HUMS2025 Data Challenge Result Summary

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Publishable: Yes

1. Summary of Findings

- A phenomenological model is proposed relating the influence of the growing gearbox casing crack to the meshing behavior between the ring gear and planet gears.
- First, the gearmesh frequencies and its harmonics are extracted and demodulated.
- The squared envelope of the gear mesh shows clear periodic peaks related to each of the four planets passing the sensor every revolution.
- Next to these peaks, in the time domain, additional peaks are present due to the planets passing the casing crack.
- Time synchronous averaging (TSA) relative to the planet passing frequency is used to extract the peak size in the squared envelope which will be used as the indicator value.
- It is clear that these peaks are present in all three sensors located on the planetary stage starting from the first provided file.
- A trend analysis is performed using Spearman R correlation to identify the file for which it can confidently be said that a positive trend exists in the health indicator.
- The proposed indicator shows a clear positive trend across the provided measurements both in the 125% rated load case and in the 100% rated load case.
- The 100% rated load case seems to be greatly affected by temperature effects after nightly shutdowns.

2. Description of Analysis Methods

The main idea behind the analysis is that the casing crack will influence the meshing between the ring gear and the planet. The crack would then introduce an irregularity in the meshing stiffness each time the planet gear passes over the crack. Therefore, the squared envelope of the gearmesh signature is computed and a time synchronous average is taken with respect to the planet carrier. This envelope shows peaks when the planet passes the cracks in addition to the peaks corresponding to the planet gears passing the sensor.

The size of this peak, quantified after a time synchronous average with respect to the planet passing, is used as an indicator for trending and early detection.

3. Key Fault Characteristics for Early Detection

Since the hypothesis is that the casing crack will influence the gearmesh signature between the planet and the ring gear, the first 8 harmonics of the gear mesh frequency (567.6 Hz) are extracted using a narrow (90Hz) bandpass filter.

The squared envelope of this signal is then computed by squaring and lowpass filtering (400Hz). This is then time-synchronous averaged (TSA) with respect to the planet carrier. The first obtained signal is then shifted so that the signal starts approximately when a planet passes the sensor (a circular shift so that the highest value is the first point). Signals from later files are then synchronized with the first acquired signal by maximizing their circular cross correlation with respect to the first signal.

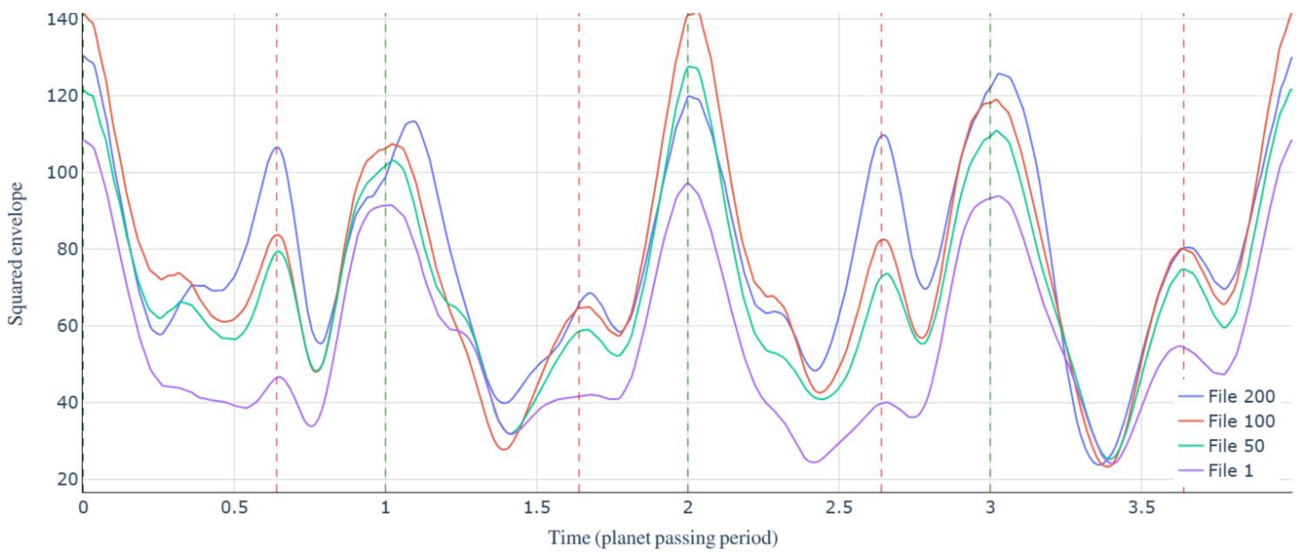

Figure 1 TSA with respect to the planet carrier of the envelope of sensor RL (125% rated load). Planet passings indicated in green, peaks related to the growing crack indicated in red.

It is then clear that next to the 4 peaks due to the planets passing the sensor there are also intermediate, growing peaks due to the planets passing the crack. In order to extract these peaks, the signal is averaged with respect to the planet passing frequency of the sensor (4 times the planet carrier speed).

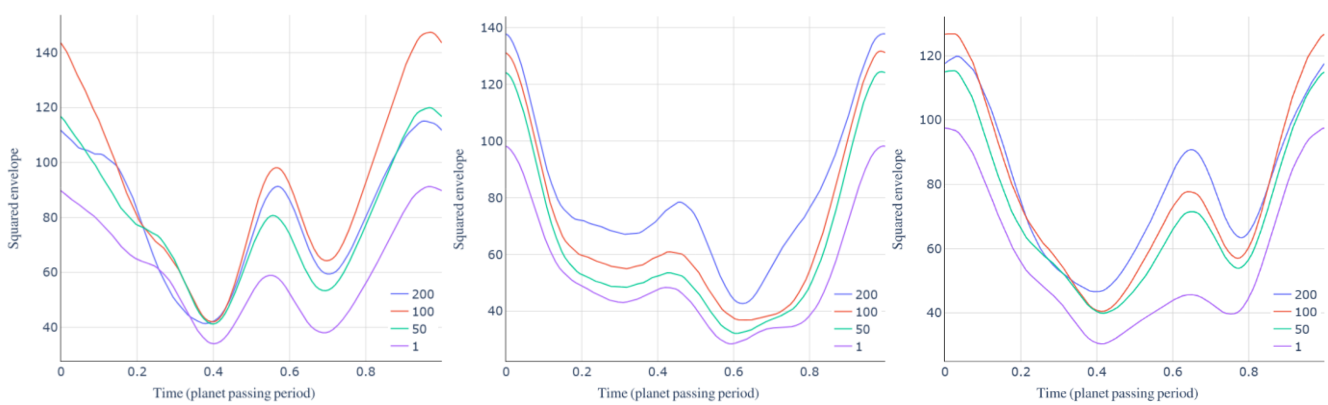

Figure 2 TSA with respect to planet passing the sensor for different files (125% rated load). Left RR sensor, middle RF sensor, right RL sensor.

It is clear that in all three sensors there is already a fault peak present from the first file provided which can be explained by the fact that the first file provided is in fact the third load cycle. The final indicator chosen will then be the average value of the TSA signal between 0.0 and 0.8 of the planet passing period as seen in Figure 2, in order to exclude the high values due to the planet passing the sensor. This results in a trend that starts from file 1, which prohibits the selection of a healthy reference section for confident detection.

In the practical case when the operator does not have a healthy reference, a single reading is often not enough to obtain confident detection. Therefore, the operator will rather look if the indicator is trending with the subsequent measurements and monitor if the indicator is trending. Therefore, the confident detection can be quantified by the certainty if the indicator is trending or not. For this the Spearmann correlation coefficient will be used which quantifies the monotonicity of the indicator.

To determine confident detection, the p-value will be used for a hypothesis test whose null hypothesis is that the indicator has no trend, with alternative hypothesis that there is a positive trend. If this p-value drops below 0.00135 (the same p-value as a threshold at 3-sigma deviation of a gaussian) then it can be confidently said that there is a trend in the indicator. Note that with this p-value threshold, a perfectly trending indicator will give a confident detection the earliest at file 6.

This p-value threshold is crossed at the files (one-indexed) as shown in Table 1. Note that all these crossovers are quite close to the lower bound of file 6 indicating clear crack growth at the start of the test.

	RL	*RF*	*RR*
125% rated load	8	7	8
100% rated load	22	16	7

4. Fault Progression Trending Curve

The best trending sensor is the RF sensor which is likely due to the fact that this sensor is closest positioned to the fault.

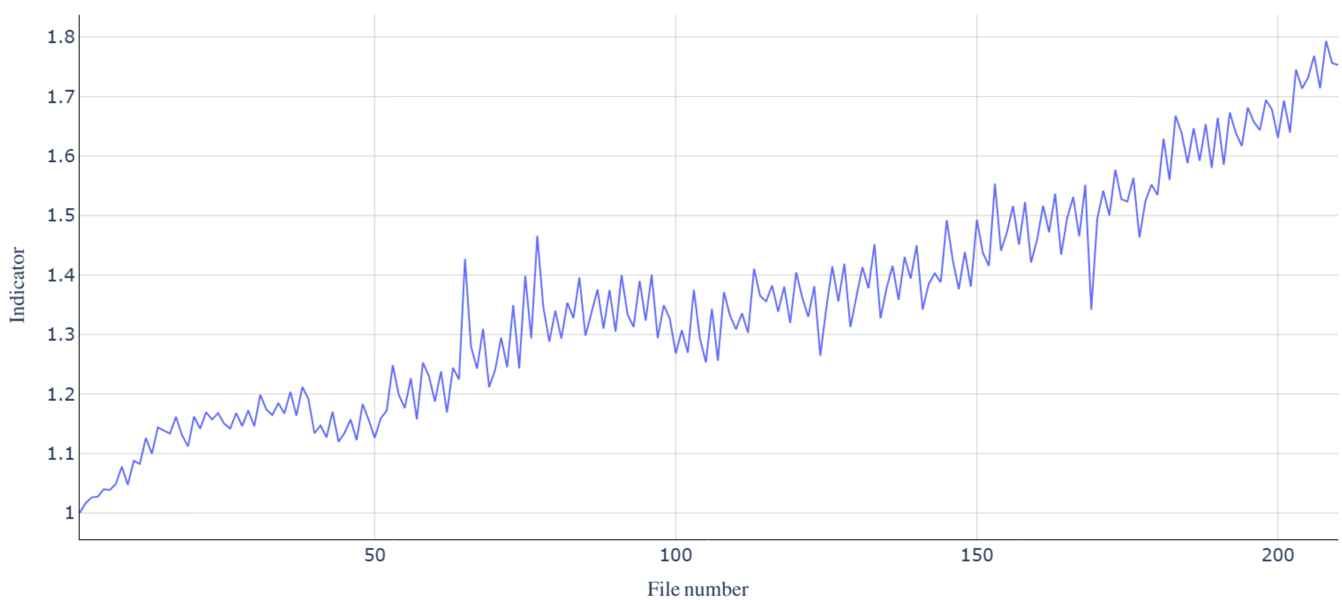

Figure 3 Proposed indicator applied to the RF sensor (125% rated load). Indicator values normalized with respect to the first recording.

The proposed indicator shows clear growth in the first 20 files followed by a slower growth rate and finally once again a faster growth near the end. This unsmoothed indicator has a clear trend with a Spearmann correlation coefficient of 0.953 (a perfectly monotonously increasing indicator would have a correlation coefficient of 1.0).

The results for the proposed indicator at 100% rated load are shown in Figure 4. Here there are significant dropdowns occurring after the nightly shutdowns. These are likely due to the setup (and the oil) being colder than the other measurements which will influence lubrication conditions. The 125% rated load measurements are not as affected as the 125% rated load files are recorded every day after running through the 100% load for some time.

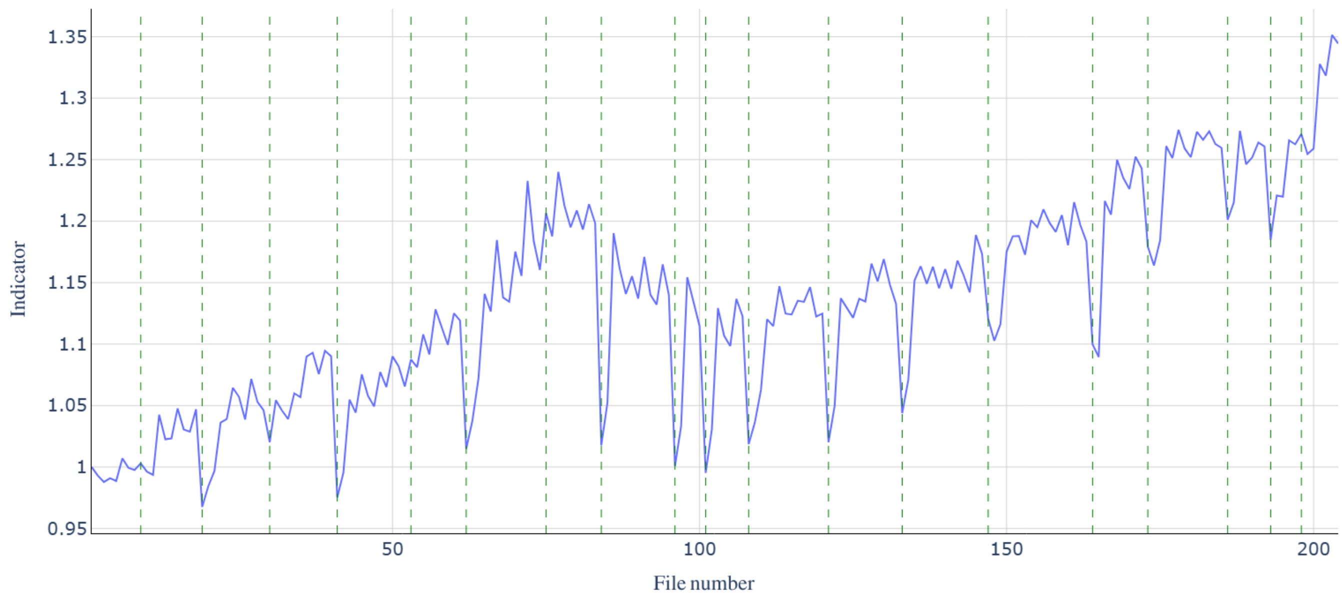

Figure 4 Proposed indicator applied to the RF sensor (100% rated load). Indicator values normalized with respect to the first recording. Green lines indicating the first file after nightly shutdowns.

5. Acknowledgements

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