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Statistical-vibratory analysis of wind turbine multipliers under different working conditions

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The aim of this research is to analyse the effect of different working conditions of wind turbines and sensor placement in fault diagnosis of a wind turbine multiplier.

The Hilbert-Huang transform has been selected to decompose and analyse the vibratory signals obtained from the gearbox. This method is divided in two fundamental steps [2]: first, the original signal is decomposed into Intrinsic Mode Functions (or IMF for short) through Empirical Mode Decomposition, then, the IMF which contain the frequencies of interest are transformed to obtain the instantaneous frequency of the signal and its energy. This methodology has been proven as the most reliable to extract the necessary information of the vibratory signals [3].

Four wind turbines were selected to be analysed from a wind farm located in the Canary Islands (Spain). These wind turbines contain a three-step multiplier gearbox with a ratio of 1 to 59.5, and meshing frequencies located at 31, 122 and 455 Hz.

The vibratory signal for each sensor was decomposed into 16 IMF, and the meshing frequencies were found at IMFs 4, 6 and 7. No defect presence was detected directly, since these units are well maintained. A posterior visual inspection performed on each gearbox confirmed this.

Different load cases were analysed to assess the performance of this methodology, by comparing the results obtained from a minimum power output state (wind speed < 3.5 m/s) and peak power output state (wind speed > 15 m/s). The results obtained show that the algorithm was able to correctly detect the meshing frequencies in both scenarios, and no single defects were found, with the only difference being the magnitude of the acceleration signals and energy spectrum, as it would be expected.

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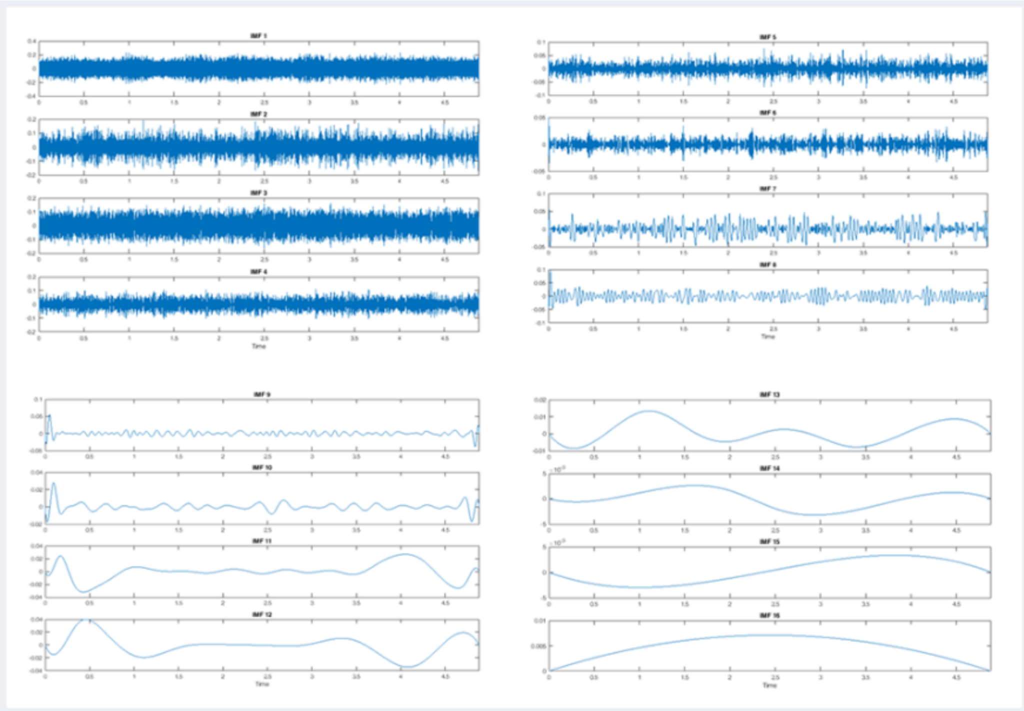

Figure 1: Acceleration signal decomposition into 16 IMF.

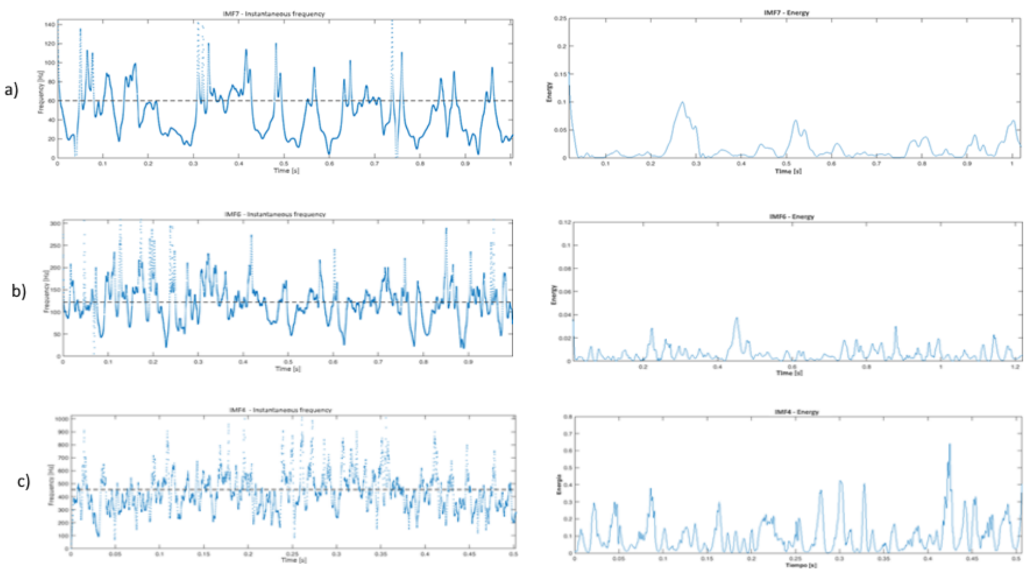

Figure 2: Instantaneous frequency (left) and signal energy (right) plots for three IMF: a) IMF7 [455 Hz], b) IMF6 [122 Hz], and c) IMF4 [31 Hz].

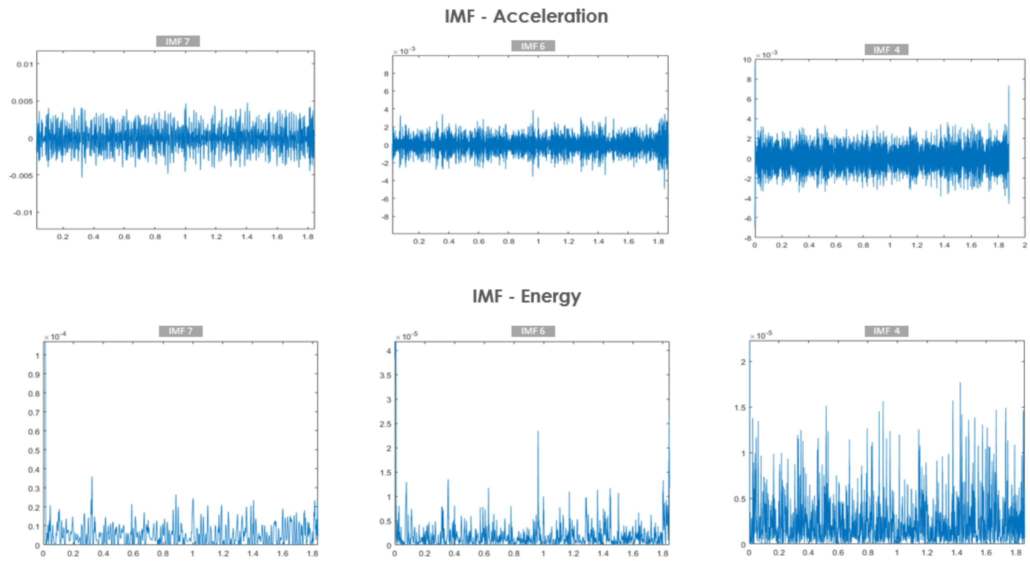

Figure 3: Acceleration data and signal energy for IMF 7, 6, and 4 (left to right) in a low power working condition (< 3 m/s wind speed).

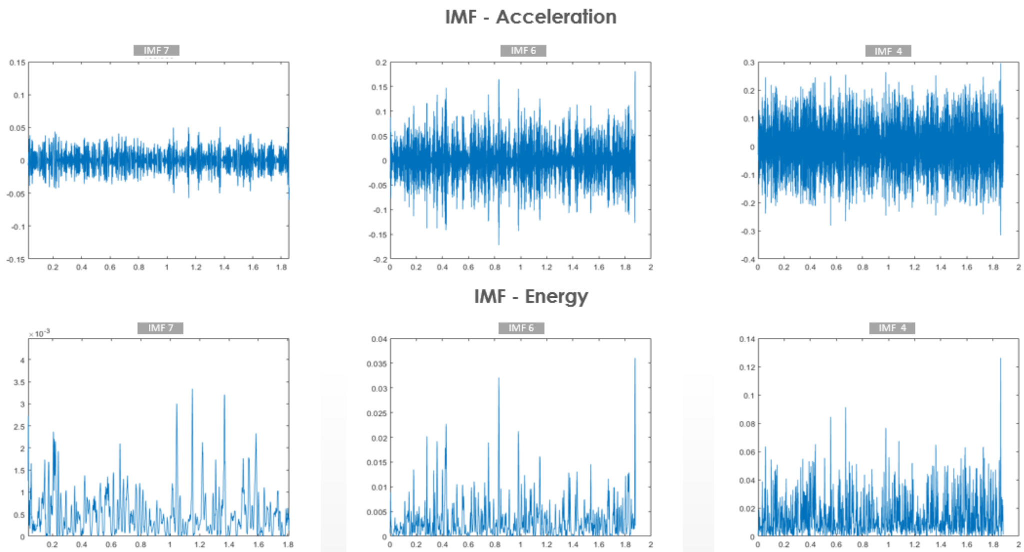

Figure 4: Acceleration data and signal energy for IMF 7, 6, and 4 (left to right) in a peak power working condition (> 15 m/s wind speed).

Different locations of the accelerometer sensors were also reviewed. The gearbox casing allows to install sensors in three different directions: radial, tangential and axial. Therefore, these three cases were tested in order to obtain the best location for the sensor location.

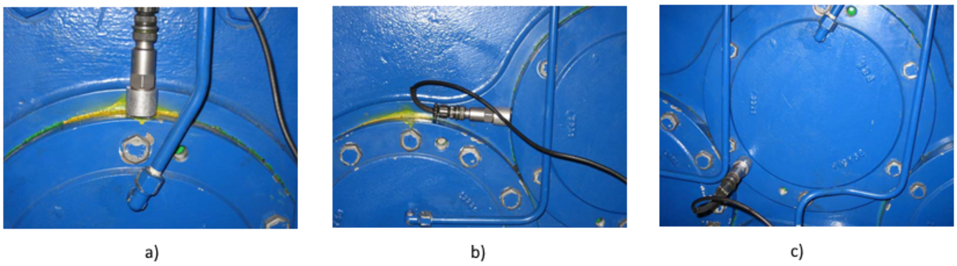

Figure 5: Sensor placement for each possible configuration: a) radial, b) tangential, and c) axial.

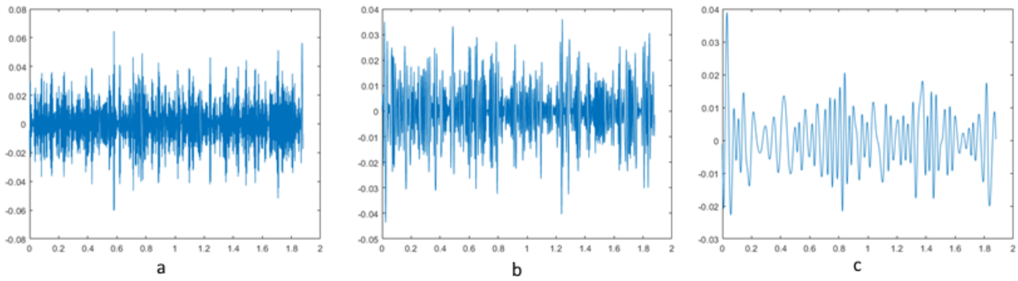

Figure 6: Acceleration plot in a 2 second time window for three different sensor directions: a) radial, b) tangential, and c) axial.

A first review of the signals obtained from each position reveals that both radial and tangential directions offer better results at detecting and obtaining the frequencies of interest, this is due to the higher intensity of the signal since most vibrations produced by the gears are transferred to the structure in these directions.

Finally, all different positions and directions were tested for each gear stage in all possible configurations, as shown in Figure 7.

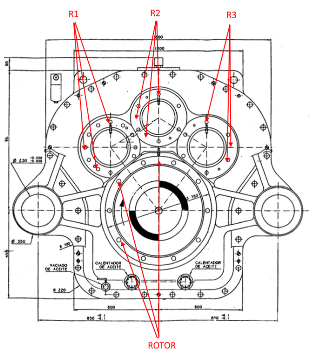

Figure 7: Sensor location in the gear box for all different possible configurations.

Statistical analysis of all collected data shows that the success rate for detecting and obtaining these vibratory signals of each step is higher for the radial and tangential sensor positions.

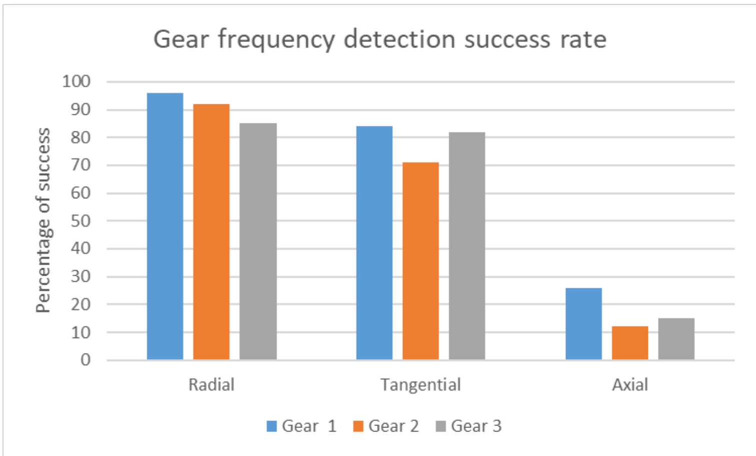

Figure 8: Percentage of success in meshing frequency detection for all three possible directions: radial, tangential, and axial.

In summary, in this work a methodology for analysing vibratory data of wind turbine gearboxes has been selected, and the necessary algorithms to process acceleration signals from the sensors installed, which can be run autonomously to process large sets of data were developed.

Data was collected and analysed from three different wind turbines during a period of two months, which, after extensive review, lead to the conclusion that the best location for obtaining the vibratory signals of interest is directly on the gearbox casing, at radial or tangential directions.

It was also obtained that different wind turbine regimes affect the obtained data by modifying its magnitude, but the necessary information can still be extracted for all possible working conditions.

For future work, different wind turbine models will be analysed, and the described methodology will be further validated by testing it in a known problematic gearbox.

References

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