Navy Ship Dynamic Maintenance

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ABSTRACT

A maintenance system complemented with condition monitoring is suggest being implemented in Navy Ships to allow its patrol on the large maritime territory of Portugal with high performance and operationality. To that an advanced maintenance system is required oriented towards Condition Monitoring. That must be done while maximizing system performance, as well as improved high level of ship availability and minimal oil consumption in the form e.g. lubricants or refrigerant gases but also marine gasoil reducing the environment impact. To meet these objectives, we propose the development of a Dynamic Maintenance Management System (DMMS) based on dynamic prioritization process for technical interventions. That is where Failure Modes, Effects and Criticality Analysis (FMECA) comes in - a structured risk analysis framework to mitigate the propensity of failures occurring with consequences on ship systems and persons. With FMECA, maintenance priorities can be changed somewhat dynamically due to components and failure modes that are most critical based on actual performance.

KEYWORDS

Maintenance; Dynamic; Ship; Risk; FMECA; Prioritize.

1 Introduction

Ship maintenance plays a critical role in ensuring the safety, reliability, and efficiency of maritime operations. It encompasses a wide range of activities, from routine inspections and scheduled repairs to more complex interventions. Preventive maintenance is key to avoiding equipment failures and extending the operational lifespan of onboard systems, while corrective maintenance addresses unexpected issues that arise during operation.

By leveraging sensors and data analysis it is possible to integrate the collected data in databases that support maintenance decision-making. This approach enables the prediction of potential failures and the scheduling of maintenance tasks before breakdowns occur, further optimizing ship performance and reducing unplanned downtime and reducing fluids and spare parts consumptions.

In the present research, a concept of FMECA-CC that is proposed for ship equipment risk analysis and maintenance defining procedure, in a dynamic maintenance concept.

2 FMECA in Maintenance Management

Frequently maintenance can be carried out on board with the ship sailing normally, but many maintenance actions are carried out on harbors. This means that maintenance opportunities can be irregular so the economic dependency between spare parts and equipment's, and its state must be determined to determine the best time to procced to an intervention (Young et al, 2023).

Maintenance is often performed onboard while the ship is sailing normally, but many critical maintenance activities are conducted in a harbor. This results in irregular maintenance opportunities, making it essential to assess the economic relationship between spare parts, equipment, and their condition. Determining the optimal timing for interventions depends on this analysis, ensuring that maintenance actions are both cost-effective and timely.

The FMECA may offer a structured approach to evaluating and managing the ongoing performance of systems in operation. Instead of relying exclusively on scheduled or reactive maintenance, FMECA allows organizations to identify areas of greatest risk and allocate resources more efficiently, prioritizing maintenance where it is needed most. (STAMATIS, 2003)

The original FMECA is calculated using equation nr 1. Where the O it's the probability of occurrence, S the severity and D de detection facility (STAMATIS, 2019).

$$RPN_{DM}=O*S*D \tag{1}$$

3 Methodology in Ship Dynamic Maintenance

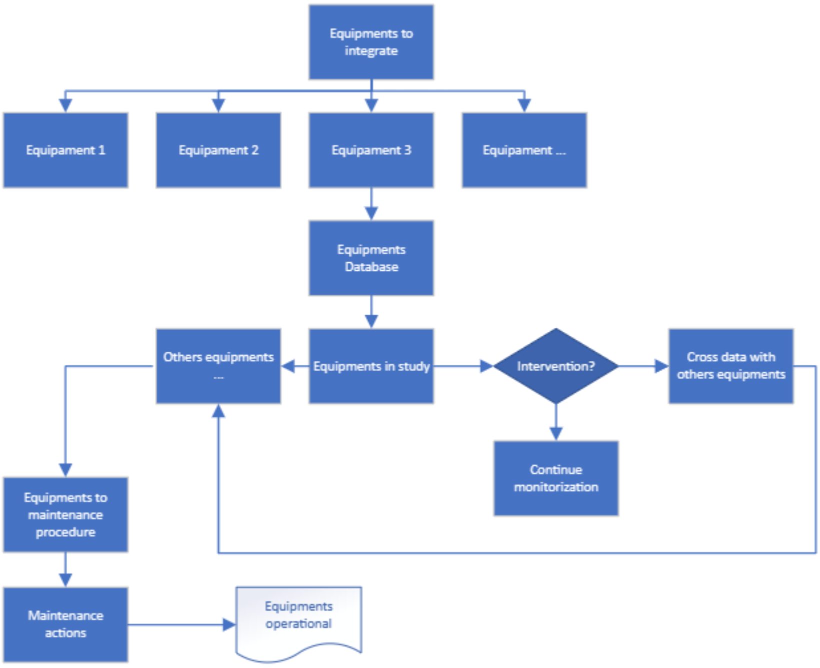

Figure 1 - Dynamic Maintenance Methodology

In the methodology, Figure 1, FMECA-CC happened when the procedure reaches the Equipment Study Box.

In FMECA-CC, the original concept it is complemented with the equipment control condition (CC). Besides the original parameters it was considered the equipment's condition control, so it was integrated in the original equation four condition control parameters (control condition for vibration (CCV)(Vibration in Root mean Square (RMS) values); condition control for elected parameters (oil pressure and temperature); control condition for thermography (CCT) and control condition for text (CCTex) from SRTD is considered for respective equipment).

To calculate FMECA-CC it was used equation nr 2, applying the logarithmical function with neper base for reduce the dimension of the result values:

$$\text{FMECA-CC} = \text{LN}(O*Sm*D*(CCV*CCT*CCP*CCTex) \qquad (2)$$

4 Case study – FMECA-CC in ships equipments

For the study it used a low-pressure air compressor from a ship, the development of the FMECA was based in the maintenance book.

Table 1. Maintenance activity, aspect, impact and how to detect.- extract from Failure Mode Effect Analysis

Nr	Low Pressure Air Compressor/Maintenance Activity	Aspect	Impact	How detect
1	Clean the air filter. (Perform every 1000 hours of operation)	Filter with impurities	Entry of impurities into the internal compressor.	Clogged filter, low compression pressure
2	Clean the air filter. (Perform every 1000 hours of operation)	Filter with impurities/Air compressor system with impurities	Compressor damage	Internal inspection of the compressor if it is impossible to detect damage by visual inspection or non-destructive testing.
3	Clean the air filter. (Perform every 1000 hours of operation)	Filter with impurities	Compressor performance loss	Low pressure compression
4	Clean the air filter. (Perform every 1000 hours of operation)	Filter collapse	Compressor does not compress.	Method of observing pressure gauges, alarms on consoles

Table 2. FMECA_CC Categorization

Linguistic term (Risk level)	Abbreviation	Description	Classification	Procedure
Not critical	Nc	Risk is totally controlled	[0, 5[	Continue with the monitoring procedure
Semicritical	Sc	There is a little preoccupation about the equipment and system state	[5, 8[	Check for eventual enhance of the monitoring system
Critical	C	There are some preoccupations about the critic equipment/system situation	[8, 10[	Reinforce condition control monitoring
Very critical	Vc	The equipment/system are in a very critical situation	[10, 12]	Study opportunity for eventual maintenance, and check for needed spare parts

Table 3. Results for FMECA-CC – considering the analysis of table 1

Nr	FMECA	FMECA-CC	Action
1	625	6	Enhance of the monitoring system
2	375	8	Enhance of the monitoring system
3	156	5	Reinforce condition control monitoring
4	156	3	Continue monitoring

5 Conclusions

The research introduces an enhanced approach to maintenance management that enables more dynamic and informed decision-making regarding equipment interventions.

FMECA with Condition Control (FMECA-CC) has proven to be more sensitive compared to traditional FMECA, offering a more detailed method for identifying critical failures and prioritizing maintenance tasks. This heightened sensitivity allows for proactive risk mitigation, minimizing the likelihood of unexpected failures and enhancing overall operational efficiency.

For future research, exploring the integration of artificial intelligence (AI) in online risk analysis and dynamic maintenance systems offers a new direction in Navy maintenance. AI-driven techniques could further enhance the effectiveness of FMECA-CC, enabling real-time adjustments to maintenance priorities and improving the overall adaptability and performance of naval maintenance management systems.

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REFERENCES

Apeiranthitis, S., Zacharia, P., Chatzopoulos, A. & Papoutsidakis, M. (2023). Predictive Maintenance of Machinery with Rotating Parts Using Convolutional Neu-ral Networks. Journal of Electronics, MDPI, Vol.13, 460, pp. 1-17.

Catic, D. & Glisovic, J.: Failure Mode, effects, and Criticality Analysis of Mechanical Systems´ Elements. Journal of Mobility & Vehicle Mechanics, Vol. 45, nr 3, pp. 25-39 (2019).

Chen, G., & Wu, Q.: Real-time Condition-based Dynamic Maintenance for Vessel Propulsion Systems Using Predictive Analytics. Ship Science and Technology, 45(4), pp. 112-120 (2023).

Degiuli, D., Farkas, A., Martic, A. & Grlj, C.: Optimization of maintenance Schedule for Containerships Sailing in the Adriatic Sea. Journal of Maritime Science and Engineering, Vol. 11, 201, pp. 1-19. (2023).

Jin, H., Qi, L., Dai, J.&Luo, Y. (2009). Handbook of Research on Grid Technologies and Utility Computing: Concepts for Managing Large-Scale Applications. InfScipedia, IGI Global.

Kanj, H., Fouad, W. & Kanj, S. (2022). A Novel Dynamic Approach for Risk Analysis and Simulation Using Multi-Agents Model. Journal of Applied Sciences, MDPI, Vol. 22, 5062, pp.1-33.

Lampreia, S., Vairinhos, V., Lobo, V. & Morgado, T. (2023). Adapted FMECA for Supporting Maintenance Actions the Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM), 26, pp. 208-216.

Li, J., & Zhang, M.: Dynamic Maintenance Decision Support System for Vessel Electrical Systems Based on Expert Systems. Journal of Marine Science and Application, 22(2), pp. 189-197 (2023).

Liu, Y., & Xu, W.: Research on Dynamic Maintenance Optimization of Vessel Fuel Systems Based on Big Data Analytics. Journal of Marine Engineering and Technology, 22(4), pp. 321-330 (2023).

Mehdi, R., Baldauf, M. & Deeb, H.: A Dynamic risk assessment method to address safety of navigation concerns around offshore renewable energy installations. Journal of Engineering for the Maritime Environment, Vol.234 (1), pp.231-244 (2019).

Stamatis, D.: Risk Management Using Failure Mode and Effect Analysis (FMEA). 2nd ed., Milwaukee, Wisconsin: American Society for Quality Press (2019).

Wang, X., & Chen, Y.: Development of a Dynamic Maintenance Framework for Vessel Machinery Systems Based on Deep Learning. Marine Engineering and Technology, 42(1), pp. 34-41(2023).

Young, R., Vatn, J. & Utne, I.: Dynamic maintenance planning for autonomous marine systems (AMS) and operations. Journal of Ocean Engineering, Elsevier, vol. 278, pp. 1-19 (2023).

Zhang, X., & Wang, H.: Dynamic Maintenance Management of Vessel Cargo Handling Equipment Using Wireless Sensor Networks. Journal of Navigation and Port Research, 47(1), 56-64 (2023).

Zhou, X., & Liu, W.: Integration of Dynamic Maintenance and Reliability Engineering in Vessel Hull Structures. International Journal of Naval Architecture and Ocean Engineering, 15(2), pp. 123-132 (2023).