A Step by Step Approach for Evaluating the Reliability of the Main Engine Lube Oil System for a Ship's Propulsion System

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ABSTRACT: Effective and efficient maintenance is essential to ensure reliability of a ship's main propulsion system, which in turn is interdependent on the reliability of a number of associated sub- systems. A primary step in evaluating the reliability of the ship's propulsion system will be to evaluate the reliability of each of the sub- system. This paper discusses the methodology adopted to quantify reliability of one of the vital sub-system viz. the lubricating oil system, and development of a model, based on Markov analysis thereof. Having developed the model, means to improve reliability of the system should be considered. The cost of the incremental reliability should be measured to evaluate cost benefits. A maintenance plan can then be devised to achieve the higher level of reliability. Similar approach could be considered to evaluate the reliability of all other sub-systems. This will finally lead to development of a model to evaluate and improve the reliability of the main propulsion system.

1 INTRODUCTION

These main propulsion engine which propels the vessel sat sea have to be highly reliable and safe at all times, whilst sailing at high seas, transiting through canals and manoeuvring in ports. It is imperative that the maintenance regime on board the vessels have to be very well structured, with utmost consideration to safety and reliability of the main propulsion system.

The Reliability of the main propulsion system is interdependent on the reliability of its subsystems, which are listed below.
- Main Engine Lubricating oil system
- Main Engine Jacket Cooling Water system
- Main Engine Fuel Oil system
- Main Engine Scavenge system
- Main Engine Air Start system
- Main Engine Safety System

This paper discusses the methodology adopted to quantify reliability of one of the vital sub-system viz. the lubricating oil system, (Mollenhauer & Tschöke 2010),and development of a model thereof.

On large two strok eengines the lubricating oil sump capacity may be as high as 30,000 litres. The lube oil pump stariner is a wire mesh type located in the sump, from where the pumps draw the Lube oil and delivers it through a fine mesh 25 microns discahrge filter, to the Main Engine Lube Oil plate type highly efficient cooler, the medium of cooling being sea water. There is a Temperature Control Valve as shown in Fig. 1 below, which controls the Lube Oil flow through the cooler as per the required temperature to the engine inlet. Normally the Lube Oil inlet temperature to the engine will be 40 -42 degs C. The function of the lubricating oil is to lubricate the main bearings, cross-head bearings (the connecting rod top end) and the big end bearings (connecting rod bottom end). It also supplies oil to the piston crown and cools the crown to acceptable working temperature in the engine. Failure of the Main

Engine Lubricating oil system could lead to major damages to engine components, resulting in expensive repair and replacement costs, (Gupta 2012).
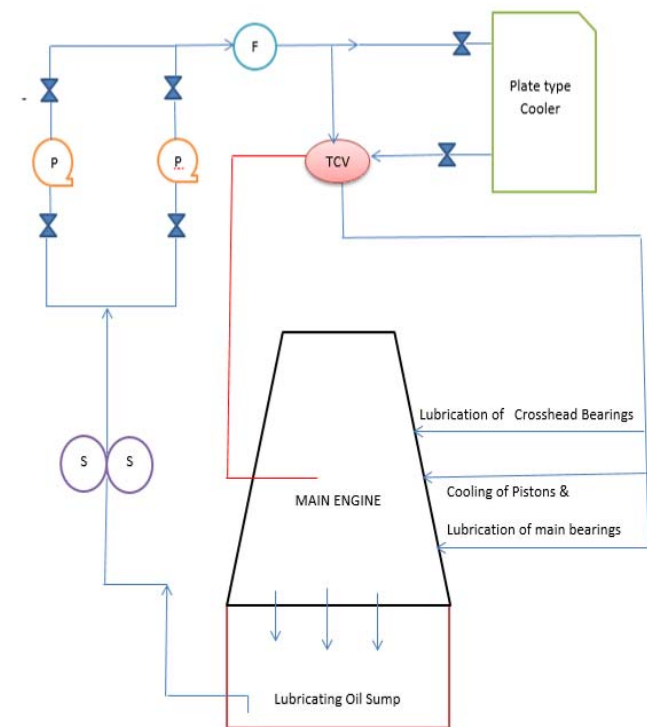
Figure 1. Main Engine Lubricating oil system for a large two stroke engine

Analysis (FTA), for the system will be considered. This will be followed by a critical component identification (CCI) and then a Reliability Block Diagram shall be developed (RBD). A model to evaluate the reliability for each of the system component is developed and the overall reliability of the system can be determined.

We shall now look into the various components of the Main Engine Lubricating oil system, (Cicek & Celik 2013), and determine the reliability of the system. The following steps are followed:
− The Fault Tree Analysis (FTA) for the Main Engine Lube Oil system, (Zhu 2011)
− Develop a Reliability Block Diagram (RBD) for the Main Engine Lube Oil sysstem.(Bhattacharjya & Deleris 2012)
− Look at the individual components in the Main Engine Lube Oil system and draw the state diagram for these components
− Carry out a Markov Analysis for these components ,(Gowid, Dixon & Ghani 2014).
− Carry out a relaibility analysis.
− Consider measures for improving the system reliability.
− Draw comclussions based on the analysis.

2 THE FTA DIAGRAM FOR THE MAIN ENGINE LUBE OIL SYSTEM

There are five (5) main components of the M.E. Lube Oil system, failure of which will lead to the failure of the main propulsion engine.
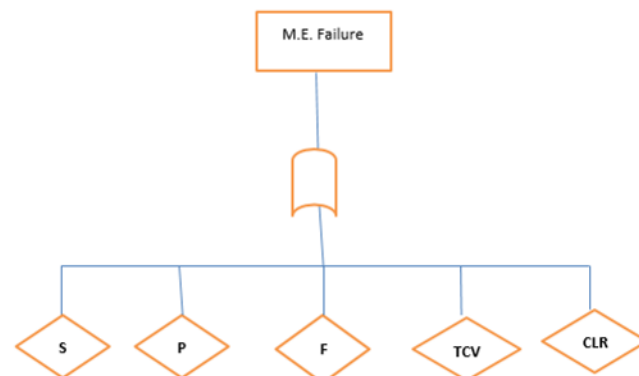

Figure 2. Fault Tree diagram for M.E. Lube Oil system

In the above diagram S represents the Main Engine Lube oil pump strainer, P represents the pumps, F represents discharge filter, and TCV is the temperature control valve and CLR the Main Engine Lube Oil cooler.

The next step in the analysis of evaluating the Reliability of the Main engine Lube Oil sysytem is asshown below:

CCThe following five (5) cases s are analysed:
− Failure of suction strainer S
− Failre of pumps P
− Failure of discahrge filter F
− Failure of Temperature Control Valve TCV
− Failure of cooler CLR

3 RBD FOR THE MAIN ENGINE LUBE OIL SYSTEM

The following points into consideration.
1 Each block represents the maximum number of components in order to simplify the diqgram.
2 The function of each block is easily identified
3 Blocks are mutually independent in that failure of one should not affect the probability of failure of another.(Anantharaman 2013; Xu 2008).
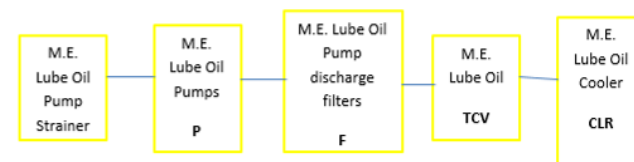

Figure 3. Detailed RBD for M.E. Lube Oil system, with all system components

4 STATE DIAGRAM FOR THE MAIN ENGINE LUBE OIL STRAINER S

The first component suction strainer S is a basket type strainer, located before the lubricating oil pumps, (Khonsari & Booser 2008).This is a duplex type of filter with a change over cock for isolation of filters. One of the filters is in use, the second one being a standby. Clogging of the strainer can result in pump's inability to draw suction from the sump, which may sound a low pressure alarm. This provides time for changing over to the standby strainer. Failure of this standby will result in pump failure, finally resulting in an engine failure. These filters will be identical as shown in Fig. 4 below. The state diagram for the filters is shown in Fig. 5 below. The reliability function is an exponential function of time t and the failure rate λ expressed as number of failures per running hours.

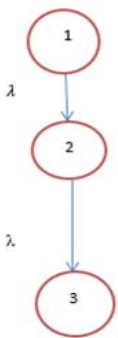Figure 4. Lube oil suction strainers for the Main Engine Lube oil system

Figure 5. Markov Model analysis for the M.E. Lube oil Strainer S

Table 1

State of Lube oil strainer S	Strainer 1	Strainer 2
1	Clean	Clean
2	Clooged	Clean
3	Clogged (Failed)	Clogged(Failed)

From the table 1 above we see that there are 3 states. In this case the two M.E. Lube Oil Pump Strainers are identical standby units, on of which is on line and the other standby.The reliability of the two identical systems isderived as,

$$R_s(t) = e^{-\lambda t} \sum_{i=0}^{1} \frac{(\lambda t)^i}{i!}.$$

In this case $R_s(t) = e^{-\lambda t}(1 + \lambda t)$ and MTTF (Mean time to failure) = $2/\lambda$.

5 RELIABILITY OF THE MAIN ENGINE LUBE OIL SYSTEM

The stae diagrams for all other components of the system are analysed on the same lines, as done for the suction strainer S. Markov analysis(Smith 2011; Troyer 2006), carried out to determine the reliability of the system components . Finally the relaiility of th Lubricating oil system is determined.

$$R_{L.O.}(t) = R_s(t) R_p(t) R_F(t) R_{TCV}(t) R_{CLR}(t),$$

where $R_p(t)$ is the reliability of the Pumps

$R_F(t)$ is the relaibility of the Filter

$R_{TCV}(t)$ is the reliability of the temperature control valve

$R_{CLR}(t)$. is the reliability of the cooler.

6 IMPROVING RELIABILITY

Reliability of the system can be improved by improving the componnet reliability as seen in the above equation. For instance in the case of the Strianer S shown in Section 5 above, physical introduction of an additional filter will increase the releiability.This cost for improvement of reliability need to be assessed and the cost benefit for the incremental reliability to be determined.If the original value of Reliability R_O at cost x is improved to Reliability R_I at cost y, then the incremntal reliability for the differential cost $\frac{R_I - R_O}{y - x}$ should be compared with the base relaibility to cost ratio which in this case is $\frac{R_O}{x}$. For cost benefit $\frac{R_I - R_O}{y - x} > \frac{R_O}{x}$.

This could be a feasible proposition for some components, bit not for all components. Similar study needs to be done for all other components and a cost beneficial CBM model could be developed.

Fig. 6 below shows the Reliability for two (2) identical suction strainers s and Fig. 7 shows the expected improved Reliability, when an additional suction filter is utilised. On similar lines means for improving Reliability for other components could be considered. Fig. 8 shows the improvement in reliability when a redundant filter is used and to Fig. 11 shows the reliability improvement when an

additional control valve is installed after the lubricating oil cooler.No additional redundancies were provided for the pumps and the cooler. This was obtained bassed on application of Markov's principle. Thus the overall Reliability for the Main Engine Lube oil system could be evaluated, and improvement in the reliability is shown, as seen in Fig. 12.
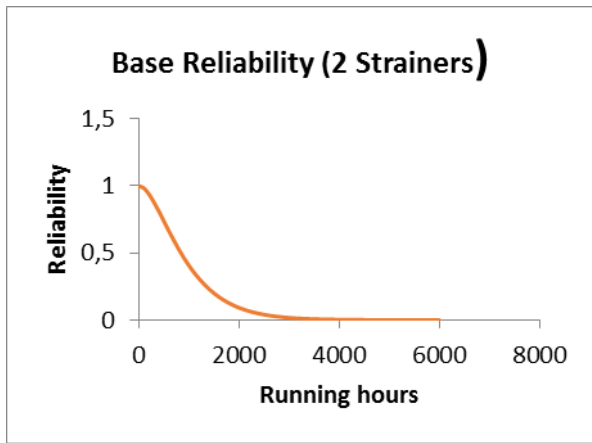

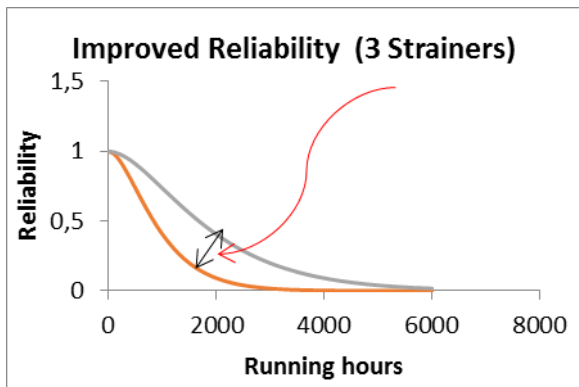Figure 6. Base Reliability vs running hours for two (2) Strainers

Figure 7. Improved Reliability vrunning hours for three (3) Strainers
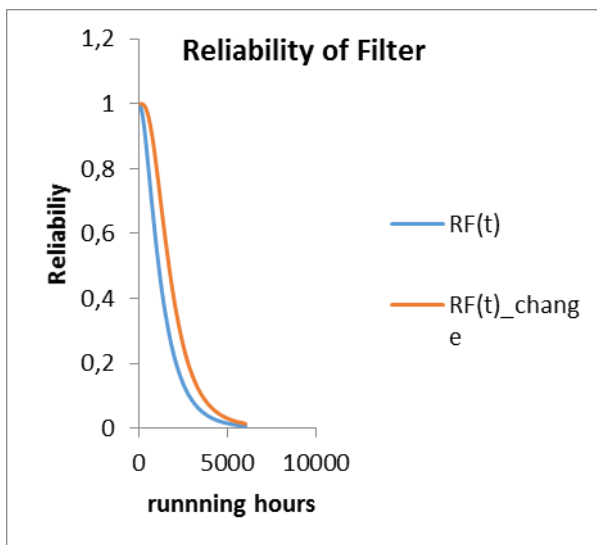

Figure 8. Change in reliability oaddition of Lube oil filter
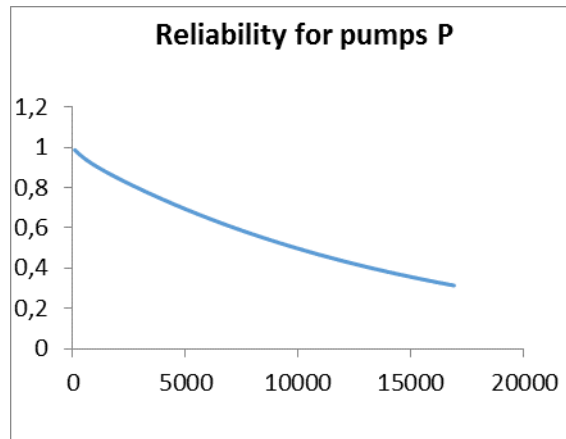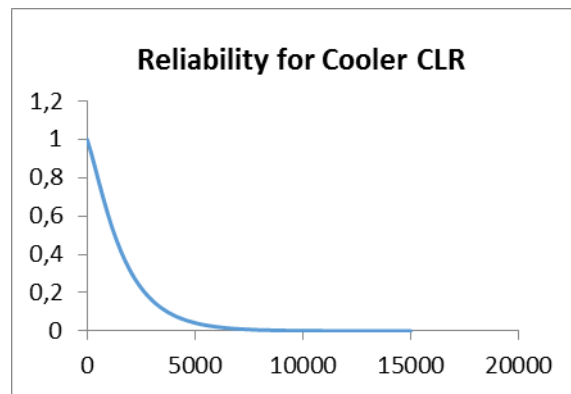

Figure 9. Reliability for Lube oil pumps
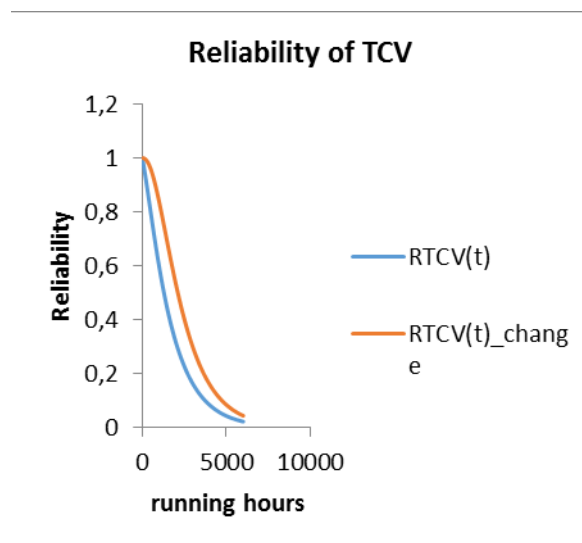

Figure 10. Reliability for Lube Oil Cooler

Figure 11. Change in reliability by addition of Temp Cont Vlave
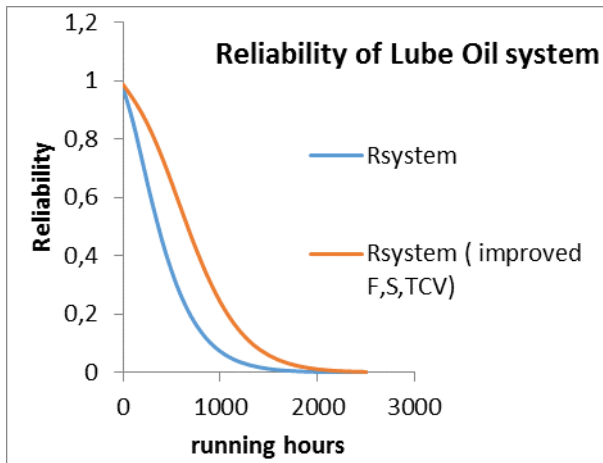
Figure 12. Improved Reliablity for the Lube oil sysytem

7 CONCLUSION

In this paper the Main Engine lubricating oil system, which is a very vital part of the Main propulsion system was analyzed Failure of the Main Engine lubricating system may result in serious damage to the engine components and failure of the Main Engine. A step by step approach for evaluating the reliability of the Main engine lube oil system was presented. Also it was shown that use of additional components in the system, could provide improvement in the component reliability and contribute to overall reliability of the Main Engine lubricating oil system. Similar process could be looked at to evaluate the reliability of other sub systems of the main propulsion engine. Next steps will involve a development of a reliability centered condition based maintenance model for the main propulsion system and determine the cost of improved reliability. Having done that a maintenance plan could be devised leading to a final development of a cost beneficial CBM model for the ship's propulsion system.

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