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Advanced Condition Based Predictive Maintenance of Electric Motors in Autonomous Ships

Project Proposal (MR-PRO-21-011)

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December 20, 2021

Declaration

We hereby declare that the work contained in this report is original; researched and documented by the undersigned students. It has not been used or presented elsewhere in any form for award of any academic qualification or otherwise. Any material obtained from other parties have been duly acknowledged. We have ensured that no violation of copyright or intellectual property rights have been committed.

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Abstract

Maritime shipping is employed to move food, medicines, and far more at the heart of world trade. For growth and development, economical mechanisms of shipping are followed, particularly within the developing world. Machinery and equipment breakdown that occur during marine transportation cause delays, swings in supplies, production, and trigger infinite downstream effects on entire supply chains. In the shipping industry planned and reactive maintenance that is primarily practiced requires halting of vessel operations for a number of days despite the fact that no fatigue or machinery and equipment breakdown is observed. Having seen the importance of motors that are widely utilized in ships auxiliary machinery, the project focuses on creating failure predictions, additionally determining remaining useful life (RUL) for motors aboard ships, albeit also quite fascinating is the role this research plays in the monitoring of equipment on autonomous ships. This is made possible with developments in information and technology. Massive amounts of data is collected and can facilitate condition based monitoring (CBM), conduct analysis on best performance and comprehensively diagnose ship engine room equipment.

Keywords: efficiency, condition monitoring, remaining useful life, autonomous ships, performance.

1 Introduction

1.1 Background

As the world's industries push the boundaries of optimization and efficiency, the exponential increase in computational ability and technology The automation of "higher-level" tasks that require human intellect is now possible. This headway brings unmanned autonomous vessels within the Maritime Industry closer to mass production. The practicality of autonomous vessels can only be achieved with constant awareness of the performance and operating state of machinery in the engine room (CBM). Observations of industry practices display that industry experience in reliability is heavily based on trial-and-error test procedures.

Most of the reliability research in industry still focuses on two distinct periods of the product life. The warranty period, where most of the failures are due to product malfunctions or quality related problems, and, wear-out period, where the failures are due excessive wear and use(1). Using sensors and logging software the condition of equipment is assessed as frequently as needed, enabling efficient analysis of data that facilitates planning of predictive maintenance on-board vessels.

The electric motor is the most used device for conversion from electric to mechanical energy and is used for electric propulsion, powering thrusters for station keeping, and different on-board equipment on hundreds of ships. Typically, 80-90 percent of the load installations will be electric motors.[2]

Smart organizations know they can no longer afford to see maintenance as just an expense. Rather, maintenance must be integrated within the business cycle in order to guarantee predictability, growth and increase the overall quality of operations. Moving from a regime of scheduled rule-based maintenance via on-condition maintenance and

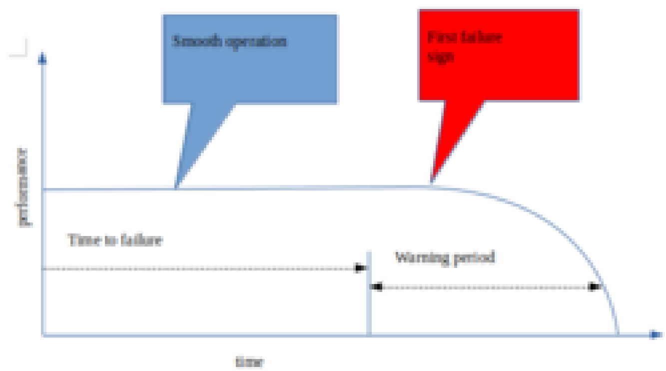

Figure 1.1: predictive maintenance model [?]

ultimately to a data-driven risk-based regime can lead to more accurate and timely maintenance tasks. This smarter view of maintenance allows for achieving many practical advantages leading to lower costs and increased safety and availability of ship systems.[3]

Making failure predictions and determination of remaining useful life (RUL), realizes significant benefits not limited to: work=style reforms, reduction in crew workload in that monitoring is done autonomously, improved safety from preventing accidents before they happen, and ensuring efficient optimal operation. [?] In future more equipment will be added in a modular manner to realize better optimal performance.

There are several parameters to be considered:

- temperature
- vibration
- voltage
- current

1.2 Problem statement

Out of 880 accidental errors in ship related incidents 62 percent are attributed to human failure; of this, 22 percent are shipboard related operations. Engine room failures are caused by a majority of three ways, either by: Natural mechanical failure, Electrical failure of components and whole systems, Human negligence, and poor competency in engine room procedures, Inaccurate diagnosis, and sub-par prevention measures.

These accidents are more notably recognized when they result in internationally felt effects such as oil spills damaging large swathes of marine ecosystems or when loss of life of crew members is realised. But with greater significance but less spoken of - the loss of millions in profits in maintenance and shipping costs incurred to the vessel's owner that would otherwise have been used more productively.

While it is impractical to try and eliminate accidents in the engine room,this design proposal seeks to provide a solution to improving efficiency and mitigating downtime by implementing strategies to reduce human through the automation of engine room condition monitoring[**?**].

1.3 Objectives

1.3.1 Main Objectives

1. To monitor the health of ship motors improving reliability and preventing downtime in ships.

1.3.2 Specific Objectives

1. To develop a predictive maintenance algorithm for electric motors in ships.

2. To model a modular framework onto which various equipment will be added to achieve predictive maintenance in the entire ship's engine room.

3. To design a product that has seamless integration on multiple motors

1.4 Justification of the study

Electric motors serve as a critical component for any facility. However, electric motors can be prone to any number of issues that lead to motor faults and failures. Failures disrupt business operations, decrease productivity, and adversely impact a company's bottom line.

Motor inspection processes have shifted from manual scrutiny to semi automated and fully-automated inspection. This will replace the time consuming task of manual review, significantly increasing productivity while preventing missed inspection as well as errors. Traditionally maintenance involves routine inspection and repair done manually. This cannot completely prevent the risk of machine downtime and will also result in the unnecessary early replacement of usable parts. [4]

The purpose of this project is to alert about problems occurring in the motor and trying to mitigate the risk of unexpected failure. A well planned predictive maintenance is the key to long life operation of motors. In ships unexpected failure causes downtime which deeply eats into profits.The traditional approach is to repair and replace equipment after a period of time but this cannot prevent downtime due to malfunctions, which put a halt to operations and incur massive losses. Advanced monitoring is implemented on parts that are about to break down and can be discovered in advance to accurately determine the time for repair and risk of unexpected shutdown can be prevented. [1]

Although Reactive and preventive maintenance will always have a part in operations,Predictive maintenance is the next big step forward in the evolution of asset management. In fact, the ability to connect assets and feed information into a central system gives organizations the power to turn data into powerful insights and automatically take corrective, preventive or predictive action.

2 Literature Review

2.1 Operation, Subsystems and Parameters

Condition monitoring is a type of maintenance inspection where an operational asset is monitored and the data obtained is analyzed to detect signs of degradation, diagnose the cause of faults, and predict for how long it can be safely or economically run. There are five general categories of Condition Monitoring techniques—vibration monitoring and analysis; visual inspection and nondestructive testing; performance monitoring and analysis; analysis of wear particles in lubricants and of contaminants in process fluids; and electrical plant testing. Condition Monitoring needs good quality data such as that obtained by carefully run tests. However, much useful information can often be obtained from a plant's permanent instrumentation once repeatability is established. [**?**].

Remaining Useful Life (RUL) is the time remaining for a component to perform its functional capabilities before failure. The concept of Remaining Useful Life (RUL) is used to predict life-span of components (of a service system) with the purpose of minimising catastrophic failure events in both manufacturing and service sectors. Our proposal involves acquiring real data from a normal working pump at its different stages in life. This will be done using multiple sensors attached to the pump at different times under different working conditions. The data include temperature, vibration and pressure. Over time, the installed sensors will generate more and more data which can be used to improve the initial models and make near-perfect failure predictions.

Currently the industry is majorly relying on sensors for condition monitoring which has facilitated decision making under time constraints. The time between the point where a potential failure occurs and the point where it deteriorates into a functional failure can be seen as an opportunity window during which decision making algorithms can recommend actions with the aim to eliminate the anticipated functional failure or mitigate its effect. The system can record and monitor vibration and temperature conditions of an industrial motor and transmit the data through a wireless network to a data logging center. The current prototype was developed using open source software and hardware and can successfully identify abnormal motor conditions from sensor input values that exceed predefined setpoints.

3 Methodology

3.1 System Modelling

The predictive maintenance algorithm for motors system will be obtained from governing equations from which a transfer function will be generated from the linearized model. The transfer function will be used to generate a state space model for the system.

The observed sources of faults and their relative frequency. Such sources can be the core components of the machine or its various sensors (such accelerometers and flow meters).

The process measurements through sensors. The number, type and location of sensors, and their reliability and redundancies all will create both algorithm and comparative model.

The sources of faults will translate to observed symptoms. Such cause-effect analysis will require extensive processing of data from the available sensors.

Physical knowledge about the system dynamics.will result in mathematical modeling of the system and its faults and from the insights of data. Understanding system dynamics will involve detailed knowledge of relationships among various signals from the machinery (such as input-output relationships among the actuators and sensors), the machine operating range, and the nature of the measurements (for example, periodic, constant or stochastic).

The ultimate maintenance goal, such as fault recovery or development of a maintenance schedule.

3.2 Simulations

From the generated models on matlab, simulations will be performed using the different controllers and the responses and other metrics will be plotted out for further analysis.

Metrics such as rise time, settling time and stochastic response will be observed to determine the system performance.

3.3 Sensors

Sensors will be used to collect data from the system as it runs. These include:

- Humidity sensor
- Temperature sensor
- Flow rate sensor
- Pressure sensors
- Voltage sensor
- Current sensor

These sensors will be used by the controller to observe system performance and optimize for each parameter as well as the performance requirements.

3.4 Data Analysis

The data collected from the simulations and sensors will be analysed using custom software created using jupyter notebooks. Graphs will be generated to compare the performance of each controller and evaluation of the selected controller.

4 Expected Outcomes

1. A functional motor health monitoring device will be developed and tested.

2. The predictive maintenance algorithm will be formulated and proved from a selection of diverse methods.

3. The controller supporting circuitry will be developed with a custom printed circuit board.

4. Electric motor system performance and efficiency will be optimized using insights from real-time data collected.

5 Proposed Budget

Item	Quantity	Price
Assembled PCB microcontroller (PIC)	1	10,000
Tough PLA filament for case	2	12,600
Micro precision current sensor	1	200
Pressure transducer	2	6,000
Total		28,800

Table 5.1: Proposed budget

6 Work Plan

Year	2021						2022					
Month	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	NOV	DEC
Literature Review												
Proposal Refinement												
System Modelling												
Controller modelling												
Simulation												
Fabrication and Testing												
Data Collection and Analysis												
Final year report preparation and submission												
Presentation												

Table 6.1: Work plan table

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