TKI DINALOG
Dutch Institute for Advanced Logistics

DATA-DRIVEN MAINTENANCE

PREDICTION MODELLING FOR CUTTER SUCTION DREDGER COMPONENTS

Due to constantly changing operational conditions, it is hard to predict when certain components need maintenance or should be replaced. Boskalis still gets surprised by sudden downtime due to this. To improve predictability of these downtimes, a more thorough look at their vessels' power train components was taken. In particular, the degradation behavior of the cutter motor rolling element bearings in Helios' cutter ladder. Using vibration- and operational data, a model that is able to describe the degradation of these power train components while accounting for changes in environmental and operational conditions was developed.

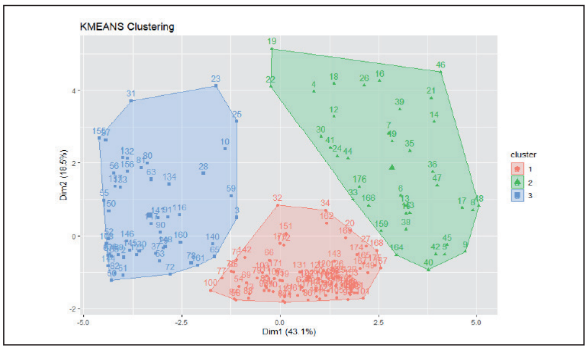
COLLECTED DATA

- Vibration data was used to represent bearing condition, while operational data (e.g. cutter- speeds, torque, forces etc.) was collected to provide context to the vibrations;
- Vibrations at specific fault frequencies indicated damage in four different parts of the bearings;

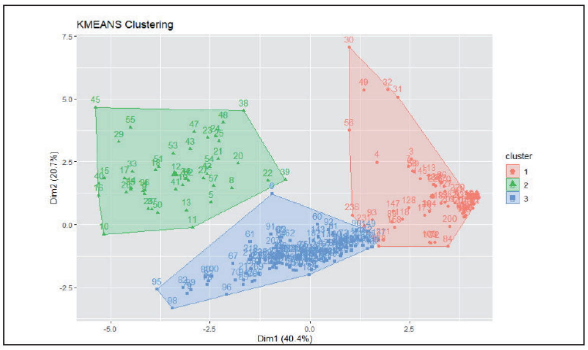
During the initial data collection, it became apparent that the data was largely censored and unlabeled. Before prediction modelling, some pre-processing was required using data-driven methods.

K-MEANS CLUSTERING

K-Means clustering was applied to identify damage states and operational modes in the combined vibration and operational data.



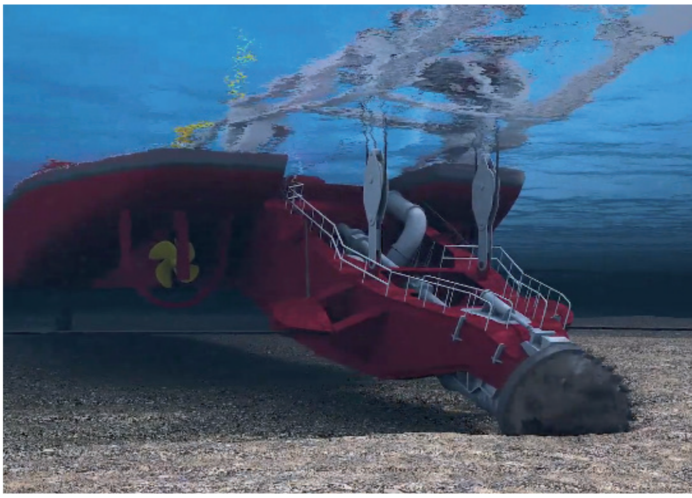
Visualization of clusters for port side bearing (CPS)



Visualization of clusters for starboard bearing (CSB)

CLUSTERING REVEALED 3 MODES OF OPERATION

- High turbulence: observations with high vibration amplitudes, high cutter speeds, forces, torque & high pressure on spud carriers. Likely moments where the vessel was dredging at a constant pace;



- Low turbulence: observations with medium vibration amplitudes, low cutter speeds, forces, torque & low pressure on spud carriers. Likely moments where the vessel was either idle or phasing out of the dredging operation;
- Medium turbulence: observations with low vibration amplitudes, medium cutter speeds, forces, torque & medium pressure on spud carriers. Likely moments where the cutter was phasing into the dredging process.

FAULT DETECTION

- Peaks in vibration data were used to label points in time where the bearings were in a damaged state. This was done using control charts;
- Points above the upper control limit (UCL) were labelled as violations: moments where damage had been detected in the bearing;
- To control for the effect of operational conditions on the vibration amplitudes, violations were identified per operational mode as defined during K-Means clustering.

Operational mode	Number of violations	
	Starboard cutter motor (n=236)	Port cutter motor (n=176)
Low	30	10
Medium	6	18
High	8	3
Total	**44**	**28**

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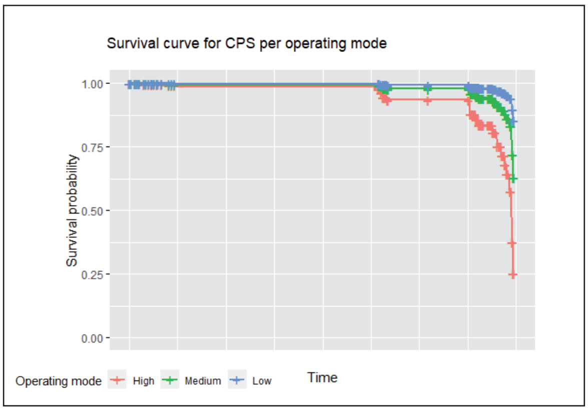
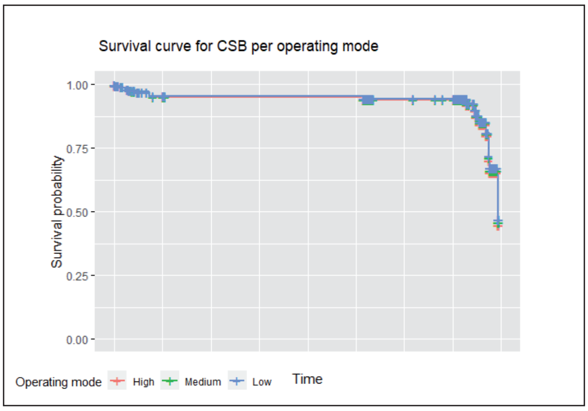
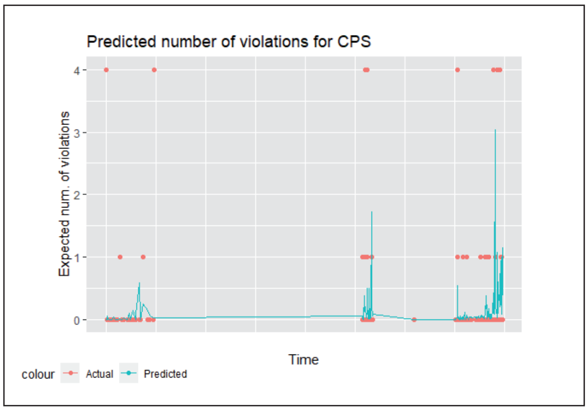
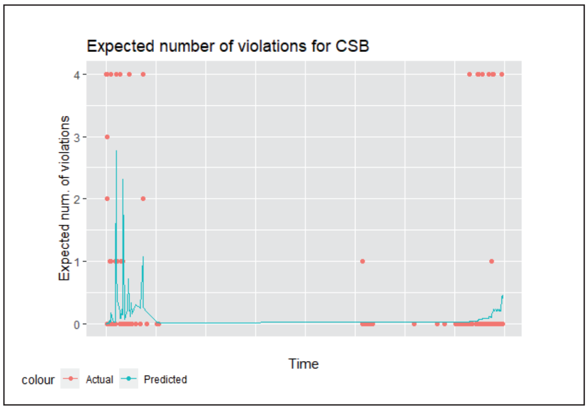
PREDICTION MODELLING

- Times between occurrences of violations and the parameter values serve as input for Cox's Proportional Hazard Model (PHM);
- The PHM assumes that a baseline hazard and a set of covariates have an effect (independent of time) on the hazard rate of a component;
- Can be translated to a survival function (probability that a violation will not occur before a specified time);
- Cox's PHM was fitted and only the vibration parameters and operational modes had a significant effect on the hazard and survival probability;
- Some covariates of the starboard-cutter dataset violated the proportional hazards assumption. This weakens the size of the effect that is attributed to purely the covariates;
- For the port side, the different operational modes affect the survival time in a negative way;
- For the starboard side, due to the violation of the proportional hazards assumption, there is no discernable effect from the operating modes on the survival probability;
- The models consistently predict that a violation will occur in the next timeframe, but fail to correctly predict the number of violations in the next timeframe.









CONCLUSIONS

- For the four rolling element bearing components, failure moments can be identified using vibration data combined with control charts;
- Times between damage occurrences can be modelled using PHM. This gives insights into effect of covariates on survival probability;
- Method can be applied to other power train components as well.

RECOMMENDATIONS

- Boskalis should work towards standardizing data collection across all data sources. This facilitates future analyses;
- Work and day reports could be used to provide more context to the operational data, circumventing the need to estimate the operational mode;
- The vibration should be supplemented with bearing temperatures to improve assessment of the condition of the bearing;
- The baseline hazard of the PHM is an arbitrary function that represents the 'natural' degradation as a function of time. This could be substituted with a life time estimation function from the components' suppliers.

Topsector Logistiek

FACTS

Researcher Symen Tran
University Eindhoven University of Technology
Supervisor dr. Alp Akcay

Marconi project – Powered by:

Gordian Logistic Experts
Maastricht University
TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY
NWO
service science factory