TKI DINALOG
Dutch Institute for Advanced Logistics

DATA-DRIVEN MAINTENANCE

A DATA-DRIVEN CONDITION MONITORING APPROACH FOR THE MAIN BEARINGS OF A MARINE DIESEL ENGINE

The Royal Netherlands Navy (RNLN) explores data-driven maintenance opportunities as part of the Sailplan 2030 and Defence Vision 2035. Part of that exploration is performing different case studies, in which Monitoring & Control data from the IPMS-system of the Holland class is analysed. This research focuses on the early detection of defective main bearings of the main diesel engines. This creates opportunities to make maintenance decisions that prevent failures, resulting in an increased reliability.

HNLMS Holland

CASE DESCRIPTION

In this project, a data-driven defect detection model is used for the main bearings. The main bearings are critical components of the main diesel engine with an impact on operational availability. These components have failed in the past, therefore it is possible to perform analyses on them.
The main bearings are located in the main diesel engine and support the crankshaft and let it rotate with minimal friction. The failure mode of this component is the increased heat generation that causes by extra friction. After a failure of one of the seven bearings, the engine is not operational until maintenance is performed.

PROPOSED MONITORING APPROACH

In deciding the approach to monitor the main bearings it is important to look at the available information source, while the IPMS (Integrated Platform Management System) data will be used to develop the defect-prediction models.
In the IPMS data, only temperature sensors are directly available for the main bearings. The rise of bearing temperature is seen as an indication of degradation. But the bearing temperature is strongly correlated with various operational conditions, such as, engine speed and lubrication oil temperature.

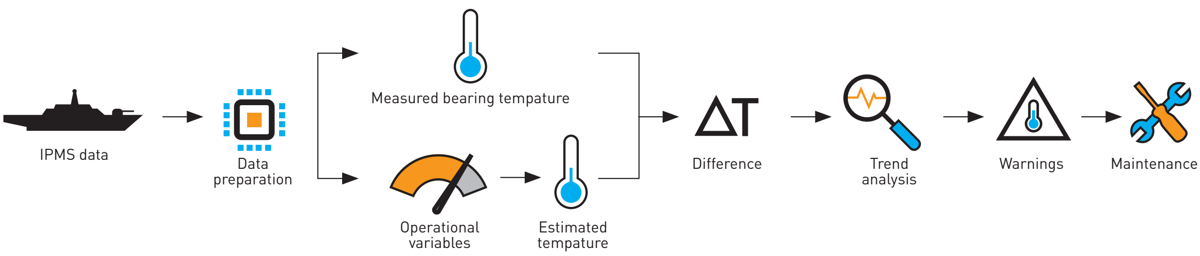

Figure 1: Proposed monitoring approach

Therefore the proposed monitoring approach consists of two steps, as shown in Figure 1. First, determining the expected bearing temperature given the operational conditions. Second, analyzing the difference between this prediction and the actual measured bearing temperature.

The 1 Hz sampled IPMS data must be prepared before performing analyses. From the data, the transient behaviour and outliers must be removed to improve the prediction quality. And lastly, multiple linear regression (MLR) is used for the estimation of bearing temperature. This is an understandable model that could be seen as a 'white-box.' This meets the needs of the maintenance engineers which is important for successful implementation in the organization.

Monitoring of the residuals is done based on exponentially weighted moving average (EWMA) control charts. This leads to an objective approach to detect an increase in temperature. Based on the EWMA small graduate changes could be detected. Three sequential data points above the control limit result in a warning to prevent outliers to have much influence.

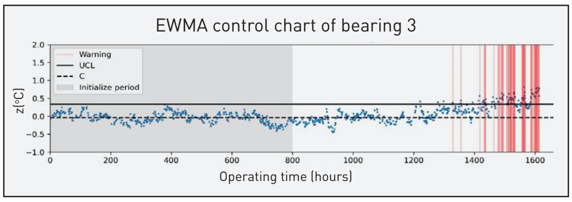

Figure 2: Resulting control chart

MONITORING RESULT

The proposed monitoring approach is tested on three different parts of the collected data. An example of the result is given in Figure 2. In this case, the first 800 hours of data are used for learning the model and setting the stationary control limit. The vertical red lines indicate the warnings that are given by the monitoring system. These warnings arrive several hundred operating hours before the moment in which the failure had occurred. This corresponds to warnings 1.5 months before the failure, which gives substantial time to optimize the maintenance process. From the other two cases, it is concluded that routine maintenance actions have a major influence on the learned physical behaviour. This implies that the models should be updated during the exploration of the engine.

IMPLEMENTATION IN THE MAINTENANCE PROCESS

For successful implementation of the proposed monitoring approach, the model should be implemented besides the current usage-based maintenance policy, see Figure 3. Warnings generated by the monitoring system referred to as 'improved warning', are presented to a 'control tower' in which they should be validated based on further data analyses or additional measurements. During the procedure of validating, the equipment is under enhanced supervision, in which the crew could be advised about the use of alternative operating modes for the propulsion, allowing the defects to be repaired before failures happen. This leads to an increase in reliability or makes it possible to extend the inspection interval without compromising on reliability.

FUTURE RESEARCH

In this research, it is proven that the proposed data-driven defect detection model has the potential to be used within the RNLN. For actual implementation of the tools three important projects must be performed, pilot project, increasing the number of assets monitored to better understand abnormal behaviour and improve the quality of the different steps of the monitoring process.

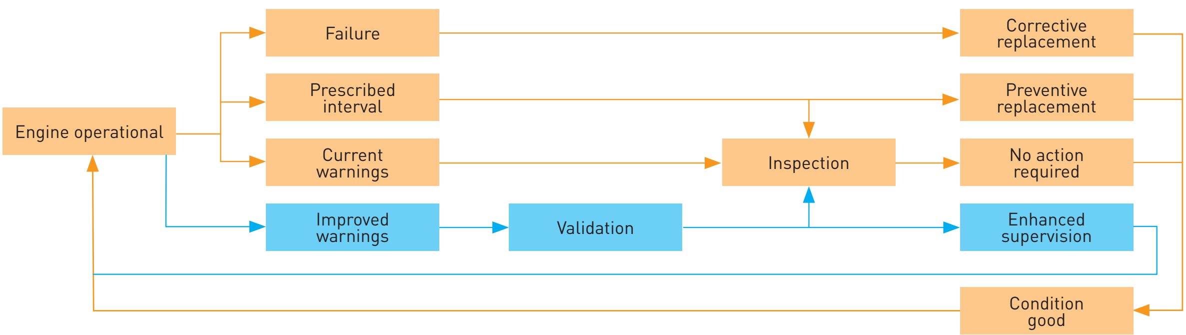

Figure 3: Proposed implication in current maintenance policy

Topsector Logistiek

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