Maintenance Workload Optimization during the In-Service Phase of Naval Ships

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aintenance strategies of naval ships and equipment onboard play an important role in determining their effective life span and overall life-cycle cost. While several approaches could be considered for maintenance optimization, this paper specifically focuses on reviewing the maintenance strategies and maintenance plans for maintenance workload optimization from a pragmatic perspective, during the in-service phase of naval ships. The review takes into consideration the various types of maintenance strategies and approaches that would enable the delivery of adequate maintenance required to ensure the reliability of the asset through its life cycle. The paper also touches upon the use of maintenance data analysis to review the recommended preventive maintenance schedule of the assets and the records of maintenance conducted, to identify options for reducing the maintenance workload. The opportunities to optimize the maintenance workload through efficient planning of all aspects of logistics support, including the relevance of improving the maturity of the Integrated Logistics Support (ILS) elements have also been discussed. Optimization of the maintenance workload shall not only help in avoiding maintenance delays but also reduce the maintenance costs and thereby the overall life-cycle cost of the asset.

Keywords: Naval Ships, Maintenance Strategies, Workload Optimization, ILS, In-Service Logistics Support, Life Cycle Cost

1. Introduction

The navies of the world countries play a significant role in protecting their national interests and in preserving global security. The extensive operational deployments of the naval platforms necessitated due to the current geopolitical and socioeconomic conditions of the world have greatly constrained the authorities in the timely planning and execution of the maintenance of the vessels and the systems onboard, in accordance with the vessel maintenance plans or upkeep cycle. As the naval platforms are expected to operate optimally over a life cycle spanning 20 to 30 years, it is necessary to have a logistics support mechanism that would ensure efficient maintenance and technological upgrades during various stages of its life cycle. The requirement to ensure the enhanced operational availability of the vessels to meet the challenging mission commitments, and to balance it with the optimal use of non-fleet time and available logistics support resources to undertake the maintenance, demands the identification and implementation of maintenance strategies that would help in optimising the maintenance workloads without compromising on the safety and reliability of the asset.

2. Maintenance Concepts

Warships are normally considered as a system of systems containing several integrated systems that are linked structurally, mechanically, electrically, hydraulically, pneumatically, and electronically (Ford, McMahon & Rowley, 2013). Considering the fact that the life span of a naval ship is more than two decades, a typical naval fleet consists of a combination of modern-day warships which are equipped with very complex and state-of-the-art systems, as well as legacy warships which are fitted with conventional systems. The wide range of technology used in these warships not only increases the overall logistic support costs of the systems onboard but also makes the process of their maintenance quite challenging. Typically, the in-service phase costs constitute up to 70% of the total life-cycle cost (Ford, McMahon & Rowley, 2015) of the ship which is quite substantial considering the current financial constraints experienced by the world navies. However, as the mission readiness and longevity of a naval fleet depends on the quality of its maintenance (Tambe, Moez, Bayoumi, Cao, McCaslin, & Edwards, 2015) which predominantly happens during the in-service phase of the ship's life cycle, the requirement is to identify the maintenance strategies and approaches to optimise the maintenance workload while delivering the required availability of the ships.

While the maintenance strategies have a direct impact on the safety, capability, reliability, and availability of the ships, an ideal maintenance strategy maintains design intent, achieves availability targets, and reduces the overall life-cycle costs (Tomlinson, 2016). Most of the navies in today's world follow a maintenance strategy based on Reliability Centred Maintenance (RCM). RCM is a mix of reactive, time or interval-based, condition-based, and proactive maintenance practices which are integrated to take advantage of their respective strengths to maximise asset reliability while minimising the life-cycle costs (Devaraj Naik & Soni, 2007).

Reactive maintenance, which is also known as breakdown maintenance or run-to-fail maintenance, is repairs done following the detection of an anomaly or failure, to restore the equipment to the normal operational condition (Tomlinson, 2016). Proactive maintenance is a combination of preventive and predictive maintenance for stabilising the reliability of the equipment (Devaraj Naik & Soni, 2007).

Time or interval-based preventive maintenance is a planned maintenance activity that is designed to improve equipment life and eliminate any unplanned maintenance activities (Devaraj Naik & Soni, 2007). Condition-based maintenance involves continuous monitoring of the equipment and collection of its condition indicators to carry out predictive analytics to identify the need for maintenance (Tambe et al., 2015).

The maintenance is generally classified into three levels – organisational level, intermediate level, and depot level (LII, 2013). The organisational level maintenance typically consists of pre-planned preventive and corrective maintenance, servicing, and repair by replacement, capable of being undertaken by onboard operators or base maintainers, utilising ship-held spares, tools, test equipment, and facilities. The intermediate-level maintenance typically consists of pre-planned preventive and corrective maintenance, servicing, and minor overhauls, undertaken by the base resident maintainer or specialist expertise, utilising base-held spares, tools, test equipment, and facilities. The depot-level maintenance consists of major equipment overhauls, structural jobs, and refit works including upgrades and renewals, undertaken by specialist skilled personnel, at the shipyard workshops, or at the Original Equipment Manufacturers (OEM) facilities.

The organisational level maintenance could be carried out while the ship is at sea or at the harbour, whereas the intermediate and depot level maintenance activities of the ships and equipment onboard are typically carried out during the maintenance availability periods, while the ship may be at harbour or at dry-docks.

One of the key factors for effective management of maintenance is the availability of an efficient Maintenance Management System (MMS). An ideal MMS will be based on a Computerised Maintenance Management System (CMMS) which shall provide all the necessary data and documentation required for the planning, execution, recording, analysing, and reporting of the maintenance activities. CMMS data and documentation shall typically include the Preventive Maintenance Schedule (PMS), Job Information Cards (JIC), spare parts information, technical manuals of the equipment, as-fitted drawings, etc., which are normally produced as a part of the ILS.

3. Optimisation of Maintenance Workload

The maintenance strategy and plans for a naval ship are normally defined during its acquisition phase of the life cycle as a part of the ILS engineering. The data and documentation required for facilitating the maintenance of the ship and equipment onboard are developed through a combination of various ILS engineering activities such as the maintenance task analysis, sparing analysis, etc., based on the technical information provided by the designer, shipbuilder and the OEM. Various factors such as the criticality of the equipment, redundancy available, cost associated with the different types of maintenance, Mean Time Between Failures (MTBF) of the components, shelf life and lead time for spares, etc. are given due consideration for determining the maintenance strategy to be adopted for each equipment. As these factors are likely to change over a period of several years during the ship's life cycle, it would be appropriate during the in-service phase to review the maintenance strategies which were earlier defined based on the design factors made available at the acquisition phase, and identify the requirements to update or modify the same.

Further, the practical information and knowledge of the equipment maintenance gathered over the years would provide insights into the need for a change in the maintenance strategy and the opportunities for maintenance workload optimisation. For example, a rigorous preventive maintenance regime set for equipment based on the recommendation provided by the OEM during acquisition, could be reviewed in terms of the tasks to be carried out and the periodicity of the maintenance routines. This would not only provide an opportunity to reduce the maintenance workload but also help in reducing the cost of the maintenance through corresponding reduction in the utilisation of resources, including the spares. The levels of maintenance prescribed in the maintenance plans could also be reviewed from time to time to identify the possibility of transferring the maintenance between organisational, intermediate and depot levels for the optimisation of the maintenance workload, with due consideration for the cost, schedule and other associated factors.

Naval vessels are data-rich environments that contain and create large volumes of electronic and paper records (Ford et al., 2013). A major part of this data is associated with the MMS for planning, execution, recording, analysing and reporting of the maintenance. Opportunities for optimisation of maintenance workload could be identified through careful analysis of the historic maintenance data pertaining to the conduct of various maintenance activities. Important information such as the impact of timely execution of the preventive maintenance or the failure to conduct the periodical preventive maintenance could be derived from the maintenance history which could be used to review and update the PMS. For example, the frequency of certain periodic preventive maintenance activities could be reduced as a result of the analysis, with due consideration for its impact on the safety and reliability of the equipment, thereby leading to a reduction in the overall maintenance workload and resource requirements.

Maintenance workload could also be optimised by converting a mandatory preventive maintenance activity in the PMS to an activity which shall be based on predictive maintenance. Predictive maintenance not only optimises the interval of execution of the maintenance activity but also extends the period of use of the parts thereby reducing the requirement of the spare parts and its associated costs (Simion, Purcărea, Cotorcea, & Nicolae, 2020).

The historical information about the corrective or break down maintenance carried out to rectify the failures of ship systems and equipment onboard, provides a vital lead towards reviewing and revising the maintenance plans and even the design of the respective system or equipment. The introduction of adequate preventive maintenance activities or implementation of design modifications could be undertaken to reduce the emergent workload due to such failures.

The workload of maintenance to be undertaken during the maintenance availability periods could be optimised through meticulous planning. The ability to anticipate and plan the emergent works coupled with advanced identification and provision of the required resources for the successful execution of the work packages will not only help in reducing the maintenance management workload but also to avoid any delays associated with the maintenance.

The quality of the data associated with the maintenance has a direct impact on the initiatives towards the optimisation of the maintenance workload and the overall life-cycle cost of the equipment. The management of the configuration information of the ship systems and equipment onboard is an area which is often overlooked during the in-service phase of the ship's life cycle. Non-availability of updated configuration information may lead to inefficient planning of the maintenance, which may in turn result in maintenance delays and maintenance cost escalations. Therefore, it is advisable to maintain the configuration information of the ship systems and equipment onboard updated in the CMMS at all times, especially during the in-service phase of the ship's life cycle. Maintaining updated troubleshooting and lessons learned information for corrective maintenance of various equipment and systems would help in reducing the man-hours required for the resolution of similar defects in the future.

Most of the suppliers of the equipment and spares normally furnish masked part numbers along with the ILS data, instead of the part number provided by the OEM. As a result of the non-availability of the part number provided by the OEM, the maintenance team is forced to spend additional man-hours and costs, for the sourcing of the equipment and its spares in the future. Updating the bill of materials in the CMMS with the OEM part number of the equipment and its spares during the in-service period is another option to optimise the workload and costs associated with the maintenance.

A comprehensive analysis of the historic data of the maintenance would reveal that a considerable amount of maintenance manpower is wasted due to the non-availability of the required spares, skill, or facility for undertaking emergent corrective maintenance, which directly affects the operational availability of the ship. This emphasises the necessity to periodically review the gaps in the logistics support plan for the asset and initiate the ILS actions necessary to address these gaps, in order to achieve the optimisation of maintenance workload and associated cost.

The extended life span of a warship induces several technological challenges which have a direct impact on maintenance. The rapid changes in the technology, especially in the case of electronic equipment, introduce obsolescence issues associated with the maintenance of the existing equipment during the in-service phase. Obsolescence not only affects the availability of the required spares for the maintenance of the equipment but also leads to complex technical shortcomings with respect to the integration of the equipment with the interconnected systems. Therefore, it is advisable to initiate timely actions for identification and resolution of obsolescence of equipment onboard in a proactive manner in order to reduce the probability of major emergent manpower-intensive maintenance jobs as well as the escalations in the life-cycle costs of the ship.

4. Conclusions

The successful optimisation of maintenance workload during the in-service phase of a naval ship depends on the efficient integration of all associated functions and stakeholder actions. It is recommended that a review of maintenance strategy and plans of the ships be conducted at specific periods during its life cycle, to benchmark it with the prevalent standards and to identify the opportunities for optimisation of maintenance workload. The approaches for maintenance workload optimisation discussed in this paper are from a pragmatic perspective and any reduction or revision in the maintenance strategy and plans should be thoroughly reviewed from the safety and reliability perspective before its implementation. The options thus identified for optimisation of the maintenance workload shall help to address the competing demands of increased fleet time for operations and limited availability of non-fleet time for the conduct of maintenance or upkeep of the vessels and the systems onboard. The maintenance workload optimisation shall also help in avoiding maintenance delays, reducing the maintenance costs, and thereby the overall life-cycle cost of the asset.

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