Maintenance strategy for a hull coating

The hull of a vessel is subject to corrosion caused by several environmental factors. It is covered by a protective coating, however, this coating also deteriorates over time. The Royal Netherlands Navy owns many vessels. To ensure that the deterioration size does not become harmful, they perform maintenance on the coating. Three types of maintenance can be performed, with each a different effect and different costs. In this project a cost-optimization model is created that determines the set of maintenance actions that minimize the total expected maintenance costs on the hull coating. The model is based on a condition-based strategy, in which maintenance is performed when a certain deterioration threshold is exceeded. The deterioration process is modelled as a non-stationary gamma process. This model is tested for different values of the deterioration threshold, leading to different total costs. Several trends have been found in the results that can be useful for application in practice.

Introduction

The hull of the Royal NL Navy vessels is constantly exposed to weathering conditions and this leads to degradation caused by corrosion. Corrosion has a huge economic impact, and studies have shown that 15-35% of the yearly costs spent on corrosion can be avoided if an appropriate maintenance strategy is applied. The options for maintenance considered in this project are full replacement, spot repair and repainting. The objective is to find a good maintenance strategy on the hull coating of naval vessels, that minimizes the total expected maintenance costs. More specifically, this project focuses on the hull skin above the waterline of the ocean-going patrol vessels (OPV's), as depicted above.

Methods and approach

The method that was used in this project is based on a paper by Nicolai et al. [1]. First of all, the deterioration process is analyzed. The deterioration process is dependent on the lifetime of the vessel and is therefore modelled by a non-stationary gamma process. Data on the deterioration process of the hull coating of OPV's are collected. Using these data the parameters of the non-stationary gamma process are estimated using maximum likelihood estimation and the method of moments. Maintenance influences the rate of the deterioration process. The effect of each maintenance action has been analyzed as well. Fig.1 shows the deterioration process before and after maintenance for each of the three maintenance actions.

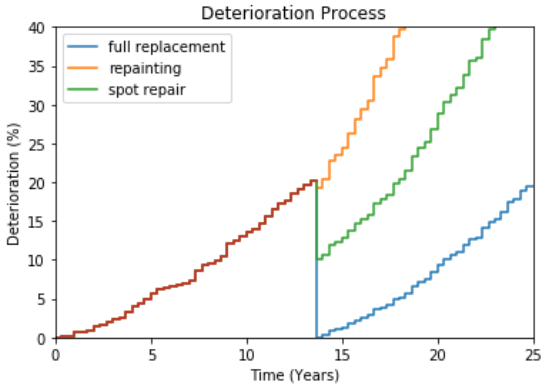

Fig.1: Deterioration process before and after maintenance.

Secondly, data has been collected on the costs of each maintenance action. A discrete time cost model has been developed in the programming language Python. In this model a lower and an upper bound to the total expected costs is computed, see Figure 2.

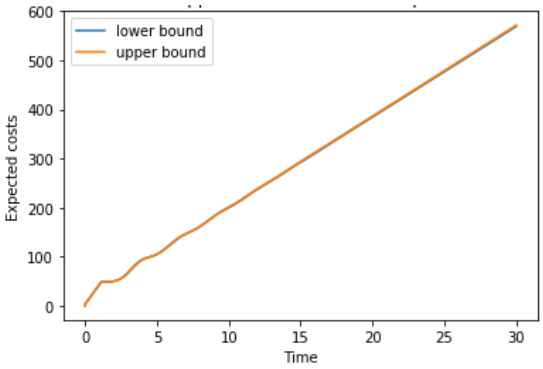

Fig.2: Minimal costs for a specific maintenance strategy.

Results and observations

The model returns the sequence of maintenance activities that minimizes the total expected costs. The results for three different deterioration thresholds are shown in Fig.3.

Discussion and implication

As there is much uncertainty in the provided data, a sensitivity analysis has been performed, in which several input parameters are changed. Three trends are found:

Trend 1: repainting is always optimal in the last few time periods before the end of the lifetime.

Trend 2: for higher thresholds, full replacement is optimal in all docking periods, except for the last one.

Trend 3: for higher thresholds, repainting is optimal just before docking periods.

The data that the Navy recorded is limited. Therefore it is difficult to address the feasibility of the model in practice. The model does provide a more data-driven perspective on the maintenance of the hull coating. If the Navy performs more and accurate measurements, the model could provide a guideline to a good maintenance strategy. It can then even be applied real-time, if the model is updated after every inspection. Future work is key to study how deterioration can be measured more accurately in the Navy setting. It could, for example, be useful to perform measurements with drones. New technology allows drones to monitor visual deterioration precisely.

References

[1] R. P. Nicolai, J. B. G. Frenk, and R. Dekker, "Modelling and optimizing imperfect maintenance of coatings on steel structures," *Struct. Saf.*, vol. 31, no. 3, pp. 234–244, 2009.

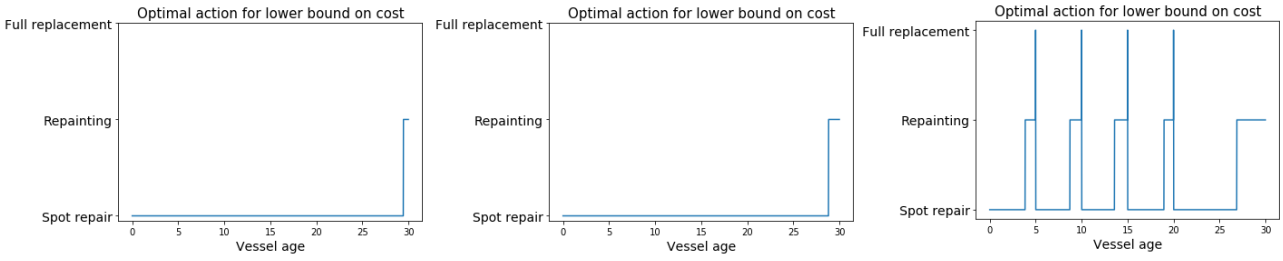

Fig.3: Optimal maintenance actions for a deterioration threshold of 5.1%, 10.1%, 20.1%, respectively

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