EDITORIAL

Vibroacoustic Measurements Without Transducers

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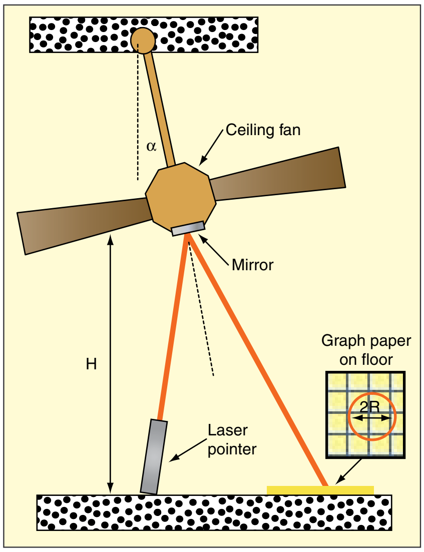
The importance of modern devices for vibroacoustic measurements is difficult to overestimate. However, sometimes we may have to do without high-precision transducers and sophisticated analyzers – because they are not available at that time, or they can be damaged or they cannot be used directly for a particular application. Four relevant case histories are described here.

STC Evaluation Without Microphones. The airborne transmission loss of a wall, window or floor is commonly measured in multiple one-third octave bands, but a single-number rating, STC (sound transmission class), is commonly used to characterize the whole spectrum. It is helpful to roughly differentiate the various STCs through the audible perception of the noise transmitted through a wall. Here are approximate rules of thumb by which we can audibly evaluate the STC rating of a partition.

- Average people can clearly hear a quiet conversation or music on the other side of an STC 30 wall.
- With an STC 40 wall, a quiet conversation or music is not audible, but a loud conversation can be heard and even understood.
- With an STC 50 wall, a loud conversation is audible but not comprehensible.
- With an STC 60 wall, a loud conversation (but not hard-rock music!) is almost inaudible.

Once I measured the STC of double-gypsum board walls separating adjacent hotel rooms. The study was requested by the hotel owner because of multiple customer complaints. Indeed, the STC of the walls measured between 38 and 41 (instead of STC 50 stated by the contractor). But at a meeting held in one of the hotel rooms, the local maintenance supervisor still doubted the measurement data (too low in his opinion). To check, he went to an adjacent room to turn on the TV set there and then listen in our room. In his absence, I presented the rules mentioned above to the other participants, closed the door, stood in the center of the room and loudly said to the wall: "Mike, will you be back soon?" My counterpart replied, "I'll be back in a minute!" from the other side of the wall to the laughter of the whole audience. The acoustical defects (in particular, holes near the electrical receptacles) were located and fixed after one of the walls was partly disassembled.

Angular Deflection of a Fan. I was working for a large company making air-circulating and ventilating fans. The quality control manager wanted to test the angular deflection of ceiling fans from the vertical axis under the imbalance force. The rotational speed of the fan was 180 RPM (3 Hz). Our small accelerometers didn't operate at such

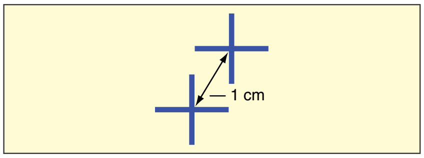


low frequencies, and it wasn't clear how to protect the accelerometer cable from the rotating blades. No one had a laser vibrometer. However, I found a simple solution by arranging a pen-shaped red laser pointer (on the floor), a small magnet-backed mirror (on the steel fan core) and a piece of graph paper (on the floor) as shown above. The red light beam from the laser pointer was reflected by the mirror moving together with the fan core. The red circle, illuminated by the reflected beam on the graph paper, was a magnified image of the fan precession. The angle of the fan deflection α from the vertical was calculated by the equation $\alpha = R/2H$, where R is the radius of the red circle and H is the height of the fan core over the floor. The manager liked this effective and low-cost technique very much.

Measuring Acceleration with a Ruler. Two company representatives from Japan were visiting the automotive laboratory where I worked as a NVH engineer. They stopped near a shaker with a large engine-cooling module vibrating on its rubber isolators in the vertical direction at the resonance frequency of the system. "What is the vibration transmissibility here?" One of visitors pointed to the side of the module. "The response accelerometer measures 5 g, and the input acceleration is 1 g, so the transmissibility should be 5," the test engineer explained.

But the visitor strongly disagreed. "Your response accelerometer is on top of the module, and the module is not an absolutely rigid body. Besides, the module vibration is not axial. Can you measure the acceleration at this point both in the vertical and horizontal directions?"

The test engineer looked for a tri-axial accelerometer but there was none in the cabinet. To answer the visitor's question, I



stopped the shaker and using a ruler and a fine-point blue marker, I drew a small cross at the point of interest. As the vibration test was started again, two similar images of the cross became visible on the side of the module. They aligned with the negative and positive displacement peaks where the vibration velocity was zero. The back-and-forth moving images between the two were obscured because of human vision inertia. This optical pattern was rather stable, and the center of one image deviated slightly from the vertical line put through the center of the other image. So, the visitor was correct but the effect was minor. With the same ruler, I measured a peak-to-peak displacement of 1 cm. For a vibration frequency of 16 Hz, the peak acceleration was calculated as: $(0.5 \times 0.01\ \text{m}) \times (2\pi \times 16\ \text{Hz})^2 \approx 50.5\ \text{m/s}^2 \approx 5.2$ g. The visitor smiled and nodded his head in agreement.

Pocket Change Acceleration Check. A friend of mine, a mechanical engineer specializing in HVAC, assisted his client, who was the owner of a multistory commercial building. The air ventilation equipment was installed on the machinery room floor. The question was whether the largest fan vibrates too much during rundown. This occurred when the speed of the fan went through the natural frequency (≈ 4 Hz) of the vibration isolators. The client pleaded for just a reasonable insight.

With no measurement equipment at hand, the consultant asked the client what vibration acceleration looks too high? "I really do not know," the client freely admitted, "but the acceleration of gravity should be a feasible upper limit."

The consultant found a horizontal spot on the fan and cleaned it of oil and dust. After that, he ran the fan at operating speed, turned it off and put a penny on the clean spot. At the "stop resonance," the fan displacement amplitude apparently increased but the coin did not chatter. "If the coin does not chatter," the consultant explained, "the fan's vertical acceleration is below the acceleration of gravity."

The client suggested he do the same test with a quarter. "The coin's mass and material do not matter," the consultant said but the client believed in the "trial-and-error" method. To his complete satisfaction, the quarter did not chatter.

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