bolt fastener, Add the bearing on the foundation of the pump, Changing the Impeller	
			The pump is spinning and suddenly stopped	The existence of objects which enter into the pump, Deformation occurs due to the heat so that the impeller was broken	Damaged pumping fast	Fuel oil supply terminated, System failure	Fuel oil supply to main engine stopped	Direct observation	Repairing if the damage of the pump minor, changing if major	
FO-08	Filter	To filter the impurities in fuel oil	Filters clogged by dirt	The presence of impurities that cannot clear	Filter was broken	Fuel oil cannot flow	Fuel oil supply to main engine stopped	Direct observation	Changing the filter	Critical
			The filter not maximum	Any dirt that cannot be cleaned	Dirty fuel oil	Damage pump	Fuel oil supply to main engine stopped	Viscometer, Flow meter	Changing the filter	
FO-09	Drain Tank	Holding excess fuel oil from the main engine	Leakage	The presence of corrosion and porous on the plate	Fuel oil losses	Fire hazard	Danger of explosion	Direct observation	Patching the leaking plate	Catastrophic

5. Conclusion

1. From the Indonesian ship accident data from 2005-2010 were 65% caused by human error, 24% caused by natural factor and 11% caused by other's factor.
2. From Table 3 there is a critical effect for Main Engine in Fuel Oil System:
    a. Transfer Pump: with the function for distributing the fuel to main engine from service tank and raise the fuel pressure.
    b. Purifier: with the function for separating fuel from the dirt and water.
    c. De-Aeration Tank: with the function for controlling the flow to main engine.
    d. Supply Pump: with the function for distributing the fuel oil from service tank to main engine and raising the fuel pressure.
    e. Filter: with the function for filter out the dirt from fuel.
    f. Circulating Tank: with the function for keeping the pressure in injection pump and circulating the fuel on the system to keep the viscosity and operational temperature
    g. Purifier Heater: with the function for raising the temperature and viscosity of the fuel
    h. Fuel Oil (FO) Line Heater: with the function for raising the temperature and viscosity of the fuel.

3. In Table 4 there is Severity Class for Fuel Oil System Failure:

i. Storage Tank : Catastrophic
ii. Transfer Pump : Critical
iii. Settling Tank : Catastrophic
iv. Purifier : Critical
v. De-Aerator Tank : Marginal (Significant)
vi. Service Tank : Catastrophic
vii. Supply Pump : Critical
viii. Filter : Critical
ix. Drain Tank : Catastrophic

4. The writer chose the FMEA of diesel engine because to prevent fire accident from happening. From the whole accident that happened in sea transportation accident, only fired ship could been used for this FMEA analysis. FMEA is a risk assessment technique with synthesizes the potential failure modes in order to identify early response and to take appropriate actions into account. FMEA is a systematic technique in analysing a form of failure and its emphasis on bottom-up approach. The point of the bottom-up approach here is an engineering analysis that was done starting from the equipment or components and then forward to the system level or a higher level. FMEA activity is aimed to get the most critical components or necessary component significant against the failure of the system of fuel.

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