Gearbox Failures

LinePulse Case Study

Objectives

- Improve end-of-line testing to identify units likely to fail under warranty
- Use NVH data to detect early indicators of future gearbox failures

Challenge

- Very large, decentralized dataset
- Training data taken from limited number of test units

Results

- Achieved **89% classification accuracy** in predicting failure during warranty period
- Approximately **€2M savings** per plant from reduced annual warranty costs

Background

A leading Tier-1 driveline supplier based in Europe was looking to reduce the number of warranty issues for its gearboxes. Although the gearboxes were under warranty for five or even ten years, some were lasting for only two. Customers were becoming frustrated, and the supplier was forced to absorb the costs of shipping and replacing the failing gearboxes. The client requested Acerta's help in improving its end-of-line (EOL) testing in order to identify more defective gearboxes and thereby avoid shipping them.

Problem

The client provided Acerta with a very large, unstructured dataset. The data for each gearbox was distributed across multiple files, with results from six independent tests recorded differently for different gearboxes. Consequently, Acerta needed to reconstruct as much as 10 TB of historical data to perform the analysis. This issue was compounded by the fact that the data came from a very limited number of gearboxes, resulting in an especially challenging case for machine learning: a large dataset from a small sample size.

Solution Process

Acerta began by meeting and consulting with the client's relevant experts to expand our understanding of the traceability and structure of their data. Domain knowledge was key, enabling our data scientists to eliminate irrelevant variables and focus on those most indicative of future failures. Our approach was to detect defects based on the noise the gearboxes generated during EOL testing.

Since the data was based on sound, the information was frequency-modulated, enabling Acerta's data scientists to find signatures by looking at the energy present at different frequencies. While the client's engineers had also been looking at the frequency spectrum, Acerta was able to examine it in significantly greater volume and depth using Anomaly Detection.

One issue with basing an analysis on the sound generated by the gearboxes is that RPM affects pitch, and hence the signature. In order to characterize signatures across variations in RPM, Acerta normalized the signatures. In other words, since gearboxes are rotational systems, the feature engineering approach filtered the spectrum by focusing on variables correlated with rotation. This enabled LinePulse to detect manufacturing defects that would produce structure-borne noise, such as gear tooth fractures. Ultimately, we were able to identify problems with individual gears on the basis of gearbox noise alone.

Results

The LinePulse Anomaly Detection module achieved 89% classification accuracy in predicting the survival or failure of gearboxes still under warranty. This approach has also proven to be generalizable to other rotating systems, such as tires, fans, and transmissions. By integrating machine learning into their existing EOL test via LinePulse, the client significantly increased the resolution at which their test data was analyzed. Based on these results, the client estimated that LinePulse would reduce their warranty expenses due to gear tooth fractures by over €2M per year for the product line.