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Joint Doctoral School

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Department of Transport Systems, Traffic Engineering and Logistics

Method of Assessing the Condition of Wheels of Wheelsets of Railcar During Railroad Drive

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Abstract

Effective condition monitoring and maintenance of wheels of wheelset of railcars require ongoing diagnostics of the technical condition of the vehicle components, in particular the wheel systems. The condition of the railcar wheels determines the efficiency and safety of the rail vehicle traffic. In this light, this dissertation presents a method for assessing the wheel condition of a railcar during railroad drive operations. The study aims to diagnosis the condition of tram vehicle wheels using micro-electromechanical systems (MEMS)-based accelerometer sensors that record rail vibrations during the passage of the vehicles. The study analyses sensor signals in the time-frequency domain to assess the condition of wheels during railroad drives.

The developed method for processing the collected sensor data is based on assessing the energy of vibrations at different frequency bands. The wavelet-based maximal overlap discrete wavelet packet transform (MODWPT) is chosen as the basis for processing. As a criterion for assessing the wheel conditions, the relative weighted difference (DW) between the extreme values of the vibration energy of “good" and damaged wheels in a given frequency range is proposed. Optimisation of transform parameters is carried out, the type of base wavelet used, the required level of decomposition and characteristic frequency bands are determined to be an important parameter for the assessment of the condition of the wheels. The optimisation task is carried out using data from initial vibration measurements during tram journeys in the depot.

The study validates the method during field test drives sessions of trams on shunting tracks at the tram depot using a prototype accelerometer sensor based on MEMS technology. The MEMS sensor with 3-axis is mounted underneath of rail track and utilised to record the vibrations of the running wheels. The recorded acceleration is sampled at a frequency of 1 kHz. During drive test sessions, the vehicle was fitted with wheels damaged to varying degrees. The energy of the recorded signals is calculated using the

MODWPT transform coefficients with the Coiflet3 base wavelet at the 8^{th} decomposition level within the frequency band of 420 – 422 Hz.

The results of the validation confirm that the possibility of using sensors in MEMS technology to assess the condition and, above all, to signal passages with damaged wheels. The use of the MODWPT transform effectively describes vibration anomalies, and thus indicates damaged wheels. The established parameters of the MODWPT transform may need to be corrected when the drives are made on tracks in a poor technical condition and when the travel speeds exceed a few km/h. The developed method has been successfully used to detect the wheel fault conditions while driving.

In conclusion, the study demonstrates the potential of MEMS accelerometer sensors and MODWPT transform for assessing the condition of wheels of the wheelsets systems in the railcars. The developed method shows promise in detecting wheel fault conditions during tram operation, which can improve maintenance practices and ensure the safety of rail vehicle operations. Future research may delve into identifying and categorising sources of vibration energy anomalies within specific frequency bands, evaluating the size and type of wheel damage, integrating supplementary measuring tools with MEMS accelerometers, and implementing machine learning-based techniques for comprehensive wheel condition diagnosis and maintenance strategies.

Keywords: wheel fault condition assessment; MEMS-based sensor; MODWPT; wavelet coefficient; weighted difference; decomposition level; vibration energy; frequency band.