Estimation of condition and remaining useful lifetime for oil lubricated machinery in ships

Morten Henneberg

Moh@cjc.dk

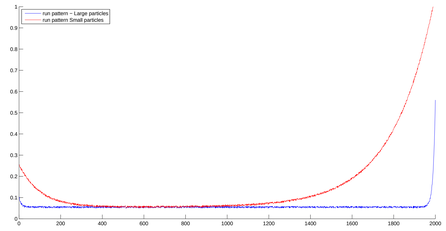
University of Southern Denmark

Contribution: Critical system surveillance

Successful operation of supply vessels in charter depend mainly upon a few critical equipments. Knowing the status and expected life-time of these equipments can both secure the charter completion as well as save cost on expensive overhauls (for instance in dry-dock).
By real-time monitoring the lubrication parameters of these critical equipment can a statistical model be developed to give feedback on the systems health and expected life-time.

System life-time

General knowledge of a systems life-cycle is that any system has a run-in time period where the surface asperities for interacting equipment (ex. gears) are worn in. The following quasi-stationary time period is the equipments normal operation. The life-cycle comes to a final event in a break-down.



The life-cycle explained have been described in theory by Szymczyk [2] preceeded by the quasi-stationary state description by Kjer [1].
The life-cycle and quasi-stationary equations can be gathered to a differential equation in C (particle concentration) over time (t),

$$\frac{dC}{dt} = \frac{1}{V}\{ae^{-bt} + P_0 + ge^{-h(F-t)} - C \cdot \beta \cdot Q\}, \quad (1)$$

where P_0 is the particle release estimation from the machinery. V is the oil volume in the system. The negative term comes from oil filtration where β is a filter constant and Q is flow. The exponential terms is the run-in and break-down.

References

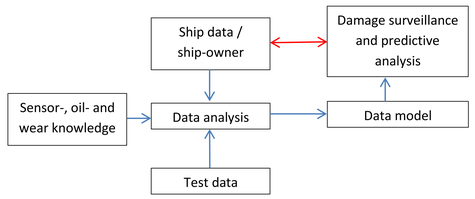
[1] T. Kjer Wear rate and concentration of wear particles in lubricating oil, *Wear 67* pp.217-226, 1981.

[2] W. Szymczyk Variationsin wear particle concentratino in lubricating oil, *Wear 80* pp. 121-124, 1982.

[3] sourcebyte.com http://research.sourcebyte.com/blog/...stochastic-processes-and-markov-chains, 18th November, 2013.

Scope of project

The project will involve building statistical models for estimation of remaining useful lifetime and in time extrapolating these models to give warnings/recommendations to the equipment owners.
The research within the project will focus on combining structured breakdown with test bench data compared to the observed data from the ship installations. The goal is to improve the general knowledge of on-line sensors, accelerated life-time test, oil characteristics compared to wear of machinery and mathematical/statistical models to monitor and explain wear phenomena.



The immediate commercial market for the project would be as upgrades for the CJC installations on 3.500 thrusters and 2.000 cranes installed primarily in Europe, USA and Asia, onboard different ships with different owners.

Basic oil parameters observed

The major issues is to measure the explanatory covariates and leave out the noise.
Some of the parameters logged:

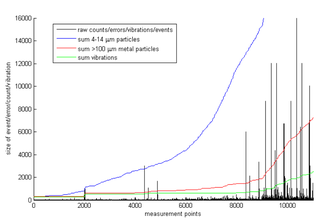
- Particles: Type, size and composition
- Water and temperature
- Run conditions
- Parameters for oxidation of the oil

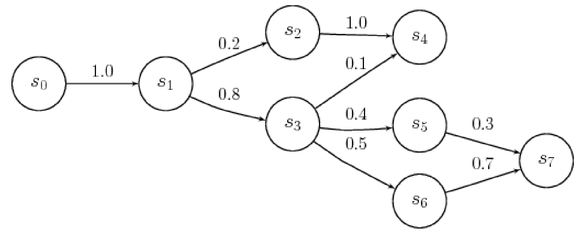
During the project will a continuous evaluation of the sensors and information be reviewed.

System installations

Project background. The project is based on a multi-sensor platform installed and running onboard three service vessels named "Achiever", "Assister" and "Attender". Each of these service vessels have oil filters and on-line multi-sensor platforms installed on expensive and critical oil lubricated systems such as azimuth thrusters, stern thrusters and cranes. The installations have been running since 2011 on Attender, and since 2012 on Achiever and Assister, and are part of a joint venture program between C. C. Jensen A/S, Maersk Supply, University of Southern Denmark and Svendborg International Maritime Academy. This joint venture is supported by the private fund "The Danish Maritime Fund" in order to improve todays routines; where oil samples are taken manually and analyzed using off-line analysis techniques.

Combining data to an explanatory model





Construction of algorithm. Moving from the diversity of data to a generic data model requires descriptive data analysis for each sensor and operation pattern. The generic data model can be a regime switching stochastic model that takes into account the different states the sensors can react to in different equipment states. A continuous-time Markov chain can be described as,

$$Pr(X_{t_{n+1}} = i_{n+1} | X_{t0} = i_0, X_{t1} = i_1, ..., X_{tn} = i_n) = p_{i_n} p_{i_{n+1}}(t_{n+1} - t_n) \quad (2)$$

where the p_{ij}'th therm is the forward solution given the initial condition at $p(0)$. The general theory behind the Markov chain is that a time process can develop forward in known directions with a probability given from the prior states.

Overall goal. Combining the practical knowledge of the equipments functionality with the theoretical background in statistics will hopefully ensure a valid, robust warning model usable for the ship owners. A simple warning model will hopefully be useful to take the correct action (from the owner side) and the basis in a rather sophisticated statistical model will hopefully ensure that the interpretation of data is valid.