EDITORIAL

Let Nothing Impede Your Getting a Head!

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The seemingly forgotten impedance head – one of the greatest tools for understanding vibration phenomena.

I am astounded by how seldom photographs of impedance heads appear in our pages and in vibration testing literature in general. In my opinion, one of the finest tools ever created for studying and understanding the vibration phenomenon seems to go unappreciated by most practitioners of the art. I would have thought every dynamics professor worth his salt would have at least one of these dual-channel sensors in the back of his drawer and would delight in exposing every one of his new students to it in a laboratory session. Sadly, this does not appear to be the case.

Over the years, I have met literally hundreds of young engineers with obviously keen interest in vibration analysis and measurement, who have never heard of (let alone seen, touched or used) an impedance head. This is really unfortunate. It is an industry-shortcoming that screams to be corrected! Does the blame lie solely with our technical educators (and their sorely deficient equipment budgets)? Hardly! There is sufficient blame to be shared by many shortsighted members of our small community. So I've decided to do my part to correct this matter by sounding the alarm.

Now I fully understand the impedance head enjoyed its heyday in the 1960s, when filter-based, swept-sine impedance systems were the latest-and-greatest gift to the vibration analyst. (This has been pointed out to me by a friend and San Diego resident whose car still wears *Co-Quad* license plates.) But these sensors have a lot to offer today when combined with small permanent-magnet electrodynamic shakers, FFT analyzers and modern analysis software.

Any competent modal analyst will explain to you the importance of a good driving-point frequency response function (FRF) measurement. In essence, these are the most important FRFs out of the hundreds measured in a modal study because they serve as the inertial references, thus determining the modal masses. The same competent practitioner should stand ready to explain the deficiencies (and merits) of impulse hammer testing that now dominates practice.

An impedance head can help determine the best driving degrees of freedom (DOF) on your structure. Using a hand-held, photo-tripod-mounted or bungee-suspended shaker with a soft suspension and long stroke, an impedance head fitted with a conical titanium tip can be roved around the structure measuring trial driving-point FRFs simply by pressing the tip against the structure. This is a surprisingly time-efficient process and it yields good data.

With the appropriate drive site or sites identified, the same sensor can be stud mounted to the desired drive DOF using a tapped hole or a bonded adhesive mounting pad. With the structure-contact side of the "head" now firmly attached to the structure, a flexible "stinger" is required between the shaker and the sensor to allow rotations and avoid imparted moments. (The conical titanium tip used in the prior roving studies accomplished this.) Impedance heads are totally compatible with MIMO as well as SIMO testing techniques.

Impedance heads are currently made by at least five major manufacturers (Brüel & Kjær, PCB Piezotronics, Kistler Instruments, Dytran Instruments and Meggitt/Wilcoxon). Modern models are available using charge mode, with built-in IEPE (ICP®) voltage electronics and even with integral TEDS technology. (I apologize to any other manufactures my frail and aged memory may have ignored – that wasn't an intentional slight – you are welcome to share in the blame.)

In my opinion, you all share responsibility for not educating your most important customers, new dynamics engineers, about something significant to them that you offer. You don't advertise the impedance head; we read your spreads about accelerometers, force gages and impulse hammers, but we essentially don't see your advertisements for impedance heads or your cost-free promotions of application notes related to them. I think you are making a strategic blunder with this omission.

Software-dominated measurement hardware vendors still find *modal analysis* and related activities a source of continued good business. Yet they fail to invest their time and effort to really understand the procedural details of how their products can be used to solve industrial problems. If they had, every modal software package would come with an impedance head in its blister pack. It's time to stop unscrewing those moment-sensitive force sensors from impulse hammers and hanging them on the end of stingers. Get your customers to use proper driving-point sensors when (multiple) shakers are suggested as the proper (MIMO) answer for testing large structures.

Why do I feel so strongly about the value of these sensors? The short answer is: personal experience. About 35 years ago, I gave up the best employed job I ever had (vice president of a very successful instrument company making leading-edge FFT analyzers) to pursue a personal dream. With friends, I formed a start-up enterprise to build a simplified modal-analysis product based on what we called a *mode-locked loop*. We wanted to demystify modal analysis and bring this important technology to the factory floor as an inspection tool.

At the heart of this idea was a precise *driving-point sensor* (an impedance head) measuring collinear force and acceleration at the drive site. We pressed this sensor against a structure using a small electrodynamic shaker driven by a sinewave. In essence, we formed an electromechanical closed loop around the structure and then sought the poles and zeros (the structural resonances and antiresonances) of that loop.

Algorithms within our *Modal Investigator* drove the sine frequency to converge on each resonance and antiresonance, in turn, within a specified search band. Once these were identified by an initial *Survey*, one could *Map* each mode shape using a hand-held probe swept over the test object to identify the node-line loci. You could also *Track* variations in natural frequency and damping of a single mode as physical changes were applied to the structure (great for tuning appended absorbers).

This was a ton of information, all made available by an impedance head and a few thousand lines of Z-80 machine-language code. While we at Fox Technology were proud of those lines, the big contribution was from the underlying physics measured by a precise impedance head. Ours were carefully manufactured by PCB.

Experimenting with that Modal Investigator gave me a lot of visceral introduction to the physics and realities of structural vibration. For one thing, I came to understand that antiresonances are not unimportant things. My understanding of this was strongly reinforced by the teachings of William G. Flannelly of Kaman Aerospace Corporation. It was my good fortune to earn Bill's friendship prior to developing the Modal Investigator.

The late Mr. Flannelly had a most uniquely perceptive view of why things shake and vibrate and he generously shared his research papers with me. He also went out of his way to introduce me to unusually creative people who could appreciate what the Modal Investigator might do.

His introductions led to my friendship with certified flutter examiner Wilmer H. Reed, III and a chance to meet with Dr. John C. Houbolt, the eminent NASA Acoustician who successfully explained to Dr. Werner Von Braun that a lunar landing must come from a lunar orbit, not an Earth orbit. Both gentlemen were among my personal heroes. I worked on propeller whirl flutter at Sikorsky Aircraft years prior; they had already authored NASA's definitive paper on the topic.

My impedance heads have served me well for nearly 35 years. I have used them for many types of test and analysis. In particular, I recall using them to analyze a new optical microscope and to search out problems on a large electron microscope and a towed minesweeper. One helped me qualify a Navy instrumentation payload for launch on a military space shuttle. I have created an article or two about modal analysis, antiresonance analysis and related structural testing using these sensors. I have come to trust and rely upon them and wonder how younger practitioners can successfully introduce themselves to a new dynamics question without one.

I remain strongly convinced that every serious dynamics investigator must be an experimentalist as well as an analyst. Mathematical proficiency is an important capability for a dynamicist. However, brilliantly conceived and cleverly derived equations are only an exercise in egocentricity if not accompanied by convincing experimental verification. The truly revered analyst is the one who can substantiate his theories with relevant experiments. Any such fellow deserves to have an impedance head in his laboratory kit, and his employer should be proud to purchase it for him! SV

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