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ScienceDirect

Procedia CIRP 59 (2017) 122 – 132

www.elsevier.com/locate/procedia

The 5th International Conference on Through-life Engineering Services (TESConf 2016)

Towards Design of Prognostics and Health Management Solutions for Maritime Assets

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Abstract

With increase in competition between OEMs of maritime assets and operators alike, the need to maximize the productivity of an equipment and increase operational efficiency and reliability is increasingly stringent and challenging. Also, with the adoption of availability contracts, maritime OEMs are becoming directly interested in understanding the health of their assets in order to maximize profits and to minimize the risk of a system's failure. The key to address these challenges and needs is performance optimization. For this to be possible it is important to understand that system failure can induce downtime which will increase the total cost of ownership, therefore it is important by all means to minimize unscheduled maintenance. If the state of health or condition of a system, subsystem or component is known, condition-based maintenance can be carried out and system design optimization can be achieved thereby reducing total cost of ownership. With the increasing competition with regards to the maritime industry, it is important that the state of health of a component/sub-system/system/asset is known before a vessel embarks on a mission. Any breakdown or malfunction in any part of any system or subsystem on board vessel during the operation offshore will lead to large economic losses and sometimes cause accidents. For example, damages to the fuel oil system of vessel's main engine can result in huge downtime as a result of the vessel not being in operation. This paper presents a prognostic and health management (PHM) development process applied on a fuel oil system powering diesel engines typically used in various cruise and fishing vessels, dredgers, pipe laying vessels and large oil tankers. This process will hopefully enable future PHM solutions for maritime assets to be designed in a more formal and systematic way.

Peer-review under responsibility of the scientific committee of the The 5th International Conference on Through-life Engineering Services (TESConf 2016)

Keywords: PHM; maintenance; maritime; vessels, FDI

1. Introduction

Regardless of their application, modern ships and vessels are becoming highly automated assets and are increasingly dependent on complex systems to deliver their main functions. The interaction of such complex systems brings an entire new set of challenges for the designers, operators and maintainers of such vessels. These challenges are becoming even more demanding when degradation of these assets occurs in service.

Three different design approaches are typically used to deal with degradation of components/sub-systems/systems over time in order to guarantee operational reliability: re-design, built-in redundancy, prognostics and health management. When a given design is not meeting the safety and reliability requirements, re-design of the asset/sub-systems/component is the selection of choice. Traditionally, to ensure safety and reliability, the majority of the critical systems on a vessel/ship were over-engineered taking advantage of built-in redundancy. In case of a fault or a severe functional failure, the redundancy features were activated (manually or automatically) and the vessel/ship was able to complete the mission/journey. This design philosophy was also adopted due to the lack of communication with shore. Traditionally, once

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doi:10.1016/j.procir.2016.10.128

ships had left the port/docking facilities they were completely isolated from communication with shore. The introduction of radio on ships changed the dynamic of technical support offered to the crew (in case of a ship failure), but now the industry is experiencing a radically step change in this field through the introduction of telecommunications that allow digital signals to be passed in both directions (to and from the ship) at significant rates independent of ship's location worldwide. According to a DNV-GL study [1], currently, the maritime industry contributes to the growth in deployment of VSAT (Very Small Aperture Terminals) equipment on board ships. According to the same report, the number of active maritime VSAT installations quadrupled from 2008 (6,001) to 2014 (21,922), and it is predicted that the number will exceed 40,000 by 2018. It is envisaged that by 2020, most classed vessels will be broadband capable. Also, the VSAT network capacity is increasing owing to the introduction of new high throughput satellite (HTS) systems, with two to ten times higher throughput than classical satellites. The overall VSAT network capacity over maritime regions has the potential of a tenfold growth to some 200 Gbps in 2025, implying a massive increase in data transfer rates and decreased cost per bit for the connected vessels. In this context, designing new ships might take a different approach through the introduction of prognostics and health management capabilities to be able to tackle fault detection and fault isolation but also to be able to make predictions by estimating the remaining useful life and end of life for a particular component/sub-system/system of the ship. The adoption of PHM capability on ships/vessels will support of change in the way these assets are maintained and operated with the overall goal of improving asset availability. If the state of health or condition of a system, sub-system or component is known, condition-based maintenance can be carried out and system design optimization can be achieved thereby reducing the total cost of ownership. A study carried out by Wartsila highlighted a reduction between 5% and 15% when comparing the yearly costs of conventional maintenance to the condition based maintenance costs of a dual fuel engine of Liquefied Natural Gas (LNG) vessels [2]. The maritime industry sector is currently defining information based processes to prevent the unexpected failures. The main objective of making prediction of the unexpected failures is to increase the overall asset availability / or even decrease the operating expenditure. The information based process requires data to be fully functional therefore monitoring must be comprehensive, continual and should be targeting the right parameters of the system at the right time by the right people. Only in this way, data can be accurately transformed into meaningful information capable of supporting informed operational decisions of the ship/vessel by increasing business performance. The structure of the paper will be as follows: Section 2 next articulates the problem statement. A brief description of the target system will be presented in Section 3. Section 4 presents the methodology adopted to identify and optimize the number of sensors capable of detecting and isolating a set of functional failures affecting the target system. Section 5 will gather the concluding remarks.

2. Problem statement

Stringent safety and reliability of safety critical systems in maritime industry sector necessitate the need for fault detection and fault isolation in order to support system reconfiguration. With increasing competition in maritime industry, it is important that the state of a critical component is known before a ship/vessel embarks on a new mission/journey. Any breakdown or malfunction in any system during operation offshore will lead to a large economic losses and sometimes cause accidents. A report published in 2015 by the Swedish club shows that within 2012-2014 the following findings, as shown in Table 1, were documented [3].

Table 1. Highlights of the Swedish club report [3]

Machinery claims	Total costs ($)
487	187.6M
Main engine & Fuel Oil System Claims	Average claim per vessel
46% of Total machinery claims	545000
Most expensive main engine claim	Average cost per claim
Bearing failure	1.6M

Since the above mentioned study was a follow up of a similar study gathering data related to failures occurred in vessels insured between 2005-2011, it is worth highlighting the findings of the study related to the top 3 causes of damage by numbers

Table 2. Top 3 causes of damage by number, 2005 - 2011 [4]

Cause	**Number**	**Average costs ($)**
Incorrect maintenance and/or repairs	33	741,354
Fuel management	27	318,000
Lubrication failure	23	1,194,000

Table 3. Top 3 causes of damage by number, 2012 - 2014 [3]

Cause	**Number**	**Average costs ($)**
Incorrect maintenance and/or repairs	17	849,000
Lubrication failure	13	926,000
Fuel management	8	324,000

The data presented in tables 2 and 3 demonstrates that maintenance and repairs arena for maritime requires significant improvements as over the last decade it accounted for nearly 50% of the total causes of damage on ships [3][4]. A large percentage of these claims are related to inefficient fault detection and fault isolation procedures. A common cause of these practices is related to the fact that, traditionally,