Technical BULLETIN

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Engine Condition-Based Maintenance (CBM): Combining multiple diagnostic methods to enable fact-based CBM in marine engines.

ABSTRACT

The maintenance of machinery has evolved from a reactive process, performed after a functional failure, to a preventive maintenance activity, where items are overhauled or discarded according to a time-schedule. To reduce the uncertainty resulting from preventive maintenance, new approaches, based on the assessment of machinery condition, have emerged, which are collectively known as Condition Based Maintenance -CBM. (Fig. 1)

Propulsion Analytics produces Engine Hyper Cube® (EHC®), a thermophysical process simulation application, able to create an accurate and dynamic reference of performance and reliable benchmarking for marine engines.

Our novel CBM diagnostic method is based on the Engine Hyper Cube®. In 2022, following extended evaluation, Det Norske Veritas DNV issued an attestation for applicability of the EHC® as a new method and diagnostic tool for Condition Based Maintenance -CBM.

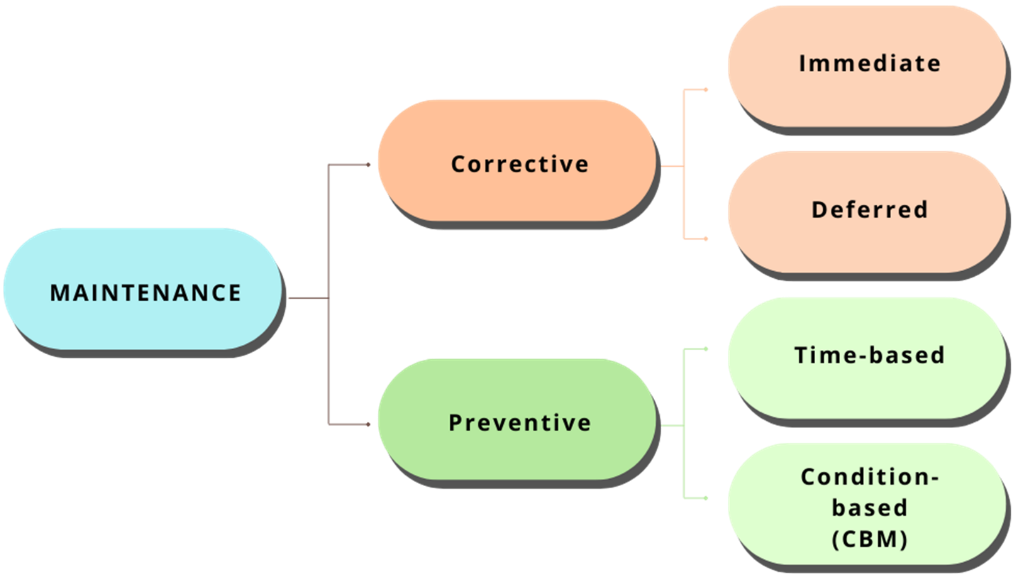

Figure 1. Types of maintenance

ENGINE CONDITION-BASED MAINTENANCE (CBM): COMBINING MULTIPLE DIAGNOSTIC METHODS TO ENABLE FACT-BASED CBM IN MARINE ENGINES.

Maintenance in shipping generally follows a preventive or scheduled maintenance system, called Planned Maintenance System (PMS), which may or may not include a condition monitoring scheme.

Preventive maintenance assumes that a component has a defined lifetime, after which its failure rate increases. However, estimates of lifetime often have large uncertainties. Hence, scheduled maintenance is often performed too early, resulting in higher costs due to unnecessary replacements, or too late resulting in functional failures. Even worse, a component that cannot be inspected from the outside is often disassembled and inspected on schedule, with the risk of introducing faults during inspection or re-assembly.

The benefits to ship-owners of implementing a Condition-Based Maintenance (CBM) strategy are related to cost savings and the predictability of operations. A system for remote diagnostics and predictive maintenance may result in drastic reduction of on-call service engineers and also substantial reduction in maintenance, through extended maintenance periods and associated costs, whilst increasing the safety and reliability. Cost savings are also related to improved equipment performance that may lead to decreased fuel consumption.

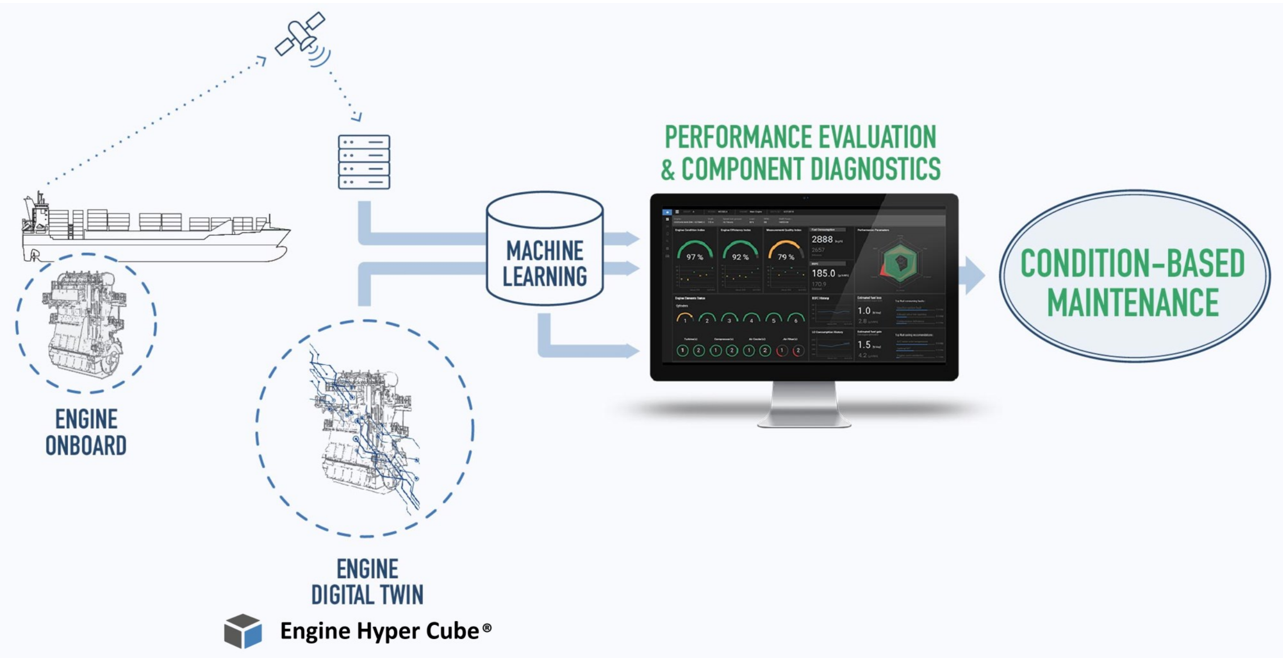

Figure 2. Combining engine digital twin and Machine Learning for CBM

Propulsion Analytics has recently developed an integrated CBM system and service for engines of marine vessels. Our core technology is an engine-process thermo-physical simulation model. For each specific engine, the model is used to produce a "reference performance" database (Engine Hyper Cube- EHC®), a multidimensional hyper map of engine performance, for all possible combinations of engine set points, throughout its load and speed range, for various fuel characteristics and any outside conditions, namely a "digital twin" of the engine. This is used in conjunction with shipboard engine measurements for the assessment of engine performance, the detection of faults and the advice on engine performance optimization. The EHC® gives warning notifications, fault diagnosis and actionable items, historical trends, as well as reliable "what-if" predictions for optimization of the engine's operation. (Fig. 2)

The engine performance assessment and diagnostics application EHC® by Propulsion Analytics is now installed in total more than 300 vessels. For the past several years we have performed pilot projects in conjunction with shipping companies, connecting the EHC® and integrating it to several established CBM technologies, comparing results and also linking to enterprise applications like PMS. This integrated CBM system includes our novel CBM diagnostic method (thermophysics-based process simulation Engine Hyper Cube®), and combines it with other established thermo-chemical and mechanical CBM diagnostic methods (Vibration analysis, Lubricating oil chemical analysis, Thermography analysis, Component wear measurements, Operational load profiles…) and uses AI on the collective results for a more dependable CBM evaluation and decision support to shipping companies. An overview is shown in Fig. 3.

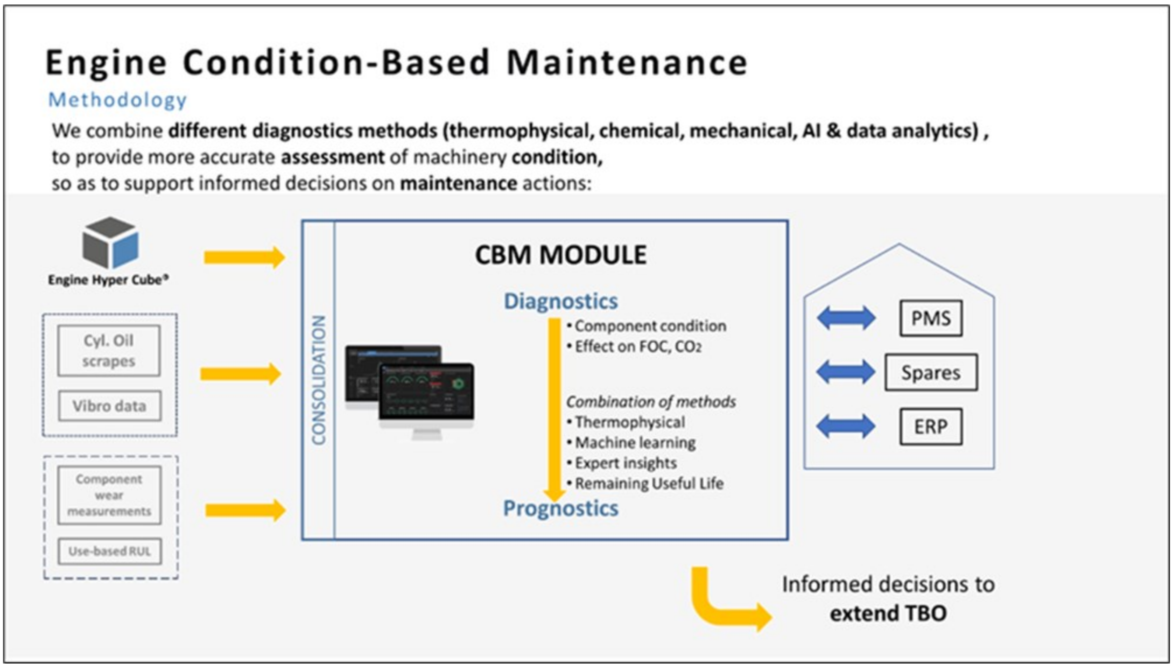

Figure 3. Overview of using multiple diagnostic methods for CBM