Numerical modelling of premature roller bearing failure associated with White Etching Cracking

Researcher(s): Gopalakrishnan Ravi
Supervisor(s): Stijn Hertelé, Wim De Waele
Partners(s): UGent (research groups MST; SMS); VUB (AVRG research group); SIRRIS
OWI-lab
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Motivation

(Offshore) wind energy is an important and growing renewable energy source globally, and in Belgium particularly. In some cases, the industry has been faced with premature rolling contact fatigue failures of roller bearings in the turbine drivetrain resulting in unforeseen wind turbine downtimes. These failures are associated with the presence of so-called white etching cracks (WEC) (see figure 1).

Figure 1 Premature bearing failures in wind turbine gearboxes are associated with White etching cracks [1].

The VLAIO and SIM-Flanders project 'Material and Signal processing based prediction of WEC probability (MaSiWEC)' comprises a multi-tier collaboration which involves holistic modelling of premature rolling contact fatigue, fed with rigorous characterizations of material characteristics of (failed) bearings, and load history data from in-the-field measurement campaigns. The main aim of this project is to provide wind energy value chain players with an improved understanding, prediction and monitoring of white etching cracking (WEC) in turbine drivetrain bearings. Starting from the level of material microstructure and supported by in-the-field measuring campaigns, material based Probability of Failure (MB-PoF) predictions will lead to better operation (less failures) and improved maintenance strategies (see figure 2). This research provides a unique collaboration between Flemish academic institutes and industrial value chain players, and involves NREL (National Renewable Energy Laboratory, USA).

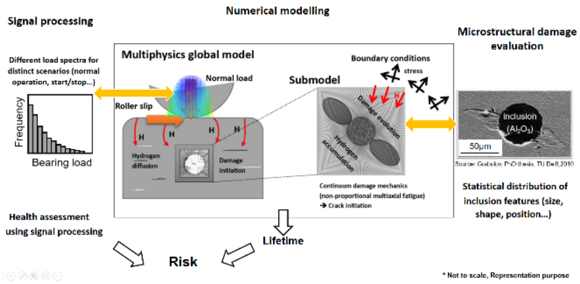

Figure 2 Project overview : Synergetic modelling framework touching multi-scales

Objectives

Within the project consortium, UGent-Soete Laboratory is responsible for the numerical modelling of premature rolling contact fatigue failure using a multi-scale finite element modelling approach, fed with load history data and microstructural insight from the project partners.

1. Explore the landscape of physical mechanisms associated with WEC formation and identify knowledge gaps in their numerical implementation.

2. Develop numerical routines for prediction of bearing lifetime, including assumed WEC drivers and an associated lifetime reduction model.

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3. Accounting for sub-surface material characteristics (from characterization studies, with emphasis on non-metallic inclusions) and loading conditions (operating states) in the evaluation of bearing lifetime.

4. Feeding the model with experimental load and material input, thus allowing to evaluate the predictive ability of the model.

APPROACH

Meeting the objectives comprises the development of a finite element (FE) modelling approach to assess the damage initiation of WECs in bearings (refer figure 3), based on the distribution of contact loads and assumed physics of WEC formation (including a prominent role of hydrogen on material degradation). The outcome is a prediction of premature bearing failures in line with WEC occurrence and its corresponding lifetime reduction relative to the classical pure rolling contact fatigue timeframe. Calculations will be based on time histories (or spectra) of applied loads, provided by VUB-AVRG, and material characterizations provided by UGent-MST and UGent-SMS.

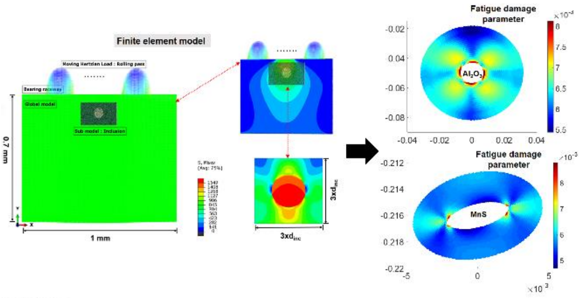

Figure 3 Numerical rolling contact fatigue model

Numerical routines for bearing lifetime prediction are developed using the commercial finite element software ABAQUS, by means of object-oriented Python scripting and FORTRAN user subroutines. This scripting approach has the advantage that large parametric studies can be easily defined, automatically processed and analysed. This powerful approach avoids repetitive human actions, thus reducing the likelihood of errors and striving towards a minimum of user effort.

The starting point of this work is a numerical rolling contact fatigue model, based on damage initiation at non-metallic inclusions and subsequent crack propagation. Then, the assumed mechanism towards WEC development is implemented. The developed model is finally adopted in final stages to predict the premature bearing failures with the occurrence of WEC and their associated lifetime reduction (see figure 4). Hereto, surrogate models for bearing lifetime will be developed on the basis of parametric studies using the modelling approach, and will be fed into Monte-Carlo analyses of virtual bearings, constructed on the basis of non-metallic inclusion statistics.

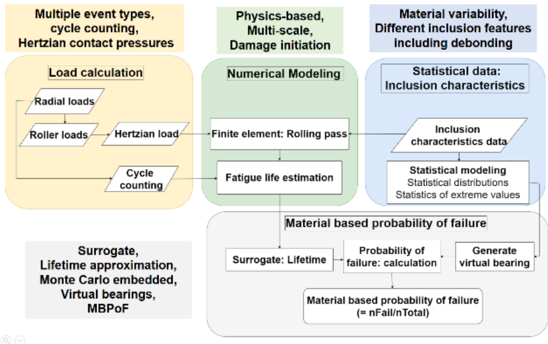

Figure 4 Material based probability of failure

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1. White etching cracks, http://evolution.skf.com/white-etching-cracks-a-consequence-not-a-root-cause-of-bearing-failure/, last accessed 2019/01/07.

Contact Details

Researcher(s):

Gopalakrishnan Ravi Gopalakrishnan.Ravi@ugent.be; Bibliography

Supervisor(s):

Stijn Hertelé Stijn.Hertele.ugent.be; Bibliography
Wim De Waele Wim.DeWaele@UGent.be; Bibliography