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Title: Non-invasive analysis for detecting gear fractures in automotive transmissions

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Presentation content

Introduction

Vibration analysis has emerged as a key technique in predictive maintenance strategies, aimed at detecting early signs of mechanical faults. This study contributes to this field by focusing on the behavior of vibration signals in damaged gears, offering insights into how frequency domain characteristics vary with different types of gear faults.

The objective of this work is to analyze vibration signals to detect and classify gear faults by inducing damage in a gear within a manual transmission. The study aims to identify how the frequency domain characteristics of the vibration signals change as gear damage progresses, providing a basis for early detection and predictive maintenance strategies.

Figure 1. Example of vibration analysis in rotating machine.

Introduction

The performance of the analysis was evaluated by inducing varying degrees of damage to the gear and capturing vibration signals under different operational conditions. Through frequency domain analysis, key indicators of gear failure were identified, and the variation of signal characteristics with respect to fault progression and frequency variations was observed. The results demostrated a clear correlation between specific frequency peaks and the severity of gear damage, validating the approach as a reliable tool for fault detection.

Figure 2. Gear with fractured tooth.

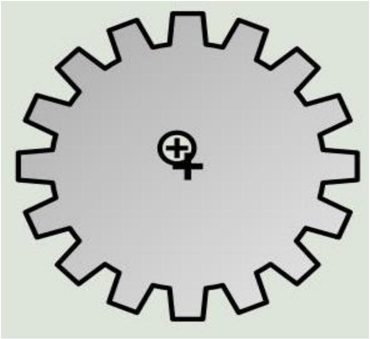


Figure 3. Gear with eccentricity.

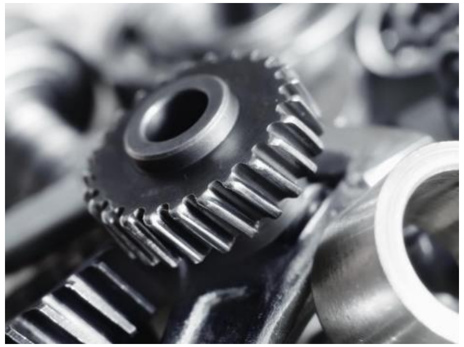
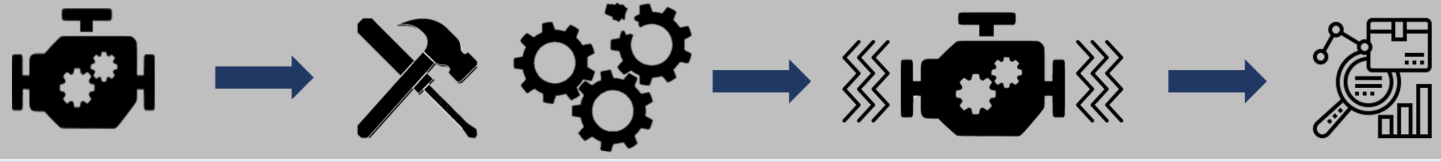


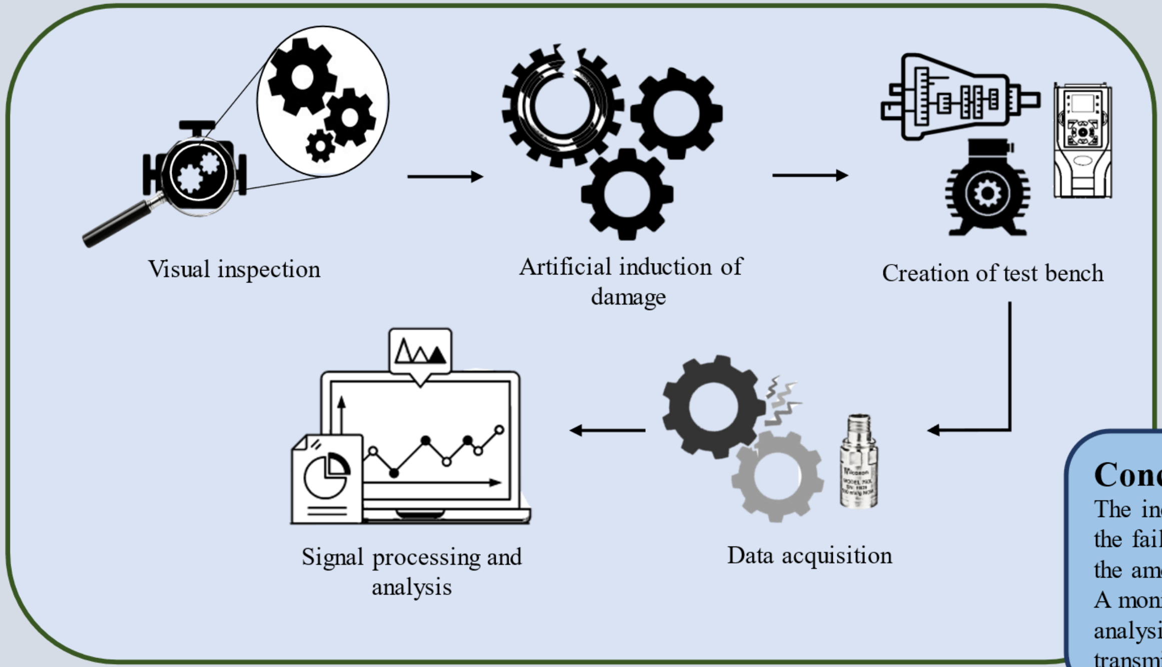
Figure 4. Gear in healthy condition.

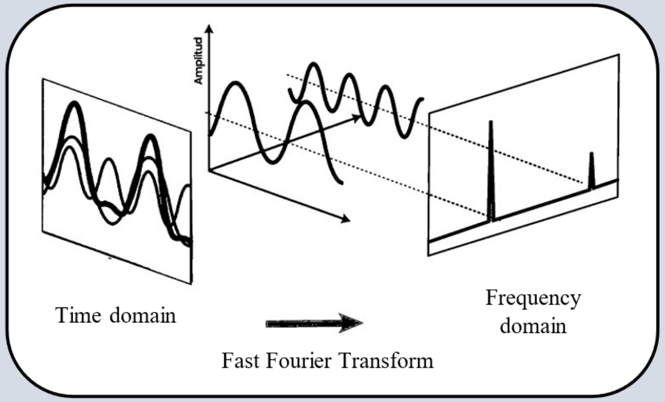
Visual abstract

Objective



Metodology





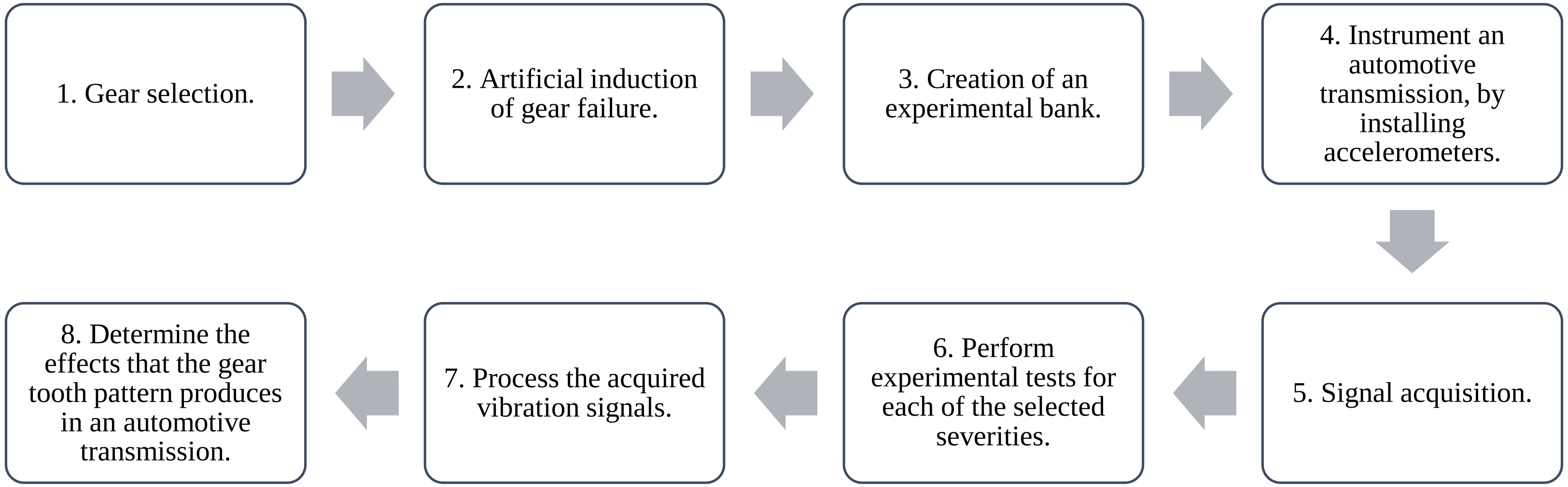
Conclusion

The increase in vibration levels in the transition is associated with the severity of the failure that may be present, that is, the partial fracture of a gear tooth increases the amount of vibrations and affects the operation of the transmission itself.

A monitoring and diagnostic condition methodology was established based on the analysis of vibration signals for the detection of faults in automotive manual transmissions.

Methodology

The methodology began with the selection of a gear in a manual transmission, checking whether it presented the failure to be studied. After selecting the gear, damage was induced manually. Then, an experimental bench was created to simulate different operating conditions (rotation speeds) and acquire a database. The transmission was instrumented with accelerometers, and the signals were acquired using the NI SCXI-1530 vibration monitor, with simultaneous sampling. Experiments were performed with the gear in optimal and damaged states to compare results. Signal processing was performed using FFT to analyze frequency components, complemented with time domain analysis calculating the rms value. Finally, changes in the signals were analyzed to determine the impact of the damage on the gear.



Methodology

Gear selection

1. Front housing.
2. Front cover.
3. Rear housing.
4. Gear lever connection.

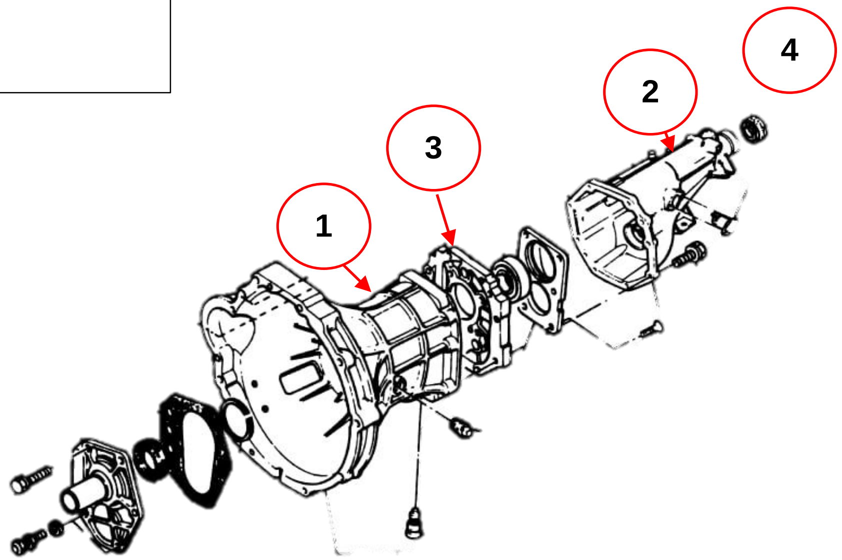


Figure 5. Support image to understand the disassembly process.

Methodology

Artificial induction of gear failure

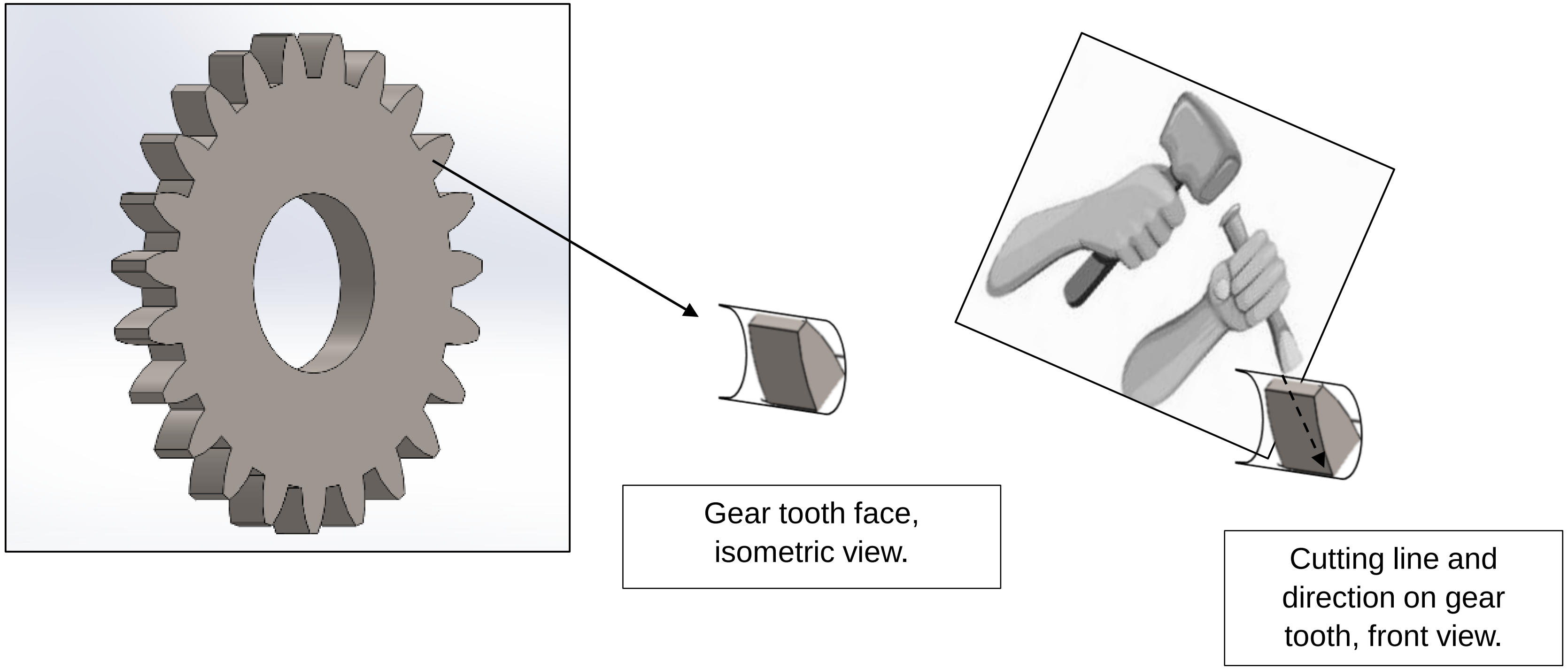


Figure 6. Failure induction process.

Methodology

Creation of an experimental bank

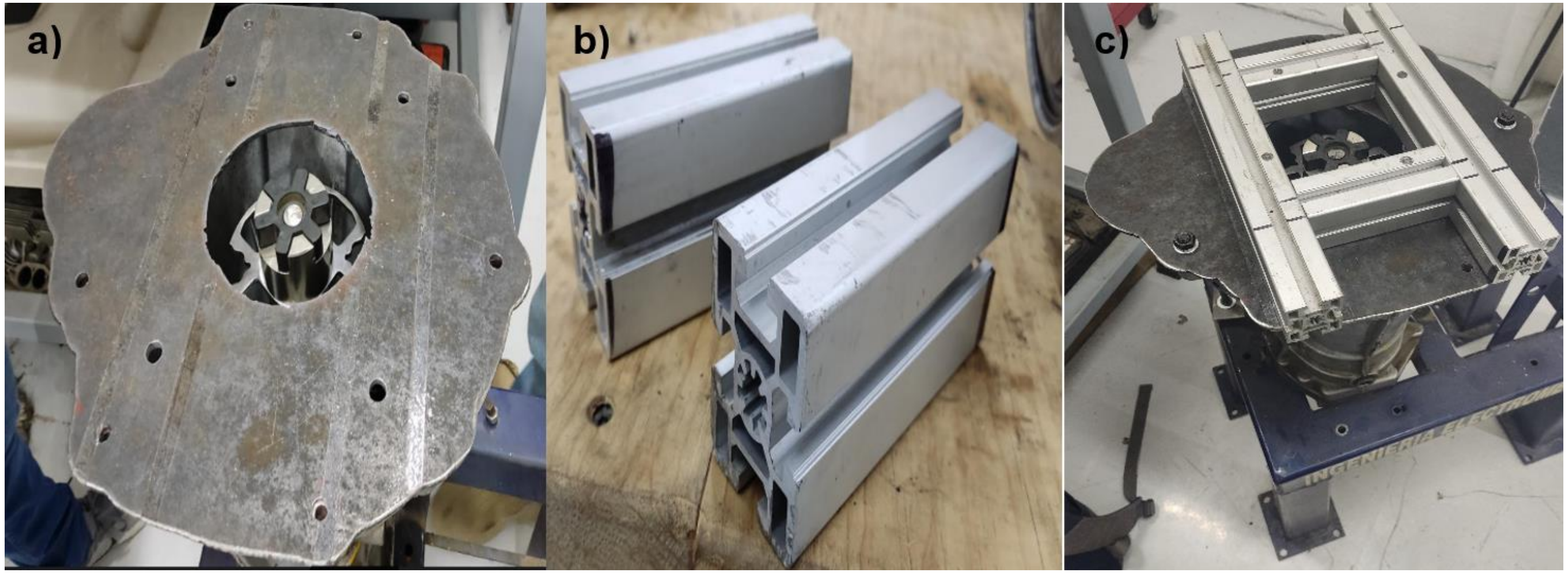


Figure 7. (a) Experimental bench. (b) Base for mounting the motor.

(c) Cut in Bosch profiles.

Methodology

Instrument an automotive transmission, by installing accelerometers

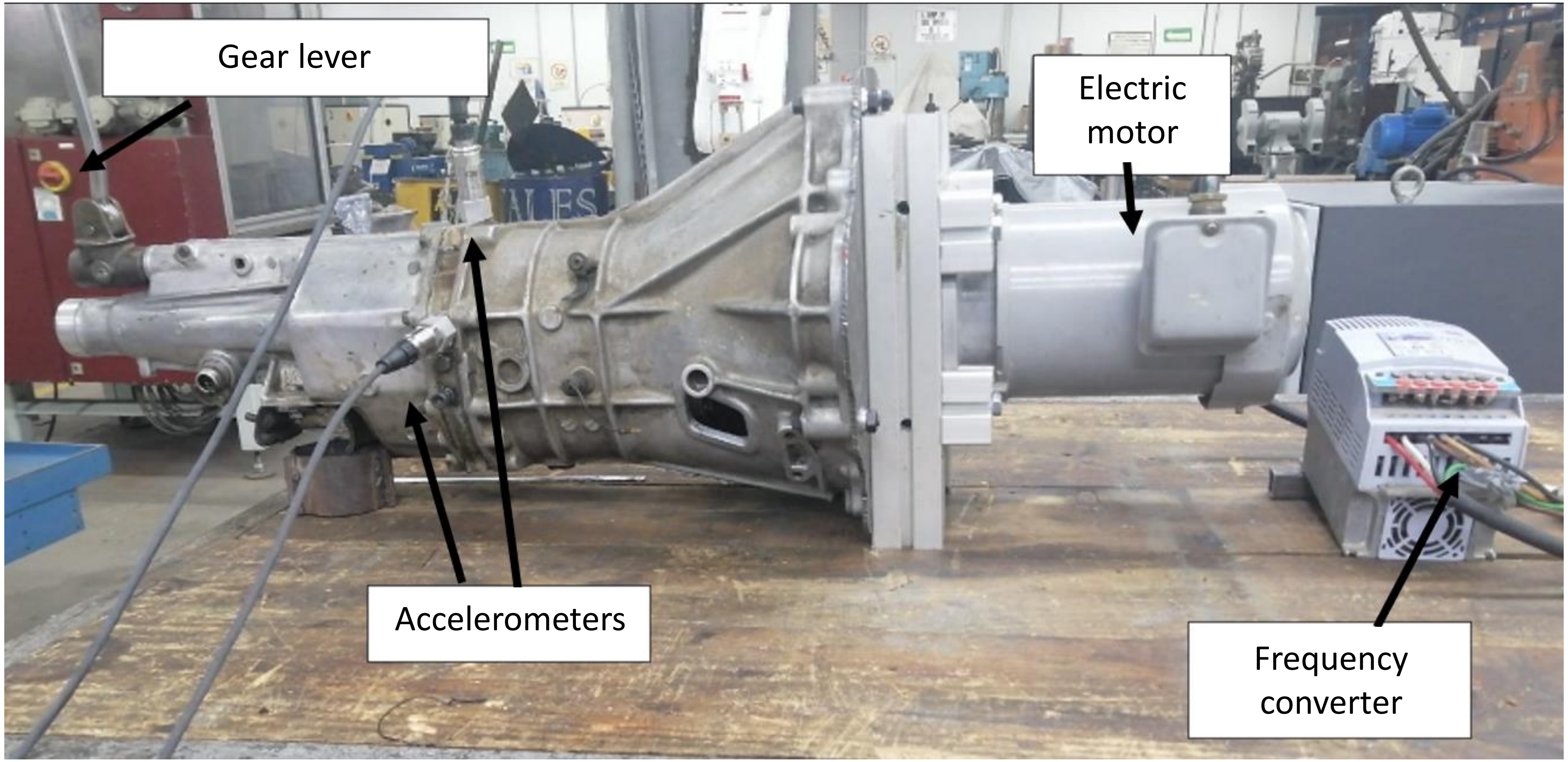


Figure 8. Instrumented automotive transmission.

Methodology

Frequency domain processing

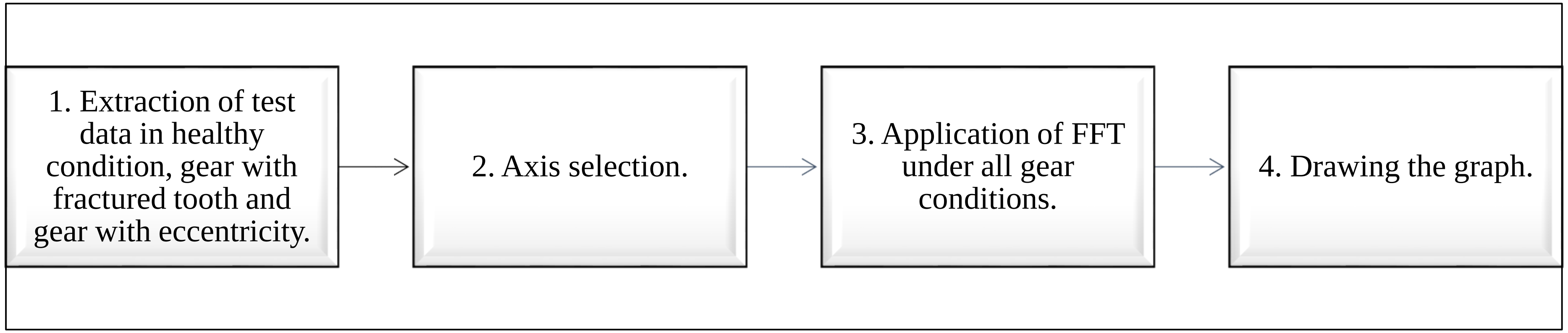


Figure 9. Phase diagram of the code for frequency domain processing.

Results

The Figures 10 and 11 show that the vibration amplitude of a healthy gear remains relatively low and stable throughout the frequency range shown. The amplitude of a gear with a fractured tooth can cause peaks at certain frequencies due to the additional vibrations generated by the damaged tooth. Regarding the amplitude of the gear with eccentricity, it presents a pronounced peak around 145 Hz and 203 Hz, indicating a much more intense vibration at this frequency compared to the other conditions. This may indicate a critical condition and require immediate attention, since uncontrolled eccentricity can lead to failures in the automotive transmission system at a global level.

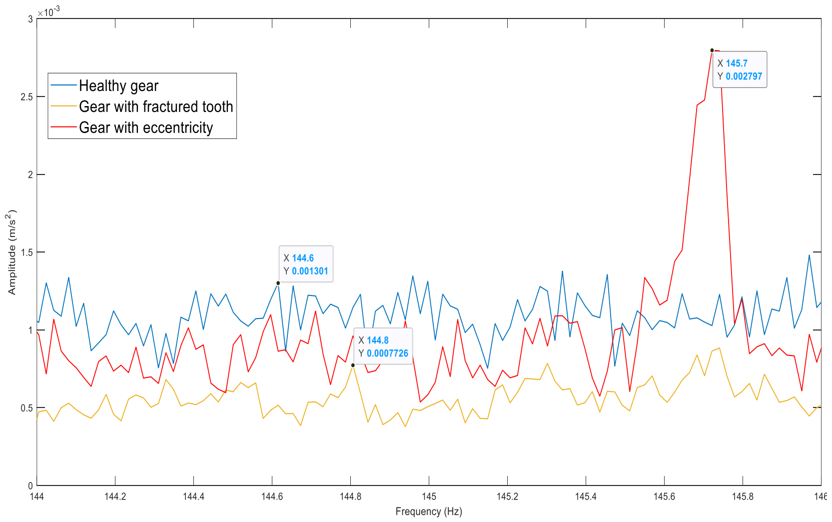


Figure 10. Vibration spectra of the experiment with the frequency converter at 30Hz (x axis).

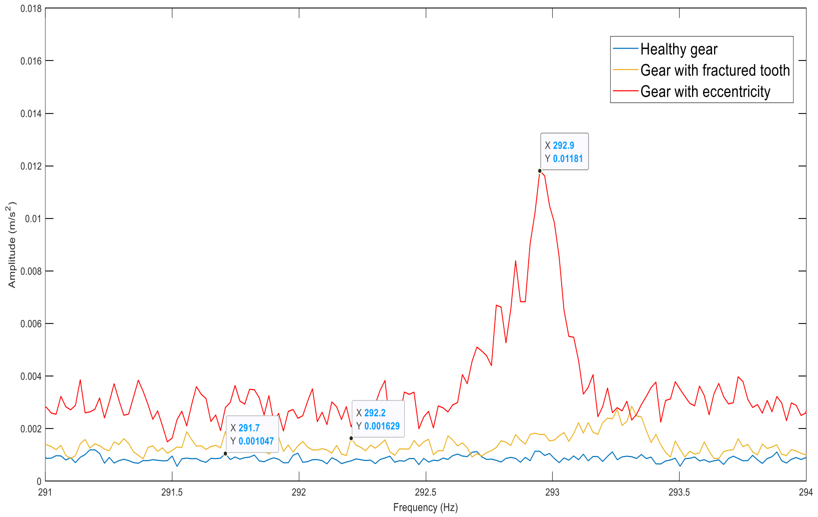


Figure 11. Vibration spectra of the experiment with the frequency converter at 60Hz (x axis).

Conclusions

The significant difference between the gear states suggests that it is possible to distinguish between different types of failure using this method. Furthermore, it can be mentioned that the increase in vibration levels during the transition is related to the severity of the current failure. For example, a partial fracture in a gear tooth increases vibrations and affects the operation of the transmission.

However, vibrations caused by an eccentric gear could be critical and potentially cause structural damage to the entire transmission.

Finally, this paper presents a methodology to assess the condition of a gear through monitoring and diagnosis based on the analysis of vibration signals for fault detection in automotive transmissions.

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