Application Note

Mobility Measurements

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Being modular and expandable, the Brüel & Kjær Multichannel Analysis System Type 3550 makes fast, easy and accurate mobility measurements on structures. In its standard dual-channel configuration, and equipped with only a force hammer and an accelerometer, even the novice can begin to explore the dynamic behaviour of structures.

This note gives an introduction to this important application area and outlines the theoretical background and experimental techniques.

Why are We Concerned with Structural Dynamics?

As economic constraints become tighter, we can no longer afford the problems caused by structures, such as machines on a factory floor, which vibrate excessively. Breakdowns and human discomfort are just two of the problems that we often face. A noisy machine is probably not efficient.

As we strive to develop faster, lighter and cheaper structures, we must have the expertise and experimental techniques at hand to deal with the vibration problems which ensue. We must also be able to characterize structures. To these ends, simple mobility measurements can help.

What is Mobility?

Put very simple, mobility is a measure of how easy it is to vibrate a structure. Consider it the opposite of impedance, which tells us how difficult it is to do the same. When dealing with structures, where we might make measurements at many points, we use the mobility function.

We define mobility in terms of the dynamic force acting at a point and the resulting velocity. In other words:

$$\text{mobility} = \text{velocity/force}$$

Mobility is a complex system descriptor. The mobility is frequency dependent and it gives the magnitude and phase relationship which exist between the excitation force and the vibration response. We plot the mobility of a structure against frequency and in this way determine the characteristic mobility function. We call this the “frequency response” of the structure. We also use:

$$\text{accelerance}^{*} = \text{acceleration/force}$$

$$\text{compliance}^{\dagger} = \text{displacement/force}$$

When plotted against frequency these mobility functions provide the same information. However, the scaling of mobility is frequency weighted and depends on whether we have measured acceleration, velocity or displacement. Simple post-processing enables us to change between them.

How do We Measure Mobility?

Essentially, we measure the dynamic behaviour of a structure to a forced input. We can measure the response i.e. the vibration, using a vibration transducer. We use piezoelectric transducers (accelerometers) in most cases due to their wide dynamic range and wide frequency range.

Note. The mass of the vibration transducer must not be so high as to change the vibration it was put there to measure. This is important when measuring the vibration of light structures.

We often use a force hammer and impact the structure to give the force input. A force transducer behind the tip of the hammer produces a signal of the force pulse. We can also use a vibration exciter. A force transducer between the measurement point and the shaker produces the force signal. Only with the latter method can the type of excitation signal be chosen.

The standard dual-channel version of the Multichannel Analysis System Type 3550, known as Type 3555, can be equipped with a generator module that provides a vast number of different excitation signals to drive the vibration exciter, including, random, pseudo-random, periodic random,

* Also called inertance
† Also called receptance

burst random, swept sine, multisine and user-definable waveforms.

The signals from the force transducer and accelerometer are fed into the two channels of the analyzer. Most transducers require an external preamplifier between themselves and the analyzer. The Type 3555, however, has built-in charge preamplifiers to allow for direct connection of the force transducer and accelerometer. ICP®* compatible transducers, e.g. the Brüel & Kjær DeltaTron™ transducers, can be connected via an adaptor, or directly to a Type 3550 system equipped with one or two 4-channel modules Type 3023.

The analyzer simultaneously measures the force and response, converts them into a digital signal and computes their Discrete Fourier Transform (DFT). High speed computation then produces the mobility function. During and after the measurement a range of post-processing facilities are available. We can display the mobility function in many different formats (magnitude-frequency, phase-frequency, Nyquist and Bode Plots). We can convert from acceleration to mobility to compliance by integrating. We can look at the time domain equivalent of the mobility – the impulse response – by using the inverse Fourier Transform. We can calculate the damping this way. Another function – the coherence – tells us about the validity of the measurement.

Sometimes it is not possible to provide a controlled and measured input into a structure. Take a large building for example. Even the largest shakers or impactors will not be able to impart sufficient energy at frequencies other than the resonance frequency to a structure this size. Instead, we must proceed from an assumed knowledge of an input, such as a controlled explosion.

What can the Mobility Measurements be used for?

Trouble-shooting. High vibration and noise levels in structures are caused by a high force input level, or by amplification of a "normal" force input level by unwanted resonances.

* ICP is a registered trademark of PCB Inc.

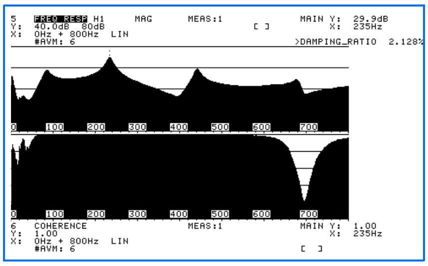

Fig.1 Typical mobility and coherence functions

The mobility function shows us these structural resonances. A structural resonance represents a structural weakness. Problems arise when the excitation frequencies encountered in normal operation coincide with the resonance frequencies.

Material Testing. The internal damping, or "loss factor" of materials can be calculated from the mobility function. Measurements can be made on concrete, asphalt, metals, plastics and composite materials.

Design. The dynamic interaction of interconnected systems can be predicted using a knowledge of the mobility of the individual parts. Vibration isolators and machinery mounting can be optimized.

Quality Control. Hidden faults, non-uniformities or tolerance deviations of items can be detected by comparing the mobility function of a standard with a recently manufactured item.

Mathematical Modelling. Mobility measurements taken at many points can form the building blocks of a mathematical model of the structure. This is the basis of modal analysis. Existing mathematical models, such as a Finite Element Model, can be verified.

Fig.2 An impact hammer and accelerometer - the front end of a mobility measurement system

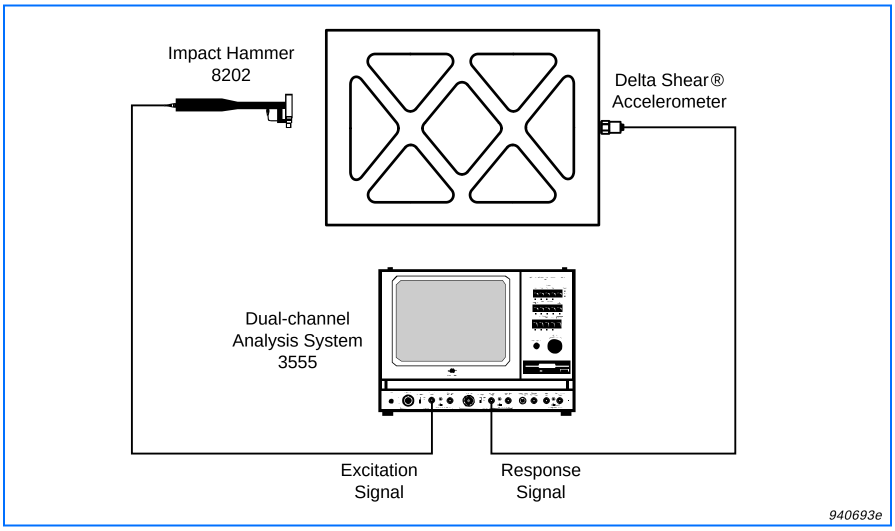

Fig.3 A typical set-up for a mobility measurement

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