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The application of time-frequency methods of acoustic signal processing in the diagnostics of tram drive components

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Abstract: The paper presents the course of investigations and an analysis of the possibilities of application of time-frequency methods of acoustic signal processing in the assessment of the technical condition of tram drive components. A pass-by acoustic pressure emission experiment was preformed on a Solaris Tramino S105p. An analysis of the recorded signal was carried out using Short-Time Fourier Transform (STFT) and Continuous Wavelet Transform (CWT). It was confirmed that the potential damage of a drivetrain is characterized by the formation of high amplitude frequency components that do not occur in fully operative systems. The highest number of these components occurs in the frequency band of 0-3.2 kHz. The authors also observed that, owing to its signal window scaling functionality, CWT is a more efficient tool in time-frequency signal interpretations compared to STFT.

Keywords: vibroacoustic diagnostics, time-frequency methods, STFT, CWT

1. Introduction

In maintenance of machinery, including rail vehicles, one of the most efficient and economical methods of diagnostics of the technical condition of an object is the analysis based on the processing of vibroacoustic signals, i.e. the time realizations of wavelet phenomena, representing mechanical and acoustic vibration as accompanying processes. The variability of signals in time in a wide band of frequencies constitutes a vast source of information that is sensitive to any variations in the system, which also includes damage [1].

In the presented work, the authors used STFT in equation 1 and CWT described by equation 2 for the time-frequency decomposition of the acoustic signal recorded by the measurement matrix during a pass-by test of a Solaris Tramino S105p rail vehicle [2].

$$STFT[x_w(t,\tau)] = \int_{-\infty}^{\infty} w(t,\tau)x(t)\cdot e^{-i2\pi f t}dt \tag{1}$$

where $x(t)$ – representation of the input signal under analysis in the time domain, τ – position of the floating window in the time domain, $x_w(t,\tau) = w(t-\tau)x(t)$ – separated segment of data under analysis.

$$CWT_\Psi(a,b) = \frac{1}{\sqrt{a}}\int_{-\infty}^{+\infty} x(t)\cdot \Psi^*\left(\frac{t-b}{a}\right)dt \tag{2}$$

where $\Psi(t-\tau)$ – base wavelet (mother function), x(t) – continuous signal in the time domain, a – scale parameter, b – displacement parameter (position), Ψ^* – function conjugate $\Psi(t-\tau)$.

2. Results and Discussion

The comparison of the STFT spectrograms obtained for the signal originating in a pass-by of an operative as well as damaged vehicle has been presented in Fig. 1. A damaged part of the drivetrain located in the third bogie of tram 554 is characterized by the formation of high-amplitude frequency components in the band 0-3.2 kHz that do not occur in the characteristics of a bogie of a fully operative vehicle. The CWT scalogram presented in Fig. 2, due to its different method of signal window formation, differs from the spectrogram of vehicle 554 and differently presents the high-amplitude components.

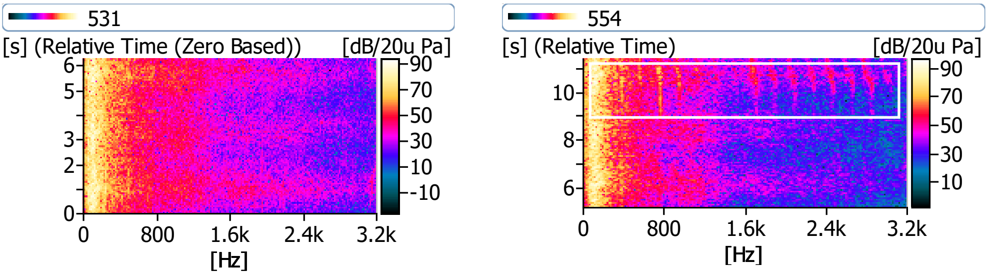

Fig. 1. The comparison of spectrograms for a undamaged vehicle (left) and a vehicle with third bogie's drivetrain damaged (right) with high-amplitude frequency components marked

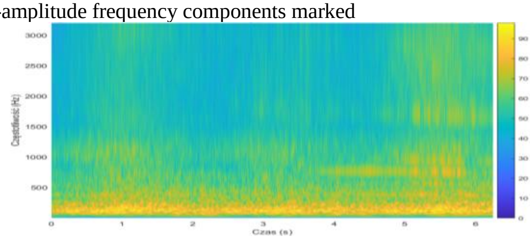

Fig. 2. CWT Scalogram of vehicle 554 – Morse wavelet of densified scaling applied

3. Concluding Remarks

During the investigations, the authors have confirmed that damage of tram drive components can be identified through the measurement of the acoustic signal and its decomposition using STFT and CWT. The modification of the parameters of both transforms may have impact on the obtained results and their interpretation. CWT allows the obtainment of a more accurate time-frequency representations owing to the use of scaled windows, contrary to the constant resolution windows characteristic of STFT.

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