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Determination of dynamic parameters of parts of a tram wheel in a numerical and experimental modal analysis

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Abstract: During the investigations, the authors performed a numerical model of a system composed of a rim and an inner disc of a wheel fitted in a Konstal 105Na tram followed by a frequency analysis in Solidworks aiming at determining the frequencies and the form of natural vibration. The simulation results were compared with the results of the experiment utilizing an impact modal hammer and piezoelectric transducers. When analyzing the measurements, the authors applied FRF and CMIF. This allowed the obtainment of frequency characteristics of the vibroacoustic response to the impact, the visualization of the form of natural vibration and the determination of the dynamic parameters of the actual object. Similarities and potential sources of differences between the numerical and the experimental results were identified.

Keywords: modal analysis, rail vehicle, natural vibration

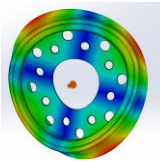
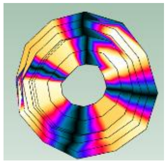
1. Introduction

The determination of modal parameters frequently takes place in the analysis of vehicle dynamics and in the diagnostics of the vehicle components. The analysis of the properties of a solid, its mass, rigidity and mutual interactions with the environment allows determining the conditions of resonance and the impact of the formed or propagating damage [1]. In this paper, the authors performed an analysis of the similarities between the modal characteristics of a numerical model of parts of a tram wheel and the experimental results. A simulation-based determination of frequency and form of natural vibration of a wheel of a rail vehicle has been described in [2], however, the conditions and the impact of the vehicle dynamics on the generated vibration were presented when the vehicle was stationary under gravitational loads only.

2. Results and Discussion

Based on the detailed results, 13 natural vibration frequencies were selected in the range 0-3000 Hz. The selection was made based on: FRF and CMIF characteristics, correlation matrix between the modes and similarity of forms obtained in the numerical analysis (Solidworks) and the experiment.
Out of 13 modes, only one experimental result did not have its numerical counterpart, which most likely resulted from a small groove in the rim material in the vicinity of one of the transducers. In the outstanding cases, the experimental and numerical values varied by 244.6 Hz maximum and 0.5 Hz minimum. Table 1 presents the comparison of the frequencies and natural vibration forms obtained numerically and experimentally.

Table 1 Comparison of a selected frequency and form of natural vibration determined numerically and experimentally

Natural vibration frequency (simulation)	Form of natural vibration (simulation)	Natural vibration frequency (experiment)	Form of natural vibration (experiment)
524,1		524,6	

The authors have observed that for the same (or very close) frequency, some modes assume similar forms only turned by a certain angle against the axis of the wheel, the value of which depends on the form of the mode. This is the case for both the low frequency vibration related to the object inertia and for the more non-uniform forms. The determined natural vibration frequencies were characterized by a low damping coefficient (except the first two modes) and a varied percentage of form complexity.

During the experiment, the most difficult was the extraction of the modes having displacements towards the longitudinal axis of the wheel and having revolutions around it. The closest to the numerical analysis were forms characterized by the symmetrical displacement of the rim.

The reasons for the differences between the experimental and simulation results were divided into those resulting from the mere measurement methodology, the quality of its performance and the numerical limitations.

3. Concluding Remarks

Upon detailed analysis of the results of the experiment, 12 forms of natural vibration were selected that are also reflected in the simulation and one form that may potentially be correlated with the structure of the rim. The modes differed among one another with their damping coefficient and complexity.

The experimental results, upon appropriate selection in the post-process, can be deemed more reliable than the theoretical ones, determined numerically due to the fact that a greater number of external factors was taken into account, high sensitivity of the measurement equipment and a better calculation accuracy of the BK Connect software. The frequency analysis carried out in Solidworks helped planning the experiment, including the selection of the frequency ranges and the initial illustration of the expected measurement results, yet, its application cannot not always stand in place of the actual object examination, due to, *inter alia*, simulation-related limitations of the software.

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