VOL. 13, NO. 21, NOVEMBER 2018 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

FAILURE MODE AND EFFECT ANALYSIS (FMEA) APPLIED FOR RISK ASSESSMENT OF FUEL OIL SYSTEM ON DIESEL ENGINE OF FISHING VESSEL

Rahmad Surya Hadi S.[1], Yuniar Endri Priharanto[2] and M. Zaki Latif A.[2]
[1]Marine and Fisheries Polytechnic of Karawang, Study program of Capture Fisheries, Karawang, West Java, Indonesia
[2]Marine and Fisheries Polytechnic of Sorong, Study Program of Fisheries Engineering,Sorong, West Papua, Indonesia
E-Mail: rahmad2002@gmail.com

ABSTRACT

The existence of diesel engine commonly used as the main propulsion engine on fishing vessel, Diesel engine works continuously during fishing operation thus requisite extra intention to ensure the diesel engine work properly. Since the diesel engine work hardly several components could be failed to work or even worst, for example fuel system. To prevent operational failure of Diesel engine caused by failure of fuel system hence proper maintenance is needed especially on components that exist in fuel system. On the fuel system consists of many components, but only on critical components that need to be treated. To determine the critical component it is necessary to analyze based on the possible failures of each component. This paper aims to apply the FMEA approach to find out how to assess the possible risks in the diesel engine fuel system used as the main propulsion of fishing vessel. The study was performed critical components of the fuel system in the event of failure will result in the failure of the diesel engine operation as follow Fuel storage tanks, transfer pumps, daily fuel tanks, separators, hand pumps, double stage filters, high pressure fuel pumps, high pressure fuel line and injector.

Keywords: diesel engine, FMEA, and fuel system.

INTRODUCTION

Diesel engine is an internal combustion engine (McCarthy, Rasul and Moazzem, 2011)that mostly used as main propulsion engine on the ship (fishing vessel) (Dedes, Hudson and Turnock, 2012). In operation of Diesel engine is operated 24 hours per day for one week even up to one-month duration. Diesel engines are selected for efficiency, power and high reliability compared to other compatible resources or other power (Lamaris and Hountalas, 2010)

The highly complex marine diesel engine structure causes some failures on certain components to cause other failures either from one system or from another (Cai, Weng and Zhang, 2017). The effective operational of Diesel engines is reinforced by several operating systems, one of them is the fuel system. Fuel system components in the Diesel engine must always be in good condition, if the failure occurs on the fuel system components probably resulting failure operation. According to Report(Maritimos, 2012)engine failure during sailing resulting the vessel uncontrolled and it might fatal consequences. Fuel system failure, may be due to air, fuel lines and the fuel filter blockage, whose fault phenomenon can be poor atomization, non-atomization or low pressure of the fuel injection pump (Cai, Weng and Zhang, 2017).

To prevent operational failure of Diesel engine caused by failure of fuel system hence proper maintenance is needed especially on components that exist in fuel system. On the fuel system consists of many components, but only on critical components that need to be treated. To determine the critical component it is necessary to analyze based on the possible failures of each component, the cause of the failure, and what impact it will have and what risks it receives if a component in the fuel system fails. It can be done using the FMEA approach. This paper aims to apply the FMEA approach to find out how to assess the possible risks in the diesel engine fuel system used as the main drivers of fishing vessel.

Methods

Failure mode and effects analysis (FMEA) is a powerful tool for identifying and assessing potential failures(Zhang and Chu, 2011) and actions needed in eliminating the cause of error(Hekmatpanah, Shahin and Ravichandran, 2011).

Currently FMEA is widely applied to marine engineering and offshore engineering such as; shipboard machinery system (Cicek *et al.*, 2010), Fishing vessel(Pillay, 2003), and oil company(Hekmatpanah, Shahin and Ravichandran, 2011).

H. R. Feili(Feili *et al.*, 2013) FMEA procedure commences with reviewing design details, illustrating equipment block diagram and recognizing overall potential failures, respectively. Following recognition, all possible causes and effects should be classified to the related failure modes. After this practice, priority of failures due to their disaster effects should be ranked by a Risk Priority Number (RPN), which is the multiplication of severity of failures (S), their portability of occurrence (O), and the possibility of detection (D).

RPN is Priority potential level of failure which shows the higher RPN value then the higher risk received. Value of S, O and D obtained through discussion process with the chief engineer, engine crew and port engineer where they have more than ten years' experiences working on board. Furthermore, The Value of S, O and D calculate obtained in the worksheet using calculation as below:

VOL. 13, NO. 21, NOVEMBER 2018 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

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

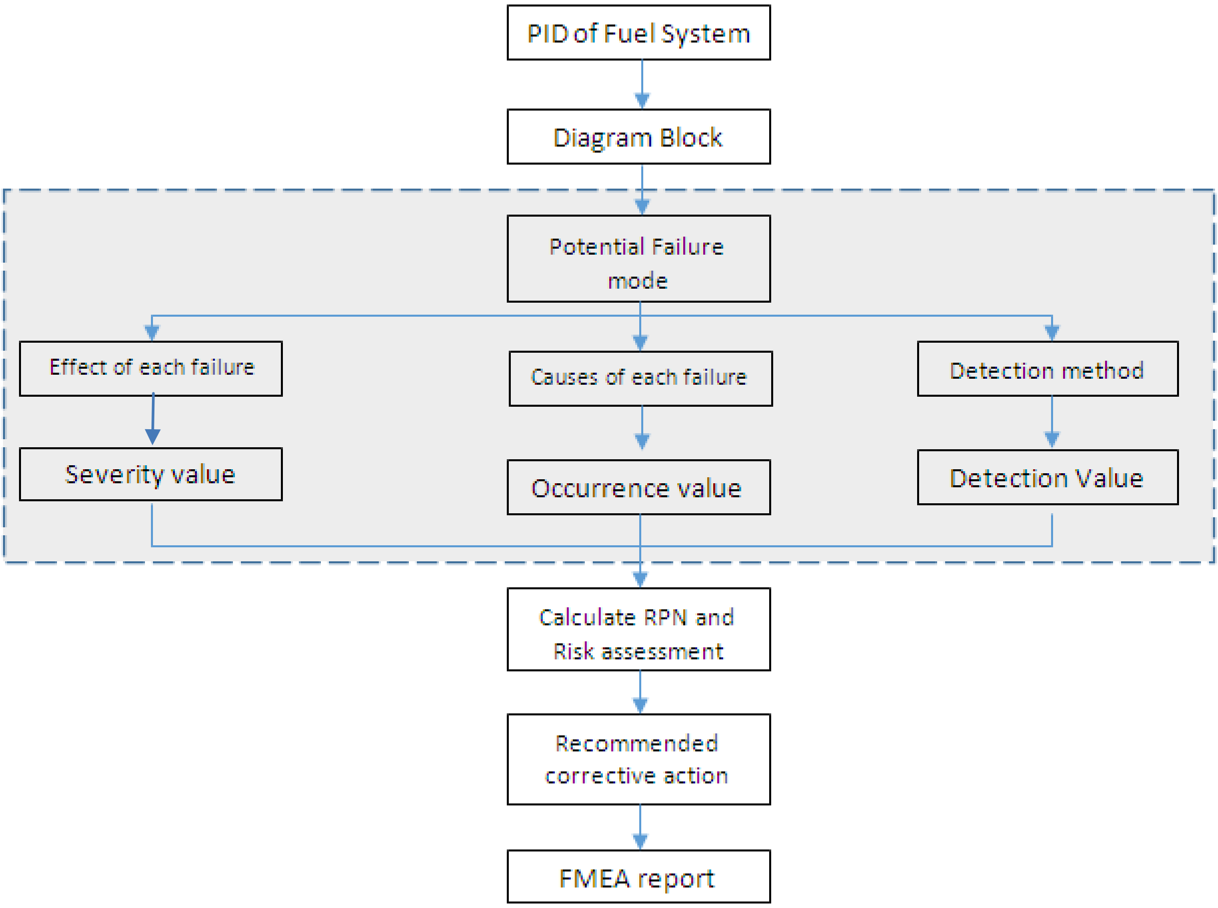


Figure-1. Flow chart FMEA report.

Severity (S) is the seriousness assessment of the effect of the potential failure to the system. Occurrence (O) is the assessment of how frequently the specific failure cause is projected to occur. Detection (D) such as assessment of the probability the operating parameters monitoring system will be detecting a cause/mode of failure before the component/system is damaged and stopped (Cicek and Celik, 2013).

Table-1. Severity of failure and criteria of hazardous level.

Severity	Criteria	Ranking
Dangerously High	The failure effect is hazardous for customer/user safety	10
Extremely high	The same as above only with warning	9
Very high	The product is not operative High	8
High	High degradation of product and customer dissatisfaction	7
Moderate	Partial malfunction of the product and customer dissatisfaction	6
Low	The product could be reworked and some customer dissatisfaction	5
Very low	The failure could be noticed by many customers	4
Minor	The failure could be noticed by few customers	3
Very minor	The failure is not apparent to the customer	2
None	No Effect	1

VOL. 13, NO. 21, NOVEMBER 2018 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

Table-2. Occurrence ranking criteria.

Occurrence	Description	Frequency	Ranking
Very High	Failure is almost inevitable	1 in 2	10
		1 in 3	9
High	Repeated failure	1 in 8	8
		1 in 20	7
Moderate	Occasional failure	1 in 80	6
		1 in 400	5
		1 in 2.000	4
Low	Relatively few failures	1 in 15.000	3
		1 in 150.000	2
Remote	Failure in unlikely	1 in 1.500.000	1

Table-3. Detectability ranking criteria.

Detectability	Criteria	Ranking
Absolute Uncertainty	Impossible to detect the failure	10
Very remote	Very difficult to detect the failure	9
Remote	Difficult to detect the failure	8
Very lob	Very low chance to detect failure	7
Low	Lob chance to detect failure	6
Moderate	Moderate chance to detect failure	5
Moderate High	Moderately High chance to detect failure	4
High	Probably the current Control Wills detect the failure	3
Very High	High probably the current Control Wills detect the failure	2
Almost certain	Surely the current Control Wills detect the failure	1

RESULT

Fuel system on the diesel engine on board regarding on the PID have several components and sub-components, however after boundary of fuel system determined and valid with proper condition of fuel system which are fuel storage tank, separator, hand pump, double stage filter, high pressure fuel pump and injector. Several components connected to the low pressure fuel pipe and some of them connected to high pressure fuel pipe. The overall components work properly in order the fuel system always worksin good condition. Components of the fuel system modelled in reliability block diagram as shown in Figure-2. Based on the system, if one of the componentsfails thus the fuel system will not work properly.

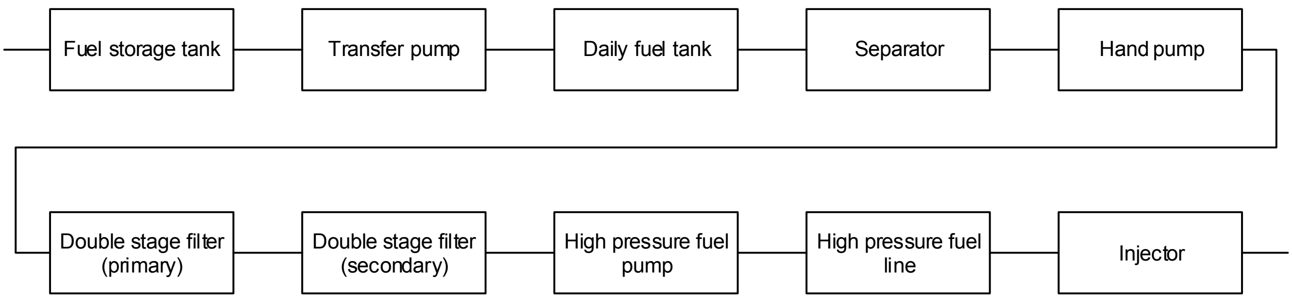


Figure-2. Reliability block diagram diesel fuel system.

Regarding the Figure-2, furthermore each component of the fuel system identified the function, failure mode that occurred and the effect of the failures. The severity rating is rated according to Table-1 with

VOL. 13, NO. 21, NOVEMBER 2018 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

reference to the resulting effect, the frequency of occurrence of the failure in Table-2 and the rank of failure detection and the detection rating rated according to Table-3.

FMEA analysis worksheet

Table-4. FMEA worksheet.

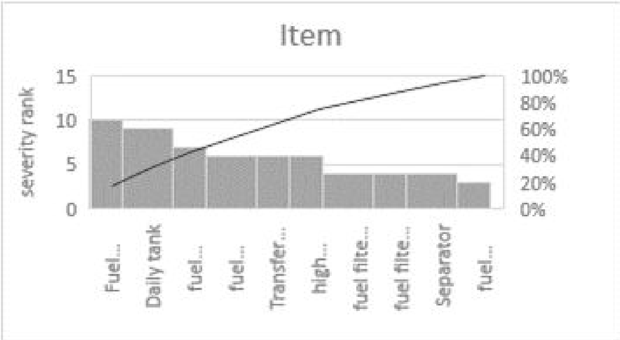
No.	Item	Function	Failure mode	Effect	S	Cause	O	Detection	D	RPN
1	Fuel storage tank	fuel storage	external leakage	fire, explode, environtmental pollution	10	corrotion	1	visual, fuel leakage	7	70
2	Transfer pump	fuel transfer	fail operation	engine stop, flat out.	6	drive fail run	4	detected, alarm	2	90
3	Daily tank	daily fuel storage	external leakage	Fire, explode,environmental pollution.	9	weak, corrosive	1	visual, leakage	5	45
4	Separator	separate fuel and water, solid waste	dirt, water sediment	Engine perform less	4	fuel dirty	9	visual, sight glass separator	3	108
5	fuel supply pump	Flowing the fuel to engine	external leakage	Seems dirty	3	weak of seal	3	visual, fuel leakage	7	63
6	fuel filter double stage (primary)	Separate oil with high sediment dirty	Filter blocked	Less perform, stopped working	4	fuel dirty	9	visual, open the fuel filter	7	252
7	fuel filter double stage (secondary)	Separate oil with fine dirt	Filter blocked	Less perform, stopped working	4	fuel dirty	9	visual, open the fuel filter	7	252
8	fuel injection pump	Flowing fuel to the injector	Internal leakage	Less perform, Stopped working	7	weak, worn out	1	tear down, pressure test	8	56
9	High pressure pipe	Flows fuel from high pressure pump to the injector	Leakage	Less perform, stopped working	6	installation of slack	1	visual, fuel leakage	5	30
10	fuel injector	Spraying fuel to the combustion chamber	Blocked	Less perform, system stopped work	6	Dirt from fuel	2	take apart, injector tester	8	96

DISCUSSIONS

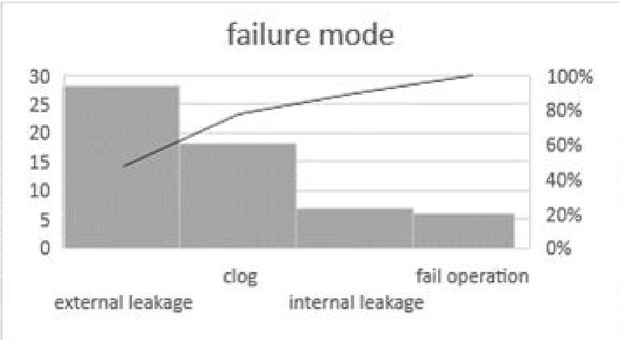
Based on FMEA worksheet on the Table-4 with the existence of cause and effect on the fuel system also be able to use as supporting equipment to identify failure arise on the component, thus accordance to (Cicek and Celik, 2013); (Stamatis, 2003) which states that FMEA is a proactive analytical tool to assist engineers in order to define, identify and eliminate potential failures, constraints, inaccuracies or other systems, design and/or operations.

Items where the failure has the highest severity is fuel storage tank, following to daily tank(Figure-3a) because it is to store the fuel, on the (Table-4) this failure has occurrence remote. The failure mode has highest severity level is external leakage (Figure-3b). This component on the fuel system potentially dangerous start from the pollution of the marine environment to the occurrence of fire.

ARPN Journal of Engineering and Applied Sciences

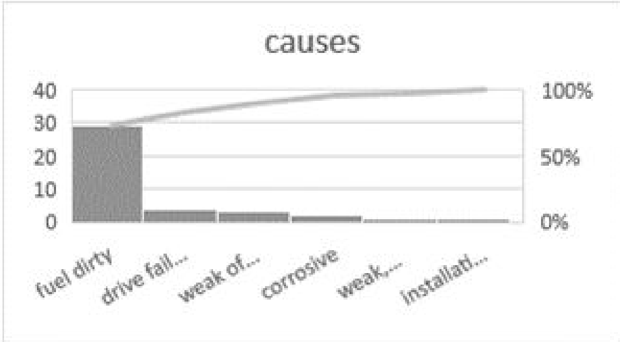


(a)

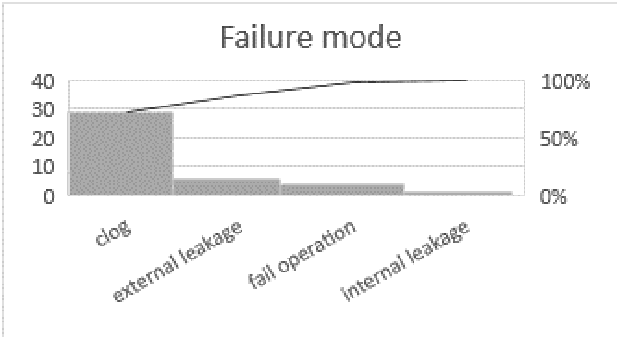


(b)

Figure-3. Failure cause and component regarding severity



(a)



(b)

Figure-4. Failure mode and causes accumulation rank based on occurrence.

On the histogram (Figure-4a) shown the failure caused the highest occurrence is fuel purity (dirty fuel), the dirty fuel caused blocked on the system therefore the failure mode has the most frequent rank (Figure-4b) regarding on the Table-4 the dirtiness of fuel causes blocked on separator, fuel filter, fuel injector. The fuel dirty affected to the system start from the unclean air, water sediment from the condensate air in the fuel tank, rusty fuel tank and others. However, this isn't a fatal impact, unclean fuel can be disturbed the engine operation, if there is no intervention therefore cause failure on the other components hence impacting engine downtime in period of time and take a long time to repair the engine to operate properly.

As shown of histogram on the Table-4 is RPN of each component as shown on (Figure-5) double stage fuel filter has the highest rank by 252. Thishappens cause the level of severity is 4, if this occurs will cause engine stopped, High occurrences with a rating of 9 is quite time-consuming for repairing, and detection is slightly difficult because it has to open the case filter. The other high RPN is separator with a rating of 108, separator has a lower point than double stage fuel filter because to detect the occurrence a little easier. Some of the separator components are made of transparent material thus it can visually detect if the separator is containing accumulation of dirt.

ARPN Journal of Engineering and Applied Sciences

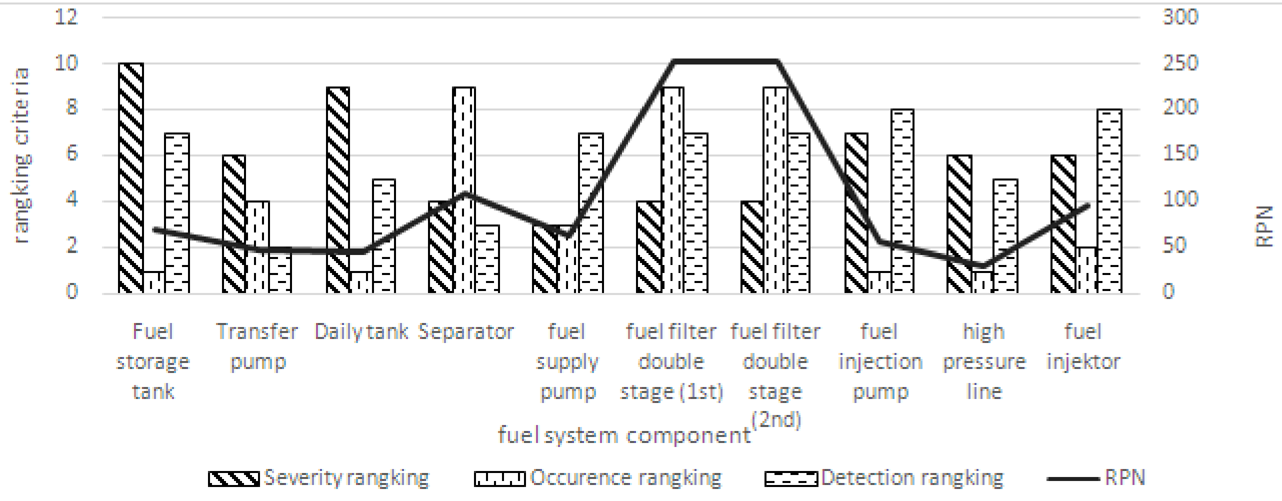


Figure-5. Ranking criteria and RPN each component.

The fourth highest RPN values are caused by dirty fuel. To shrink the RPN Value while preventing further destruction therefore it will reduce the occurrence rate by making a schedule of removing the dirt deposits contained in the bottom of the fuel by drain fuel tank, separator and cleaning or replacing the fuel filter.

The next high rate RPN is fuel injector, a failure of fuel injector as a result of fuel dirty. Furthermore, the engine Performa is less, when more than a half amount of fuel injector blocked may result in the diesel engine isn't being able to operate. To detect this failure is not easy and takes a long time to make the failure of this item has a detection rating by 8. Fixed fuel injector also requires a special tool. With a low occurrence value thus should be checked the condition of the injector while fishing vessel is docked. According to the size of fuel injector which is small therefore every fishing vessel carries reserve to anticipate if the injector is clogged while on a fishing trip.

The RPN of the component subsequently lies below the average RPN value, however, in the event of a failure in this component will cause the engine stop operations and potentially even a high risk. Therefore, if the fishing vessel is docked (repairing) this component shouldn't be missed during maintenance process. A small part of diesel engine such a driver transfer pump with medium occurrence value, should be always keep carrying this component to anticipate when the failure occurred during a fishing trip.

CONCLUSIONS

Critical components of the fuel system in the event of failure will result in the failure of the diesel engine operation as shown in (Figure-2). As follow Fuel storage tanks, transfer pumps, daily fuel tanks, separators, hand pumps, double stage filters high pressure fuel pumps, high pressure fuel line and injector.

The high RPN value is above average due to unclean fuel resulting in a clogged system, as well as the impact of failure with the highest severity value (fire) this is due to unclean and moisture content on the fuel. Fuel that contains water will be oxidized and resulting corrosion on the fuel tank that triggers leakage.

To suppress the occurrence value by using filters and separators. Components are very important because if the dirt entering through the filter will cause damage to other components. Therefore, with the importance and frequent failure of this component should be redundant and disposal schedule. Failure Components with moderate occurrence should be accelerated the scheduled maintenance by skilled labour, spare parts, and tools to do the maintenance.

To define, identify and eliminate possible failures, constraints, improprieties or other systems, design and / or operations using the FMEA worksheet (Table-4) (Table-4) proves to be effective. With the RPN can help the technician to determine the priority of care that should take precedence. Subsequent to determining the component with critical criteria can be optimized maintenance time on fuel system components.

ACKNOWLEDGEMENT

The authors express sincere appreciation to the anonymous referees for their helpful comments and advice in order to improve the quality of this paper. Thanks also to marine and fisheries polytechnic of Karawang and Sorong for the support to carry out this research.

REFERENCES

Cai C., Weng X. and Zhang C. 2017. A novel approach for marine diesel engine fault diagnosis. Cluster Computing. Springer US, 20(2), pp. 1691–1702. doi: 10.1007/s10586-017-0748-0.

Cicek, K. *et al.*2010. Risk-based preventive maintenance planning using Failure Mode and Effect Analysis (FMEA) for marine engine systems. Engineering Systems Management and Its Applications (ICESMA), 2010 Second International Conference on. pp. 1-6.

Cicek, K. and Celik, M. 2013 Application of failure modes and effects analysis to main engine crankcase explosion failure on-board ship. Safety Science, 51(1): 6-10. doi: 10.1016/j.ssci.2012.06.003.

Dedes, E. K., Hudson, D. A. and Turnock, S. R. (2012) Assessing the potential of hybrid energy technology to reduce exhaust emissions from global shipping. Energy Policy. Elsevier, 40(1): 204-218. doi: 10.1016/j.enpol.2011.09.046.

Feili, H. R. *et al.* 2013.Risk analysis of geothermal power plants using Failure Modes and Effects Analysis (FMEA) technique. Energy Conversion and Management. Elsevier Ltd, 72, pp. 69-76. doi: 10.1016/j.enconman.2012.10.027.

Hekmatpanah, M., Shahin, A. and Ravichandran, N. 2011. The application of FMEA in the oil industry in Iran : The case of four litre oil canning process of Sepahan Oil Company. 5(8): 3019-3027. doi: 10.5897/AJBM10.1248.

Lamaris V. T. and Hountalas D. T. 2010. A general purpose diagnostic technique for marine diesel engines - Application on the main propulsion and auxiliary diesel units of a marine vessel', Energy Conversion and Management, 51(4): 740-753. doi: https://doi.org/10.1016/j.enconman.2009.10.031.

Maritimos, C. P. de I. de A. E. I. 2012. Technical report S-17 / 2012 Investigation of the collision of vessel BESIKTAS PERA against the pier during the docking manoeuvre at the port of Valencia on the 22nd of October 2011. This report has been drafted by the Standing Commission for Maritime A.

McCarthy P., Rasul M. G. and Moazzem S. 2011. Analysis and comparison of performance and emissions of an internal combustion engine fuelled with petroleum diesel and different bio-diesels. Fuel. 90(6): 2147-2157. doi: https://doi.org/10.1016/j.fuel.2011.02.010.

Pillay A. 2003.Elsevier Ocean Engineering Book Series Technology and Safety of Marine Systems. 7.

Stamatis D. H. 2003. Failure Mode and Effect Analysis FMEA from Theory to Execution. 2nd edn. ASQ Quality Press, Milwaukee, Wisconsin.

Zhang Z. and Chu, X. 2011 Expert Systems with Applications Risk prioritization in failure mode and effects analysis under uncertainty. Expert Systems With Applications. Elsevier Ltd, 38(1): 206-214. doi: 10.1016/j.eswa.2010.06.046.