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COURSE NAME: Sustainable Maritime Operations and Green Ports

Module 11 (Week 11)

Lecturer

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ADVANCED METHODS OF MAINTENANCE OF SHIP SYSTEMS AND EQUIPMENT



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1. Introduction

- **Traditional ship maintenance methods**, which have mainly relied on manual inspections and reactive measures after failures occur, are gradually giving way to advanced technologies that enable a proactive approach to maintenance
- **Advanced methods for the maintenance of ship systems and equipment** encompass a wide range of technologies and approaches, from **schedule-based preventive maintenance** to sophisticated **predictive systems using artificial intelligence (AI) and the Internet of Things (IoT)**



2. Predictive and preventive maintenance techniques

- **Corrective Maintenance (CM)** is a traditional approach which involves repairs that are carried out only after a failure occurs
- It does not require an initial investment in planning or monitoring, but it often results in unexpected downtime, significant financial losses, and disruptions to global logistics networks
- The average downtime per failure can be as long as 14 days, which poses a significant challenge in maintaining schedules within global supply chains

2. Predictive and preventive maintenance techniques

- **Preventive Maintenance (PM)** is based on scheduled servicing or maintenance after a certain number of operating hours, regardless of the actual condition of the equipment
- Although PM reduces unexpected failures and downtime compared to CM, it often leads to unnecessary repairs and over-scheduling of maintenance, resulting in increased costs and extended downtime
- It reduces repair costs, increases asset reliability and longevity, ensures compliance with regulatory standards and contributes to sustainability by improving fuel efficiency and reducing emissions

2. Predictive and preventive maintenance techniques

- **Predictive Maintenance (PdM)** represents a transformative approach that uses real-time data, analytics and machine learning to optimize the maintenance process
- PdM proactively predicts potential equipment degradation or failures based on operational data from the vessel
- This approach significantly reduces unplanned downtime, extends machine life and lowers costs, while improving overall fleet availability and safety
- PdM integrates advanced technological innovations to transform traditional ships into "smart ships"

3. Use of digital tools for maintenance management

- Computerized Maintenance Management Systems (CMMS) are software solutions designed to plan, perform and document vessel maintenance in accordance with the requirements of classification societies and manufacturers
- These systems offer centralized data management, enabling efficient data synchronization between ship and shore, which improves communication and optimizes time
- Key features of CMMS include fault reporting, document management, fleet monitoring, spare parts inventory management and electronic management of job lists

3. Use of digital tools for maintenance management

- The benefits of implementing a CMMS are multiple: it simplifies the planning, documentation and execution of maintenance tasks, ensures compliance with all applicable regulations
- Furthermore, CMMS protects assets and optimizes their management, reducing manual data entry and operating costs

3. Use of digital tools for maintenance management

- The Internet of Things (IoT) is revolutionizing the approach to maritime logistics and vessel monitoring, enabling real-time data collection and improving operational efficiency
- IoT devices, such as sensors, are placed at critical points on a ship (e.g. engines, generators, cooling systems, hull) to continuously monitor metrics such as temperature, vibration, pressure and fuel efficiency
- These sensors enable technical teams to respond quickly to anomalies, providing early detection of potential problems

3. Use of digital tools for maintenance management

- IoT applications include continuous monitoring of fuel consumption, exhaust emissions and energy consumption, enabling optimization and compliance with international environmental standards
- IoT also helps in early detection of hazards such as fires or floods, sending immediate alerts to the crew and emergency response teams on shore
- Despite challenges such as signal attenuation in the complex steel structures of ships, multi-hop wireless networks and advanced protocols enable efficient communication

3. Use of digital tools for maintenance management

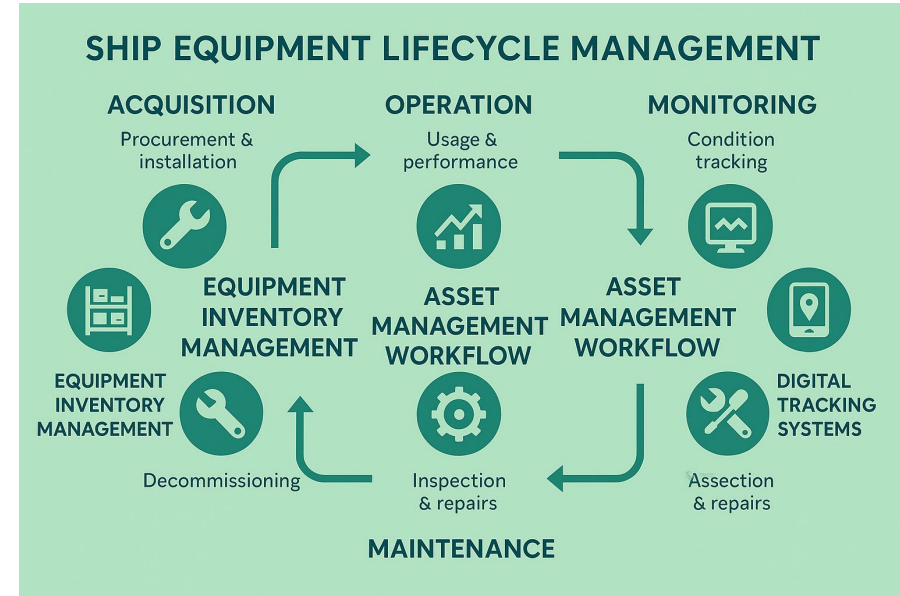
- Digital twins (DT) are virtual replicas of physical assets that enable continuous monitoring, simulation and prediction of the condition of ship systems and components
- This technology enables operators to monitor, analyze and optimize their assets, providing a comprehensive overview of operations and facilitating predictive maintenance
- By using digital twins, maritime companies can optimize maintenance processes, improve decision-making, increase operational efficiency, reduce downtime and extend asset life

3. Use of digital tools for maintenance management

- Big data and analytics are key to optimizing logistics processes and improving overall efficiency in shipping – this involves collecting, processing, and analyzing complex data sets from diverse sources such as sensors, RFID tags, GPS devices, and ERP systems
- In particular, big data analytics can predict equipment failures and maintenance needs, thereby reducing downtime and extending the life of assets
- Technologies such as machine learning and artificial intelligence within the big data framework enable process automation, predictive analysis, and operations optimization

4. Life cycle management of ship equipment

- Effective Life cycle Management (ELM) of ship systems and equipment is essential for the sustainability, safety and economy of maritime operations – this process encompasses all phases, from planning to disposal, considering regulatory requirements
- ELM is usually divided into five phases: planning, procurement, use, maintenance and disposal
- Integrating Reliability and Maintainability Engineering (R&ME) early in the design process is essential to avoid prohibitive maintenance costs throughout the system life cycle



4. Life cycle management of ship equipment

- R&ME treats reliability and maintainability as performance parameters from the outset, directly impacting operating and maintenance costs and total life cycle costs
- This includes reliability prediction, failure physics analysis, failure mode and effects and criticality analysis (FMECA), fault tree analysis (FTA), parts selection and stress analysis
- R&ME focuses on controllable design elements such as system reliability, system architecture (including redundancy) and system maintainability through design for reliability and design for maintainability activities

5. Conclusion

- **The shift from reactive to proactive and predictive maintenance strategies is not only an operational necessity, but a strategic imperative that enables safer, more efficient and more environmentally friendly maritime operations**
- **Digital tools are key to this transformation**
- **Integrating the principles of equipment lifecycle management into maritime operations ensures long-term sustainability**

6. Case Study: Regular maintenance of tugboat engines

- The implementation of advanced maintenance methods on tugboat engines provides a practical example of applying theoretical principles to real-world operating conditions
- A tugboat engine preventive maintenance program begins with establishing a comprehensive maintenance schedule based on manufacturer guidelines and operating conditions
- This program includes regular cleaning and lubrication of engine components, which can result in a reduction in energy consumption and a significant reduction in wear-related failures



6. Case Study: Regular maintenance of tugboat engines

- Key activities include regular checks and replacement of engine oil, filters, checking the condition of the cooling system, and inspecting the drive belt
- The integration of predictive maintenance through the installation of sensors to monitor engine temperature, pressure, and vibration enables early detection of potential problems
- AI algorithms analyze data in real time, identifying patterns that precede engine failures – e.g. unusual temperature fluctuations can signal early stages of cooling system failure, allowing targeted maintenance before the problem escalates into a major failure

6. Case Study: Regular maintenance of tugboat engines

- Implementing a CMMS system allows for centralized tracking of all engine maintenance activities, work order scheduling, and maintenance cost tracking
- The system automatically generates notifications for regular inspections, tracks spare parts consumption, and keeps a record of all engine interventions
- Through historical data analysis, operators can optimize maintenance schedules and identify components that require more frequent attention



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