imc

Ground vibration testing:

Applying structural analysis with imc products and solutions

Just as almost any mechanical structure, aircraft body parts or complete aircrafts can be modelled precisely and realistically in FEM software. This provides a vital means of understanding whether the design of an aircraft fulfils the requirements needed for a safe and long operation. Not only static strength or fatigue behavior is important in this regard, but also Eigen frequencies and the reactions to the various vibration sources that the structure is subjected to, during its operation.

Ground vibration testing (GVT) is a major task in the development cycle of new aircraft that helps to understand the structure of the aircraft. Design models are validated and optimized based on GVT tests, to diminish the uncertainties that remain from pure simulation. Simulation software and test systems have to work hand in hand to identify the critical or uncertain parts of the model, and validate them by doing real tests on a prototype.

As with every structural analysis, the device under test (DUT) has to be excited, and accelerometers are typically used to measure the vibration propagation from the point of excitation to certain critical locations. Usually, 3-axial ICP accelerometers are used, so that all possible degrees of freedom (DOFs) can be examined. The propagation of the vibration is expressed by calculating the FRFs (Frequency response functions) between the input and the output locations.

In very rigid structures such as railway car frames, or in small structures such as aircraft or vehicle components, the excitation is provided by injecting impacts using impulse hammers. The concept behind this is that a sharp impact contains a full spectrum of frequencies, well suited to stimulate any possible resonance in the structure. A perfect impact actually contains all frequencies equally distributed. Such a perfect impact is called Dirac impulse.

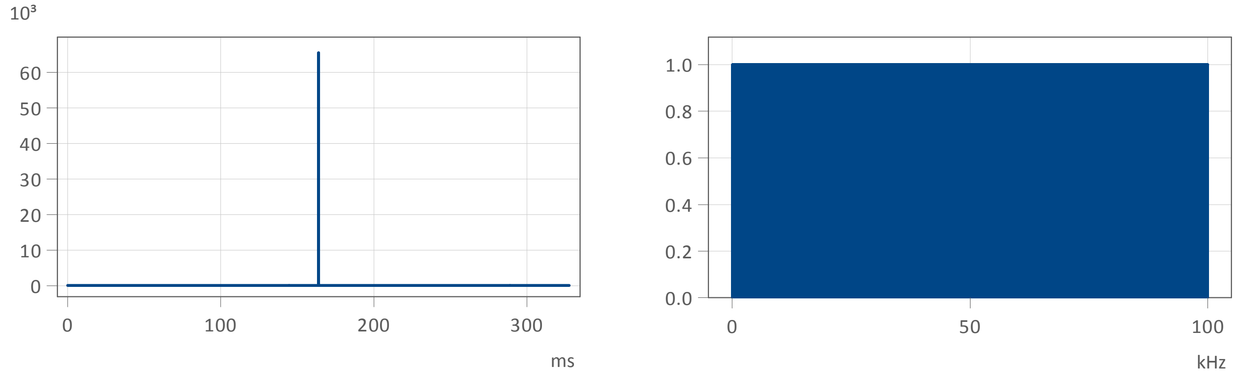

Figure 1 A Dirac impulse and its FFT spectrum

As in real-world testing, impacts can of course never represent an absolutely perfect Dirac impulse. However, this is not necessary as impulse hammering will yield sufficiently diverse excitation spectra in order to accurately track a broad frequency response. To account for the actual “shape” of the non-ideal dirac stimulus, both the input as well as the output response signals are measured to calculate the FRF.

When working on structures that don’t allow using impulse hammers, or in cases where multiple simultaneous stimulations a applied to different DOFs, electric or hydraulic shakers are often used for excitation. FRFs from all input DOFs to all output DOFs are then calculated.

One of the strengths of imc’s test & measurement systems is to perform all of these steps in an integrated, synchronized and dedicated hardware device. Typically, an imc CRONOS*compact* device is used.

Figure 2 An imc CRONOScompact device in portable housing

This modular system can be equipped with a variety of plug-in modules, which can be selected as per test requirements:

1. The main processor. It takes care of controlling the test process, on-board data storage as well as communication with the control PC
2. The imc Online FAMOS processor. It handles real-time data processing. For example, it can monitor RMS values of accelerations or amplitudes of FFT spectra and trigger emergency shut offs within milliseconds if needed.
3. The Synthesizer and Control module. It is used to store and output profiles and patterns of the excitation signals. It also features hardware-level PID controllers for closed-loop controlling.
4. The measurement modules. Dedicated measurement modules for IEPE accelerometers are provided. However, a broad selection of amplifier and interface modules is available, suited to adapt to additional sensor signals, which might be useful if the same test system is used in other contexts as well, e.g. in automotive vehicle testing or in flight tests.

In GVT testing, the Synthesizer module controls the actuators. It contains large buffers to hold pre-defined excitation signals like broadband noise signals or other specific stimulus patterns to be re-played. It also directly integrates the required analog outputs, so that replaying the excitation signals can be performed with maximum speed, without involving any additional system delay. As all this processing is handled on the dedicated controller board, an output frequency of up to 80 kHz is achievable, which allows exciting any desired frequencies.

Besides its capabilities as universal and flexible signal generators, the Synthesizer module is a powerful engine for closed loop control. It additionally provides independent and richly featured PID controllers that can be assigned to each of its 8 analog outputs. In this case, the real-time communication with the measurement input boards in the imc CRONOS*compact* provides the feedback for the controller. Even in this mode, an output rate and control cycle of up to 10 kHz is still achievable.

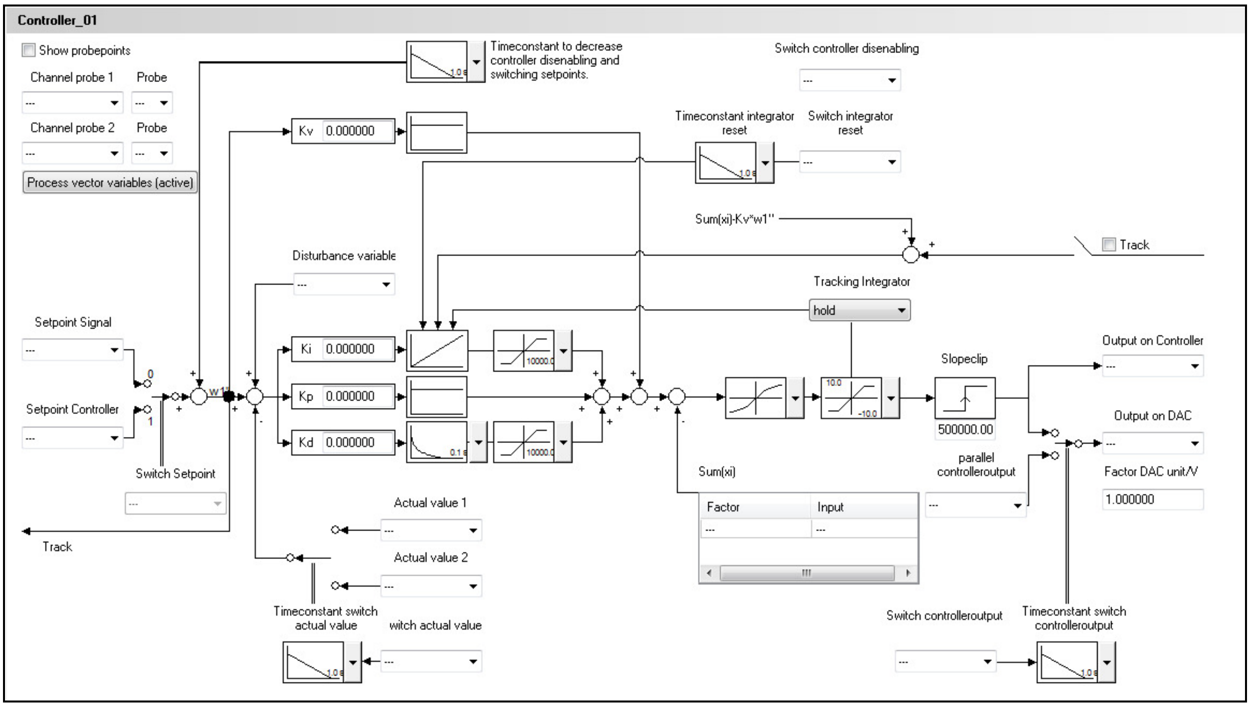

Figure 3 Schematic picture of the imc Synthesizer PID controller features

When exciting only a single frequency, the Synthesizer offers maximum flexibility: The frequency as well as the amplitude of the sine wave can be adjusted dynamically by using variables. The main processor usually controls these variables, to generate a sine sweep signal, or to generate a stepped sine. For example, an excitation can be performed for 10 sine cycles before proceeding to the next frequency. These steps and test states can easily be defined in imc's test control software imc STUDIO.

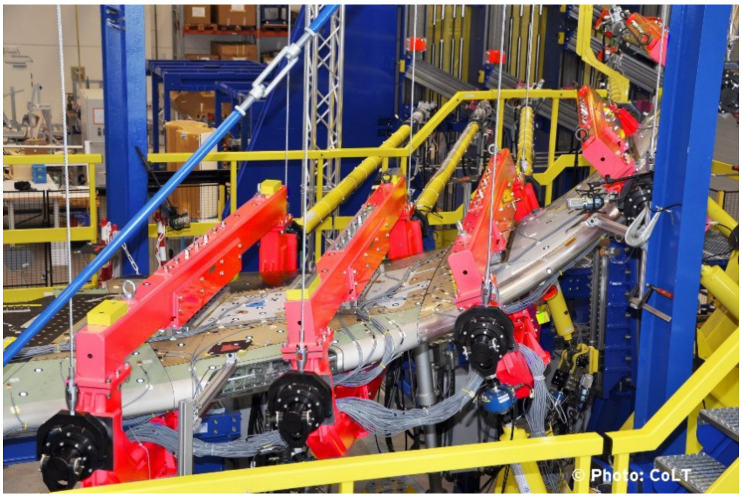

Figure 4 Winglet fatigue testing setup carried out by imc's hardware and software

imc STUDIO even provides the possibility to interactively set the excitation frequency using virtual instruments on the screen, e.g. potentiometers or input fields. These can be used for special testing, if no automatic test process is wanted.

Figure 5 Example test operation screen in imc STUDIO

imc STUDIO also handles the immediate calculation and validation of FRFs, cross spectra, power spectra etc. To accomplish this, two software packages are seamlessly integrated:

1. imc Inline FAMOS, for arbitrary calculations on the data streams of an active running measurement
2. imc FAMOS, for any calculations on partial datasets at certain intervals or after finishing a measurement (e.g. FRFs). imc FAMOS can also be used separately as a full-featured post-processing software for test & measurement data.

With these integrated processing capabilities, imc STUDIO can directly and immediately show the FRFs and any other processing results as soon as they become available.

Figure 6 imc STUDIO showing FRFs at 3 DOFs from a vibration generated with an impulse hammer

After checking the data in imc STUDIO, exporting it to the FEM software is just a click away. imc STUDIO can export the already calculated FRFs to the universal file format. The exported files contain not only the data, but also all metadata information about the DOF number and direction (+X, -X, +Y, -Y, +Z, -Z). This is important for the FEM software, because based on this metadata information, the transfer functions can directly be assigned to the model and the normal modes can be calculated and displayed in 3D simulation models.

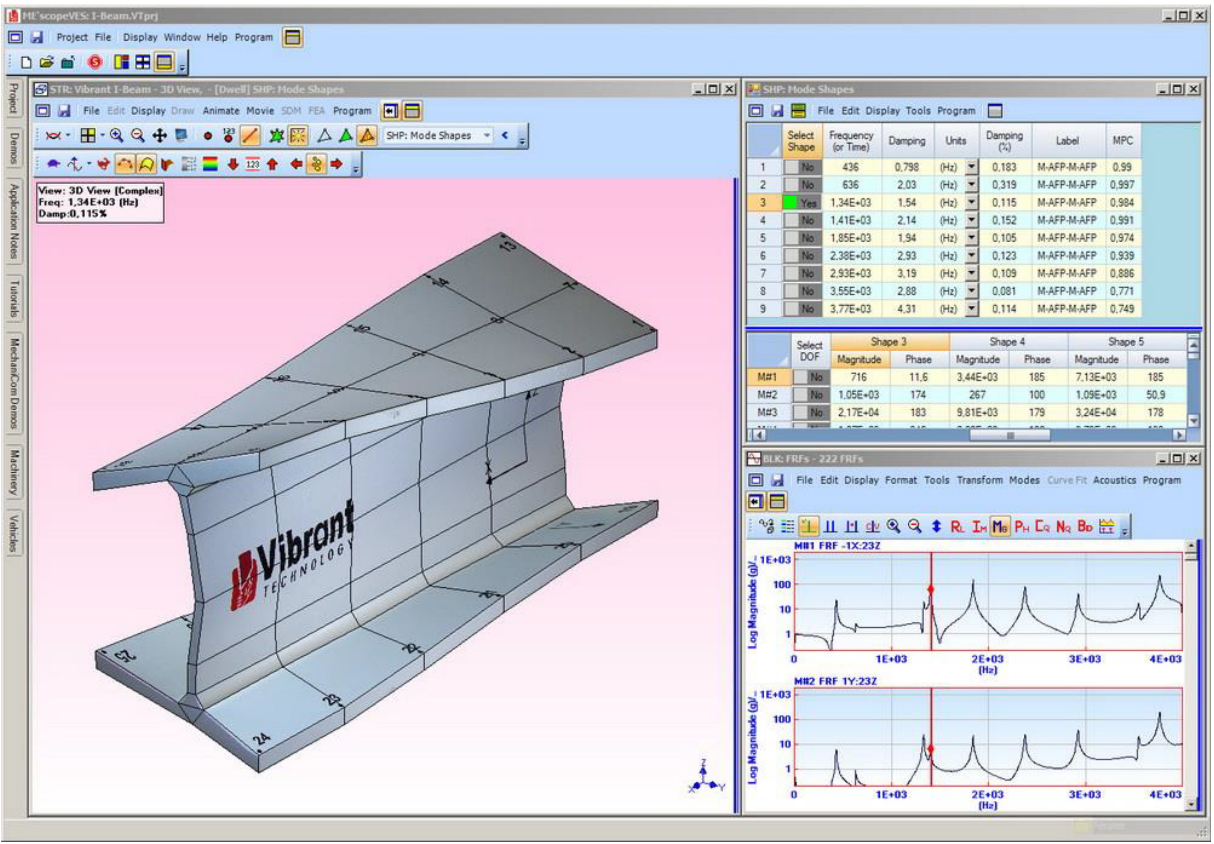

Figure 7 Screenshot of ME'scope visualizing normal modes

As imc STUDIO uses the universal file format for exchanging the data, various FEM software can be used such as Vibrant's ME'scope, LMS software etc.

The imc test solution consists of the imc CRONOS*compact* with its modules and imc STUDIO with its packages. One of the most powerful capabilities of this combination, and the distinct advantage of this approach is, that it can be used for various other tests as well. The imc CRONOS*compact* device is a platform device that can be fitted with various modules that make it suitable for a wide range of tests, such as:

- A universal measurement module. When not used for vibration measurement, it can as well be used for strain gauging, pressure measurement (s/g or 4-20 mA), temperature measurement, displacement sensors, load cells etc.
- Dedicated modules to measure temperatures, voltages, acoustic phenomena and signals using microphones, high voltages up to 1000V as in high-power batteries etc.
- CAN or ARINC interfaces, to integrate information from an aircraft's avionics or a vehicle's ECU
- Communication interfaces to exchange information with fatigue test controllers such as Moog's Aerospace Test Controller
- Communication interfaces to integrate pressure scanners as from PSI for instrumenting flight tests involving large-scale pressure testing
- PCM interface modules for transmitting live data from the airplane to the ground stations

Figure 8 A Eurocopter prototype during structural testing, controlled by an imc CRONOScompact

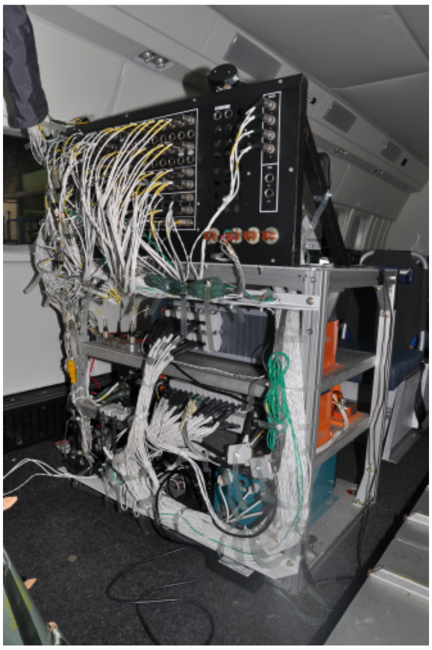

Figure 9 Several imc CRONOScompact devices synchronized during flight testing

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imc Test & Measurement GmbH is a manufacturer and solution provider of productive test and measurement systems. imc implements metrological solutions for research, development, service and production. imc has particular expertise in the design and production of turnkey electric motor test benches. Precisely outfitted sensor and telemetry systems complement our customer applications.

Our customers from the fields of automotive engineering, mechanical engineering, railway, aerospace and energy use imc measurement devices, software solutions and test stands to validate prototypes, optimize products, monitor processes and gain insights from measurement data. As a solution provider, imc offers their customers an attractive and comprehensive range of services. These include project consulting, contracted measurements, data evaluation, specialist deployment, customer-specific software development and system integration. imc consistently pursues its claim of providing services for "productive testing".

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