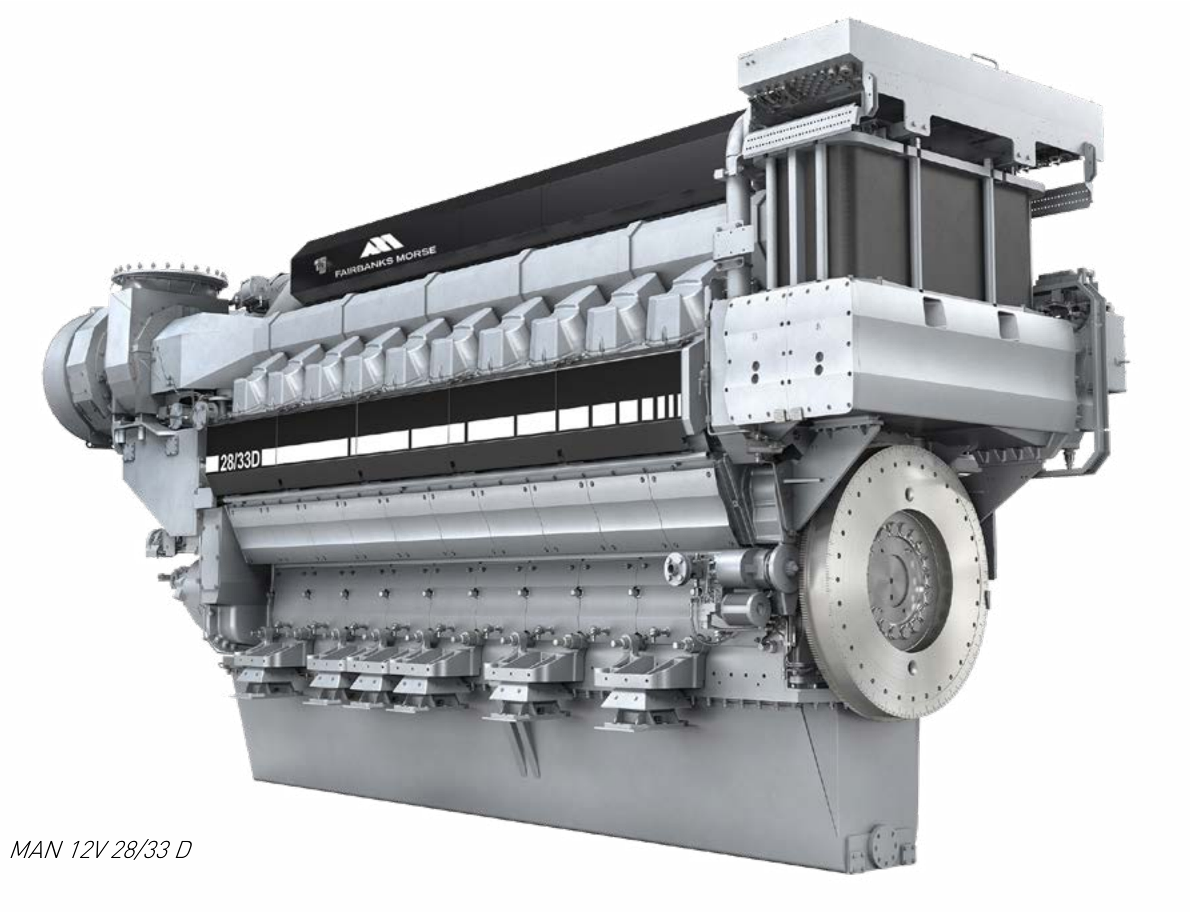
TKI DINALOG
Dutch Institute for Advanced Logistics

A CASE STUDY ON FUEL INJECTION NOZZLES

DATA-DRIVEN CONDITION MONITORING OF MARITIME DIESEL ENGINES

Conducting maintenance is an absolute necessity for the Royal Netherlands Navy (RNLN) to keep on safeguarding national and international waters. The availability of logged data on many of the modules aboard naval vessels brings along the opportunity of monitoring these modules more narrowly and then applying maintenance when the system actually requires it. Given this opportunity, research is conducted in collaboration with the RNLN. The goal is to investigate the application of smart maintenance on their existing fleet.



MAN 12V 28/33 D

THE EFFECT OF DEGRADING NOZZLES

Marine diesel engines are highly complex reciprocating systems. Their function is to translate potential energy inside fuel into propulsion for the vessel as whole. It is very much desirable that this happens in a most efficient fashion possible.

In the proposed maintenance policy of the MAN 12V 28/33 D, the fuel injection nozzles have the shortest service life. Every 4000 operating hours, the set of twelve nozzles per engine is replaced for new ones. It is expected that these nozzles have the most direct relation to consumption of additional fuel when engines run more imperfectly over time.

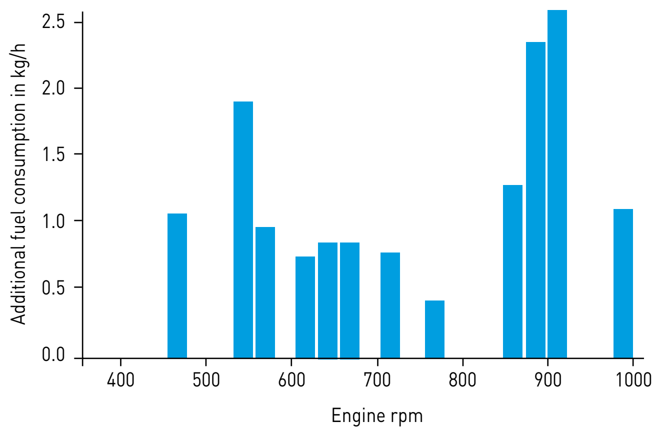
In regard of nozzle replacement, in order to evaluate maintenance opportunities on cost efficiency, two parameters are required. Firstly, a usage prediction is required. It is desired to know how intensively the engine is going to be used, in order to determine whether to do maintenance at the upcoming opportunity, or to postpone it until a next one. Secondly, the additional fuel consumption due to nozzle degradation needs to be extracted. Unfortunately, the engine does not register this directly.

USAGE PREDICTION

Additional fuel consumption levels are expected to differ per rpm range. Therefore, in order to predict additional fuel consumption, a prediction on expected rpm usage is required. This could be done by either using all historic rpm usage for a general prediction. However, there is a clear distinction between day-to-day tasks a vessel can perform. (e.g., patrolling, ocean crossovers or training).

By using AI-clustering algorithms, these unique day-to-day tasks are identified from historic data. Through an exploratory analysis with real-world data, using the distinctions in day-to-day tasks, the rpm range predictions are expected to improve over 10%, with the stability of prediction performance improving 25%.

Starboard linear: Additional fuel consumption at 2000 hours



ADDITIONAL FUEL CONSUMPTION

In order to extract additional fuel consumption, a comparison to a fuel-consumption benchmark is required. A deviation from that benchmark over time is an indication for a change in fuel consumption. Due to the vast amount of operating circumstances, no benchmark could have been made when engines were new. However, thanks to the vast amount of data, a benchmark is made by modeling fuel consumption through machine learning.

The random forest regression algorithm is used to model fuel consumption. Given the registered rpm, torque and external parameters (e.g., vessel roll, trim and draft), fuel consumption is considered to be modelled with an accuracy of only 0.6% prediction error. Therefore, the model is considered to be a perfect benchmark. By comparing actual fuel consumption to the benchmark over time, additional fuel consumption levels are found for the relevant rpm ranges.

RECOMMENDATIONS

When distinct day-to-day tasks are considered explicitly, a significant improvement in rpm range (and therefore fuel consumption) prediction can be made.

Additional fuel consumption costs right before fuel injection nozzle replacement are found to be insignificant relative to fixed maintenance costs. However, the condition-monitoring approach is very effective. With only slight alterations, other components can be monitored. For instance, degradation or instantaneous failure of bearings can be monitored by benchmarking bearing temperature under vast amount of circumstances.

Topsector Logistiek

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