DETECTION OF GEAR TOOTH DEFECTS USING NVH DATA FROM END-OF-LINE TEST

Acerta LinePulse™ Case Study

Acerta
AI-Powered Machine Analytics

OBJECTIVES

- Demonstrate failure prediction using small amount of training data
- Identify defects indicative of future failures

CHALLENGE

- Limited examples to train the models on
- Use only historical data as collected by the client
- Real-time analysis

RESULTS

- Identified 40% of previously undetected defects
- Allowed for €2M reduction in warranty costs
- Compensated for lack of data by integrating domain knowledge into models

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BACKGROUND

All gearboxes include electrical units that continuously monitor signals from internal sensors, which are used for end-of-line (EOL) testing. At the end of each EOL test, the system generates a report that is examined by a test operator, who manually looks for any deviation from pre-set thresholds. These thresholds are useful for identifying problems such as poorly placed sensors, faulty connectors, or certain assembly issues. Other problems, such as material hardness or an unreported change in an internal module might go undetected or result in a tedious and time-consuming root-cause analysis.

THE PROBLEM

A leading European Tier-1 manufacturer was looking to allow its OEM customers to reduce service costs on its gearboxes. This was attainable either by reliably stretching maintenance cycles or by providing an extended warranty period on the gearboxes.

The client's engineers have been encountering difficulties identifying gearboxes that would fail in the field during the warranty period. Their analysis showed that most signals had similar summary statistics across both functional and failed gearboxes.

The client requested that Acerta demonstrate the ability of LinePulse to detect defects in the gearbox that would result in warranty claims, using only a limited set of recorded EOL test data to train its models. The goal was to reduce the number of defective gearboxes not being flagged in the current EOL test process, ultimately improving the long-term reliability of the gearboxes and reducing warranty-related expenses.

SOLUTION PROCESS

Acerta began by running an exploratory analysis on the dataset, which included both defective and non-defective gearboxes, and confirmed that the provided data contained information necessary to detect issues leading to warranty claims. Next, Acerta's data scientists worked with the client to understand the test process to make the necessary adjustment to the models that will account for the small set of historical data.

As part of the process, the data scientists conducted a machine-learning-guided feature reduction, dropping features that had little or no value to the prediction algorithm. Several iterations of classification models were carried out using different feature sets, such as extracted power spectral density peaks, energies in different frequency sub-bands, and summary statistics.

The data scientists used NVH and RPM data to construct an order feature which made the models significantly more accurate. It contributed to a larger area-under-curve (AUC) of the receiver-operating-characteristic (ROC) curve, which represents a better ratio between false positives and true positives of a predictor. PSD data was considered as a feature as well but provided no additional value on top of order data.

This came as no surprise to the client, since their existing EOL test analysis relied on thresholds that were pre-set for various orders. However, their test did not detect these faults since they were not reflected in the energy of any specific order. As our algorithm demonstrated, **it was the correlation between different orders which was indicative of the problem**. By analyzing various channel combinations and by working with the client to improve the input to LinePulse, it was able to provide unique classification accuracy.

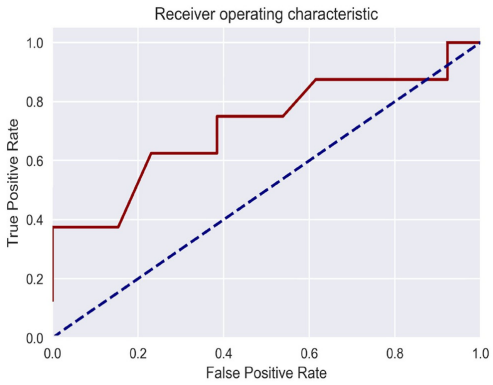

Figure: the ROC curve displaying the ratio between true positive and false positive rate achieved by the algorithm.

RESULTS

Even when using historical data from only a small sample of 104 gearboxes, Acerta demonstrated high accuracy in predicting survival or failure of gearboxes during warranty period. After comparing the output from LinePulse with the historical warranty records, the client concluded that LinePulse identified 40% of the gearboxes that passed the existing EOL test but still failed during the warranty period.

Using 3-fold cross-validation to determine the statistical significance of the model's performance, Acerta's data scientists showed that the results achieved using the small dataset are scalable to the entire dataset of gear-tooth fractures from the same BOM. Based on the results, the client estimated that using Acerta's LinePulse will reduce warranty expenses due to gear tooth fractures by 2 Million Euros per year, per plant.

Following the success of the project, the client began to implement a full deployment of Acerta's LinePulse at the manufacturing plant where the pilot took place.