Executing the modal analysis of a structure is crucial in order to analyze the modal parameters of a test object. The natural frequencies, damping and mode shapes of the unit under test provides help to adjust the mechanical properties of a structure by optimizing the design and improving the structural behavior of the test unit. Consequently, modal analysis is a critical part of product development.

This article examines the acquisition of modal characteristics from a train wheel through experimental modal analysis. Train wheel and rail interactions are an important subject to study. If the wheel-rail interactions while accelerating or braking excite any of the system modes during the ride operation, it can induce an undesirable effect upon the passengers' ride and comfort. Hence, the execution of modal analysis is vitally important.

A hammer impact test is carried out using a modal hammer and 5 uni-axial sensors to obtain the vibration characteristics of a locomotive wheel. The short pulse induced with a modal hammer excites a wide range of frequencies. Another advantage of a hammer impact test is the quick and easy setup process. The modal test is carried out with a roving excitation method to avoid the mass loading effect induced with a roving response measurement.

The efficient Spider-80Xi dynamic measurement system is used to execute the modal test. The latest 10.0 release of EDM Modal software is used to execute the hammer impact modal test.

Figure 1. Modal Hammer Testing of the Train Wheel

A mesh configuration of 144 measurement points is distributed radially and circumferentially over the train wheel to obtain a good spatial resolution for the mode shapes. Using a flexible band, the train wheel is hung to imitate a free-free boundary condition (as shown in the experimental setup). A modal hammer with a metal tip is roved through the various measurement points. The responses to the impact excitations are captured using 5 uni-axial accelerometers that are placed accordingly. Measuring the excitation and response in the vertical direction facilitates the procurement of "out-of-plane" mode shapes.

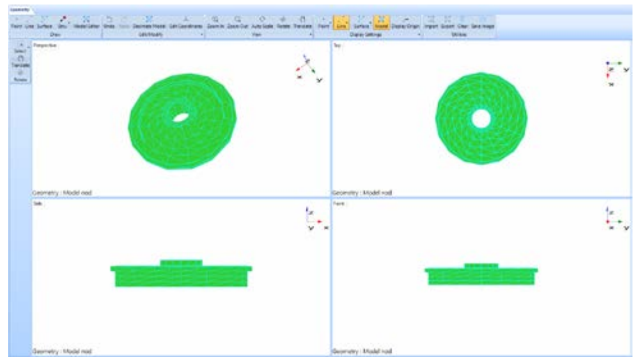

Figure 2. Train Wheel Geometry

For this modal test, the first 6 modes are of interest and therefore a sampling rate of 12.8 kHz is set. A block size of 16384 is selected. A fine frequency resolution of 0.781 Hz is produced with these configuration settings. Measurements of higher accuracy and reduced noise are obtained by linearly averaging 3 blocks of data at each measurement DOF.

The broadband spectrum from the metal tip on a modal hammer assists in exciting the modes up to a frequency range of 3 kHz. The large block size implemented helps ensure a natural decay of the structure response without introducing a conventional force-exponential window. Another added advantage of this block size is a finer frequency resolution. With this setup, there is no leakage, and a uniform window can be selected.

Figure 3. Hammer Impact Measurement of the Train Wheel

The DOF of the excitation and response for the measured FRF signals are switched automatically during roving excitation testing. This can be observed from the Modal Data Selection tab.

The FRF measurement displays good dominant peaks in the 0-3000 Hz frequency band. Overlapping the 720 measured FRFs, several modes can be identified. The good alignment of these peaks indicates good measurement results, and no mass loading effect was induced.

Figure 4. Modal Data Selection tab showing the magnitude and phase part of all overlapped FRFs

The Complex Mode Indicator Function (CMIF) is used to locate modes in the desired frequency range. In addition, the summed FRF is also observed to identify the modes. The new Poly-X (https://www.crystalinstruments.com/modal-analysis) method is used to curve-fit the FRF's to procure the following stability diagram. Six flexible modes are selected within the desired frequency range.

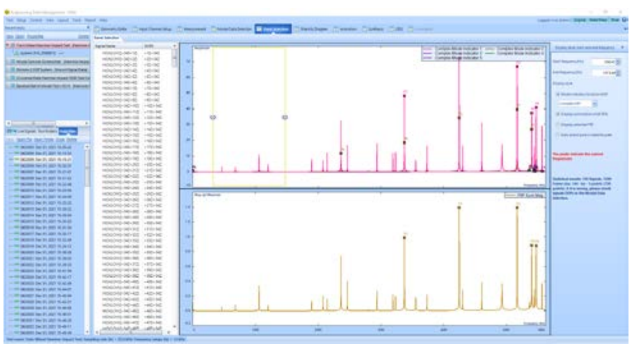

Figure 5. Mode Indicator Functions to locate and identify the modes in the desired frequency range

The stable poles (stable frequency and stable damping) are selected to obtain the natural frequencies and the damping ratios of the interested modes. The residue calculation facilitates in obtaining the mode shapes associated for each of the modes.

The Auto-MAC matrix helps users validate the results. The Auto-MAC matrix below shows users that the modes are orthogonal to each other (low off-diagonal elements) and are uniquely identified (high diagonal elements).

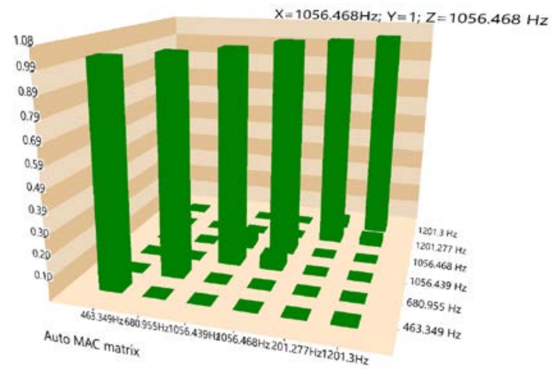

Figure 6. Auto-MAC chart for the identified modes

The 2nd order bending mode of the train wheel at 463.3 Hz is animated in the following screenshot.

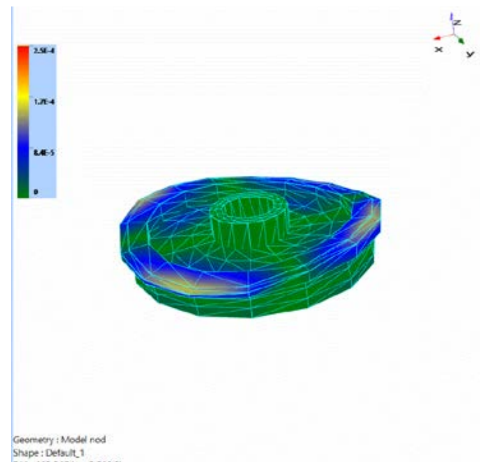

Figure 7. 2nd Order Bending Mode of the Train Wheel at 463.3 Hz

The following mode shows the bending vibration of the train wheel at 708.342 Hz.

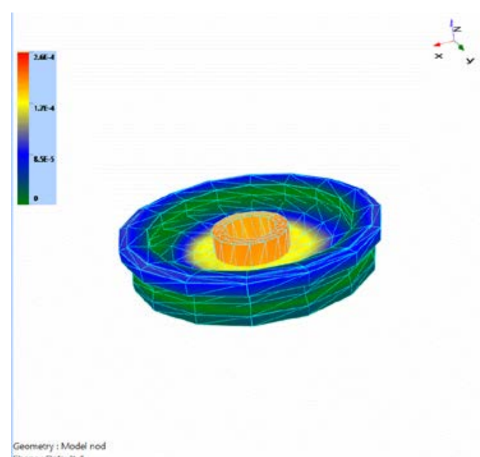

Figure 8. Bending Mode of the Train Wheel at 680.9 Hz

The following modes show the torsional vibration of the train wheel at 1056.439 Hz which is then shifted by 90 degrees at 1056.468 Hz.

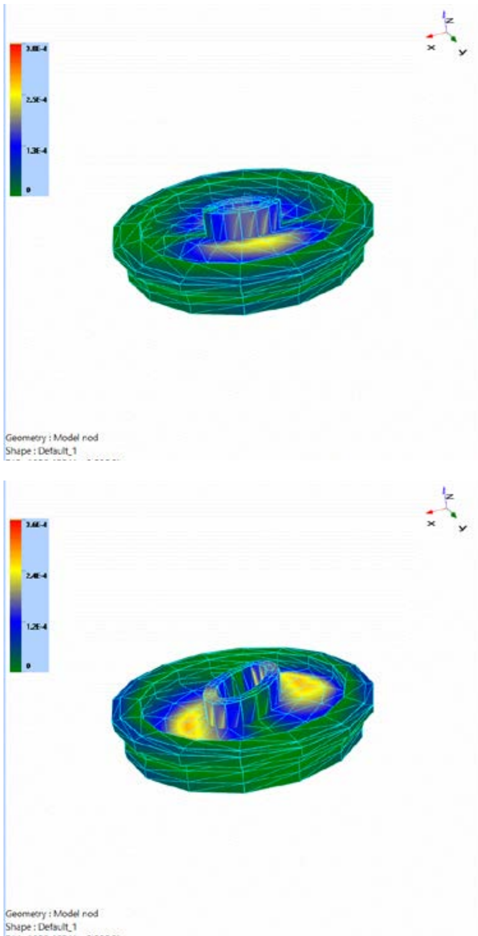

Figure 9. 1st Torsion Mode shifted by 90 degrees at (1056.439 Hz and 1056.468 Hz)

The following modes shown the 3rd order bending of the train wheel and how it shifts by 45 degrees within 0.023 Hz frequency.

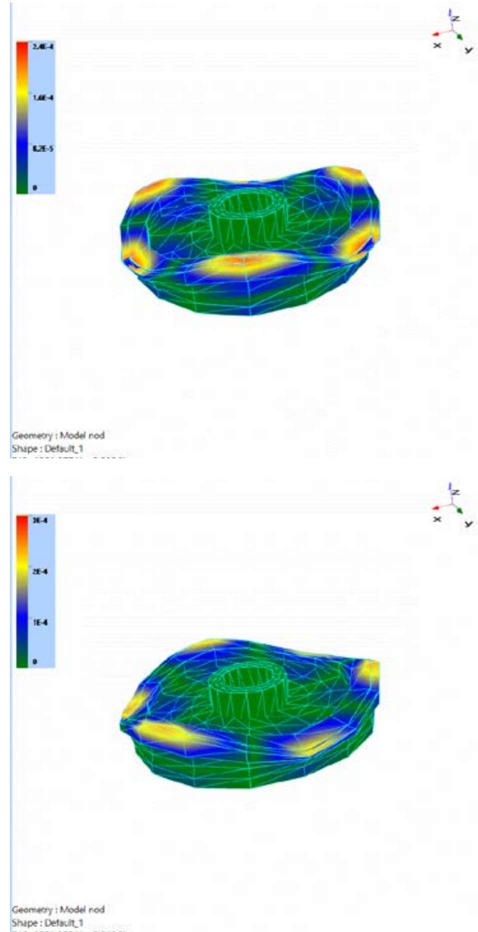

Figure 10. 3rd Order Bending mode shifted by 45 degrees (at 1201.277 Hz and 1201.3 Hz)

The modal analysis results show the practical use and application of modal testing on industrial structures. The results emphasize the strength of the Spider-80Xi DAQ system and the efficiency of EDM Modal software to execute sophisticated modal tests on intricate structures.

To learn more about EDM Modal software, visit: www. crystalinstruments.com/structural-testing

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