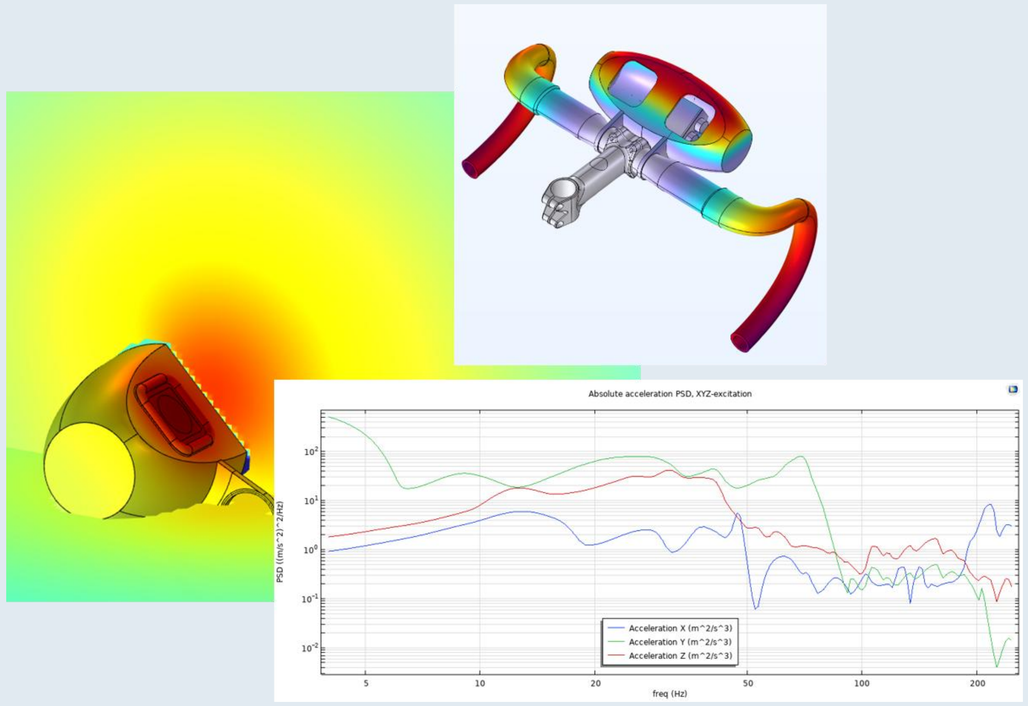


Vibro-Acoustic Modelling, Structural Optimization of a Bicycle Speaker

A handlebar mounted bicycle speaker experiences more operational challenges than typical home use wireless speakers. Road vibrations and bump shocks deserve deeper study. Acoustic radiation directed towards to the rider is necessary.

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Abstract

Handlebar-mounted speakers provide an open-ear alternative, but designing such devices requires resolving severe vibro-acoustic trade-offs while maximizing acoustic directivity towards the rider in an open-air environment.

This study presents results from a coupled structural-acoustic model. Real-world vibration data is collected in the field. The power spectral density (PSD) are used for random vibration analysis.

Acoustic performance is modelled in the Acoustics Module using a coupled Finite Element Method (FEM) and Boundary Element Method (BEM) approach. The FEM domain resolves the internal back-volume acoustic compliance and cavity resonances, while the BEM domain computes open-field acoustic radiation patterns and directivity toward the rider's ear level.

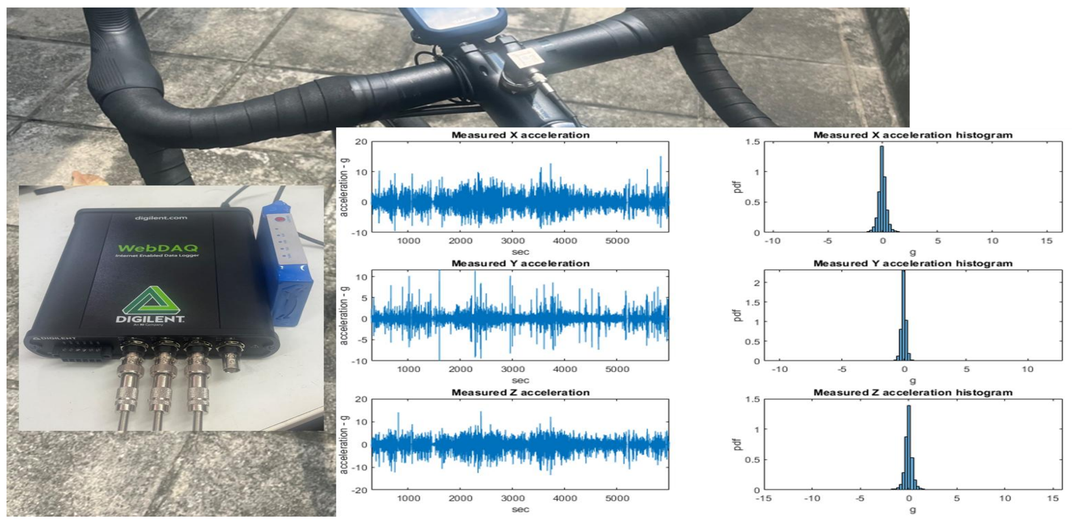


Figure 1. The 3-axial sensor mounted on the stem, the portable 24-bit data acquisition device for the road test and recorded data/histograms.

Methodology

A triaxial acceleration sensor is mounted on the stem of a carbon road bike, Fig. 1. The 700x28c tires on the carbon wheelset are inflated to 60 psi. The collected acceleration time history are used to obtain auto- and cross-power spectral density to define the correlation matrix in random vibration which is a modal method based on prestressed eigenfrequency results.

Response spectrum study is needed for this non-stationary, high g vibration. Shock pulses exhibiting 15 g are used to derived the shock spectra.

Enclosure air cavity acoustic pressure is analyzed with the finite-element (FEM) method whereas the open-air acoustic radiation is handled by boundary-element method (BEM).

Results

Given the vibrations exhibiting heavy long-tail, exponential like distribution (Fig. 1), the commonly employed 3x sigma (3σ) in structural integrity assessment will be too conservative A multiplier of 6 may provide a more reliable first-order peak stress estimation. In Fig. 2, a hot-spot at enclosure-mounting arm has a peak stress of 24 MPa (6σ). This is well within the safety limit of the CY6414 material.

Durometer of the handlebar mounting rubber and the battery vibration isolator are determined dynamically by the results of random vibration and response spectrum studies. The selected hardness protects the components from damage.

Vibro-structural enclosure modes study guides the enclosure shape optimization. Angle of the loudspeaker drivers in is determined with the outcomes of pressure acoustic FEM+BEM, Fig. 2.

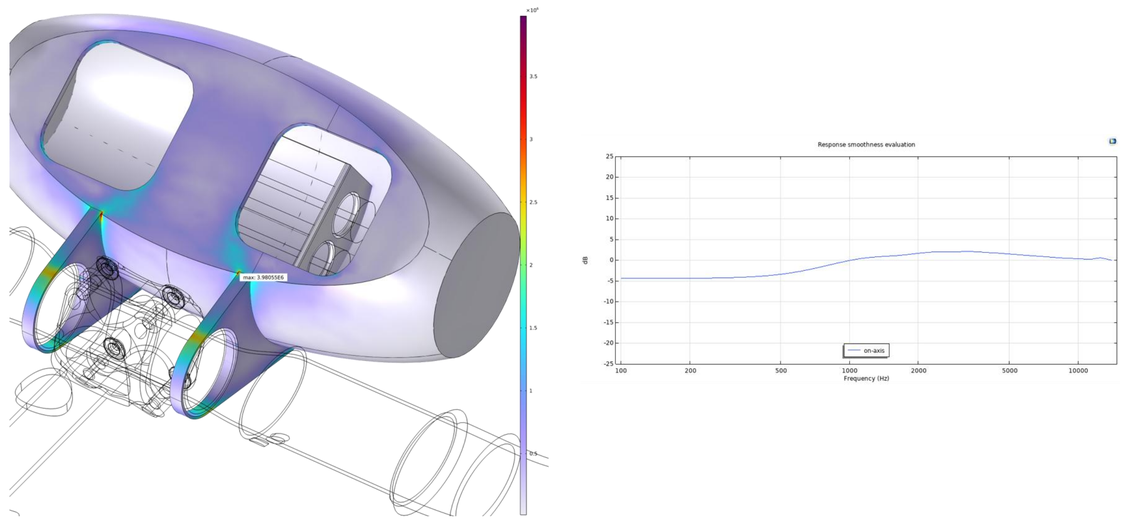


Figure2. Left: RMS von Mises stress of random vibration study. Right: Response flatness at rider ear level obtained from acoustic pressure FEM+BEM.

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