MOUNTAIN-PLAINS CONSORTIUM

RESEARCH BRIEF | MPC 24-571 (project 672) | October 2024

Local Resonances in Rail Structures

the ISSUE

Inspecting railroad rails is an expensive and labor-intensive process, which is essential for safe and efficient railroad operations. The cost of inspecting tracks can be as much as $10,000 per mile. New approaches to this process are needed that will reduce costs while assuring the safety and integrity of rail lines. Zero-group velocity (ZGV) mode, a form of ultrasonic vibration, generates local resonances that appear as distinct, sharp peaks in the amplitude spectrum and whose resonant frequencies can serve as indicators of structural integrity. Although ultrasound is used to evaluate rails, there is no research related to local resonances as an approach to evaluate railway track structures.

the RESEARCH

Local resonances appear as distinct, sharp peaks in the frequency amplitude spectrum, whose resonant frequencies can serve as indicators of structural integrity condition. Given these indicators of structural integrity condition, a research team from the University of Utah explored the existence of local resonances and approaches to promote these resonances as a means of evaluating railway structure condition.

To better understand these interesting modes, the research team used a semi-analytical finite element analysis to compute dispersion curves of a standard rail cross-sectional shape and to identify potential ZGV points and backward waves, which were identified through opposing senses of group and phase velocities. They employed the frequency-domain and time-dependent finite element model to simulate responses of a free rail when subjected to impulse dynamic testing and harmonic excitations from piezoelectric devices. Experimental rail dynamic data were collected from a 25-meter free rail sample with multiple excitation-sensor configurations to understand the detectability and excitability of specific resonances associated with ZGV and cutoff frequency points in rails. Spatial sampling of wave disturbance is performed to calculate the dispersion relations experimentally via two-dimensional Fourier transforms (2D-FFT).

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Project Title

The Feasibility of Promoting Local Rail Vibrations Using Electromechanical Impedance Method

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the FINDINGS

The excellent agreement between simulation and experimental results confirms the existence of ZGV modes and cutoff frequency resonances in rails. The researchers found local resonances ranging from 5 kHz to 80 kHz using impulse-based dynamic tests and piezoelectric devices.

the IMPACT

The research will enable the implementation of local resonances for rail defect detection and rail thermal stress measurement. The Federal Railroad Administration and the Association of American Railroads have funded additional research on using local resonances for these two purposes. The method offers substantial benefits for local rail steel inspection because of its potential to isolate local rail behavior from the influences of rail fastener, tie connection, and foundation effects when collecting data away from the supports.

For more information on this project, download the Main report at https://www.ugpti.org/resources/reports/details.php?id=1239

For more information or additional copies, visit the Web site at www.mountain-plains.org, call (701) 231-7767 or write to Mountain-Plains Consortium, Upper Great Plains Transportation Institute, North Dakota State University, Dept. 2880, PO Box 6050, Fargo, ND 58108-6050.