Vibration and Modal Shape Analysis

High speed Digital Image Correlation: A powerful platform for vibration and modal shape analysis

Vibration analysis

For today's demands of high reliability, durability and environmental performance of machines, electronics or mechanical components, static measurements of stress/strain properties are often time consuming. Dynamic measurements are necessary and therefore Vibration Analysis (VA) has found widespread use.

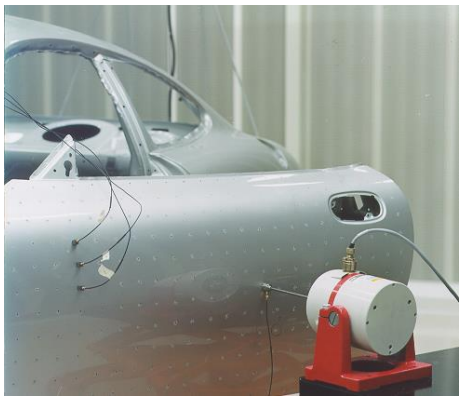
In some instances vibration can be desirable. For example, a mobile phone vibration or the motion of the wooden body of a violin, as well as the cone of a loudspeaker.
In many cases, however, vibration is undesirable because it wastes energy, causes fatigue symptoms or creates unwanted sound. The vibrational motions of an engine, electric motor, electronics or any other mechanical device in operation are just a few examples of unwanted vibrations. Such vibrations can be caused by imbalances in the rotating parts, uneven friction, the meshing of gear teeth, material design flaws, etc.
Careful designs usually minimize unwanted vibrations. Experimental vibration measurements are typically used to validate analytical models or are used when theoretical models are impossible or inaccurate.

Vibration analysis systems

Today's vibration analysis systems are composed of:

- Sensors like accelerometers or load cells
- Laser vibrometer/laser vibrometer scanner
- Data acquisition system to digitize sensor signals
- Computers to view data and analyze it

The disadvantage of a sensor is that it has to be mounted on the test object, which could affect or even invalidate the measurement result due to sensor mass or stiffness loading of the structure.
Another disadvantage of a sensor as well as a single-point laser vibrometer is that these VA systems deliver vibration data only in one point. To monitor the whole surface at once, several sensors are needed and the preparation of the test object becomes very time consuming. Laser scanners can monitor larger surfaces but come at a higher price level, especially 3D scanners. Scanners can only measure at different points of time, which prevents the analysis of transient events. VA is typically performed as part of a company's research or quality assurance programs. VA is a key component of a Condition Monitoring Program, and is often referred to as Predictive Maintenance.



Car's door attached to an electromagnetic shaker (Cjp24[1])

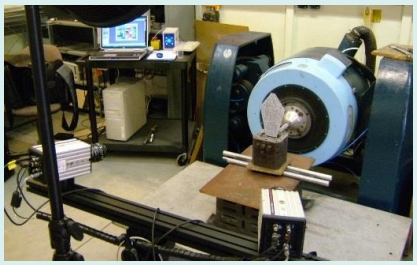
Dantec Dynamics's solution

Dantec Dynamics, a specialist for optical surface measurement, uses Digital Image Correlation (DIC) for Vibration Analysis.
DIC is a full-field, non-contact image analysis method based on pattern recognition. DIC allows the determination of the contour and surface displacements of a test object in three dimensions. Since the system determines the absolute position and displacement of the object in space, deformation measurements with very high resolution are possible even under the presence of large deformation amplitudes and macroscopic rigid body movements.
The displacement resolution depends on the field of view and is in the range of **µ-meters** for an A4 sized test object. Dantec Dynamics' fully integrated DIC high–speed cameras support VA up to **1 KHz** (options available up to 20 kHz) with a very attractive benefit-cost ratio.

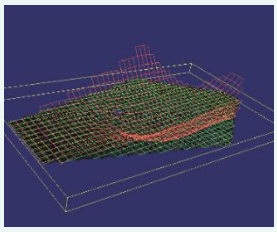
Vibration Analysis example: **Harmonic excitation of a composite beam**[1]

Setup

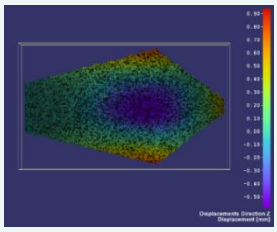
- Two high-speed cameras for VA up to 1 KHz
- Focusable High-Speed Illumination (400W)
- Shaker, 5 to 3000 Hz, max. acceleration 1000 m/s^2, max. amplitude ±12.7 mm
- Composite beam 3 x 40 x 150 mm
- Excitation at resonance frequency 2.5 kHz



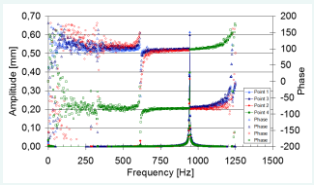
Results



Out of plane 3D displacement scaled 50x



Out of plane displacement max. amplitude +/- 0.6 mm



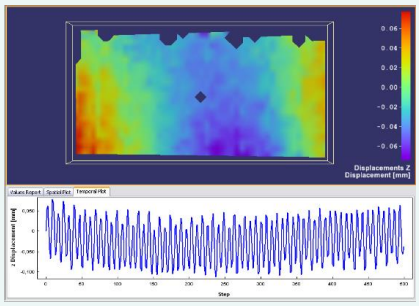
Spectral analysis of 4 points on beam

Vibration Analysis example: **Harmonic excitation of a composite panel**[2]

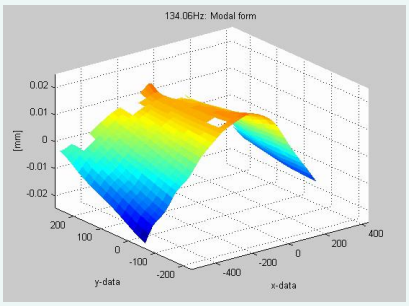
Setup

- Two high-speed cameras for VA up to 1 KHz
- Focusable High-Speed Illumination (400W)
- Shaker 134 Hz 1.4N
- Composite panel size: 1000 x 500 mm

Results



Out of plane displacement max. amplitude 50µm



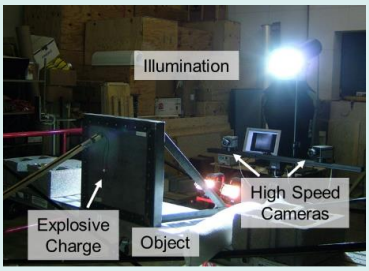
Panel Modal Shape Analysis at 134Hz

[1] Measurements performed at Rolls Royce, Derby, UK
[2] Measurements performed at Liverpool Uni, ADIVSE project

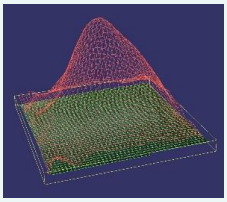
Vibration Analysis example: **Shock excitation on an aluminum plate**

Setup

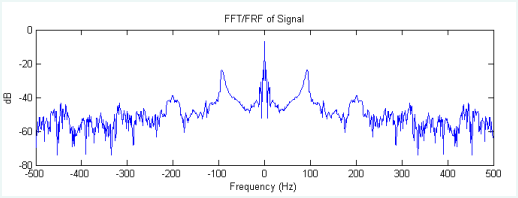
- Two high-speed cameras for VA up to 1 kHz
- Focusable High-Speed Illumination (400W)
- Aluminum plate size: 700 x 700 mm
- Excitation: Explosive charge
- Trigger: Automatic Triggering on an accelerator signal
- Acquisition time: 3.2 s



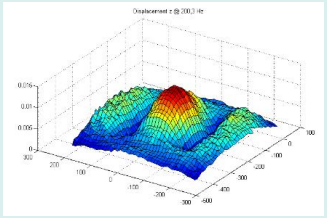
Results



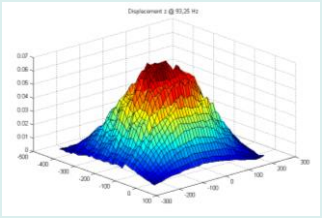
Shock deformation at 12 msec max. amplitude 1.2 mm scaled 300x



FFT analysis of vibration acceleration show peaks at 90Hz and 200 Hz



Modal Shape Analysis for 200Hz

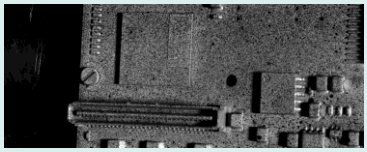


Modal Shape Analysis for 90Hz

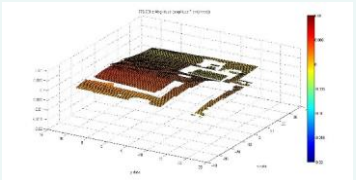
Vibration Analysis example: **Noise excitation of circuit board**

Setup

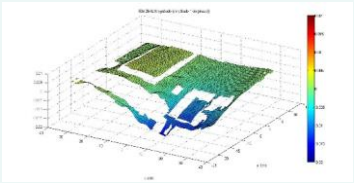
- Two high-speed cameras for VA up to 1 KHz
- Focusable High-Speed Illumination (400W)
- Circuit board field of view 65 x 30 mm
- Excitation: White noise 200 to 1000 Hz
- Amplitude up to 50µm



Results



Modal Shape Analysis 777 Hz, max amplitude about 5µm expected mode measured by accelerometer on the board



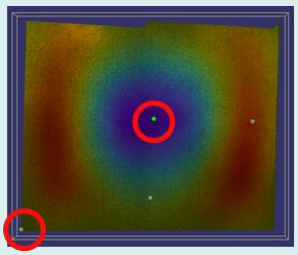
Modal Shape Analysis for 534 Hz, max ampl. about 20 µm unexpected mode with higher load for components

Vibration Analysis example: **Harmonic excitation rubber membrane**

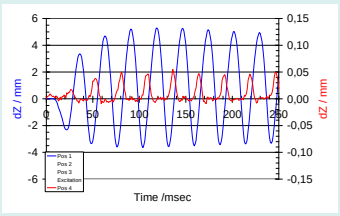
Setup

- Two high-speed cameras for VA up to 1 kHz
- Focusable High-Speed Illumination (400W)
- Excitation: Bass loudspeaker with rubber membrane
- Frequency: 25,4 and 50,8Hz

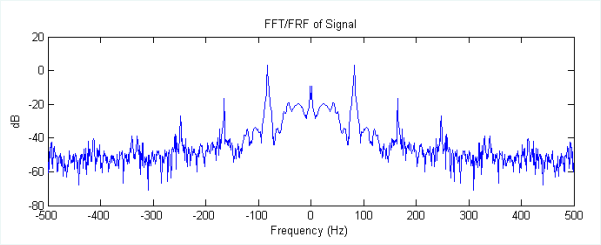
Results



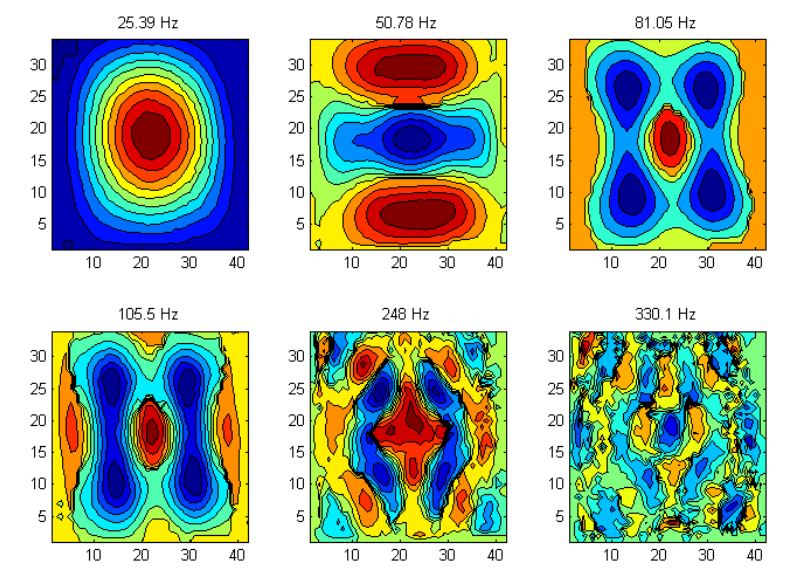
Amplitude measurement at two points (marked with red circles)



Amplitude results at 36.5 Hz 5 mm to 50 µm. Excellent resolution over high dynamic range



FFT Analysis

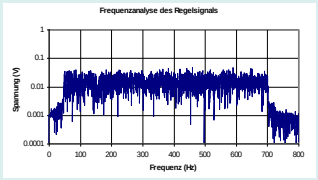


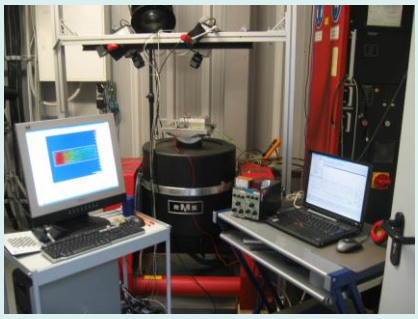
Modal Shape Analysis

Vibration Analysis example: **Noise excitation of a bending steel beam**

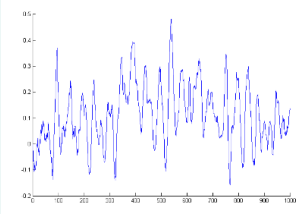
Setup

- Two high-speed cameras for VA up to 2 kHz
- Focusable High-Speed Illumination (400W)
- Steel beam size: 150 x 40 x 3 mm
- Excitation: White noise 50 to 700 Hz

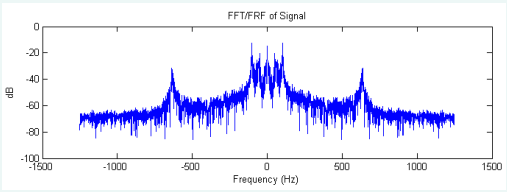




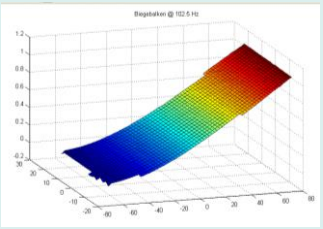
Results



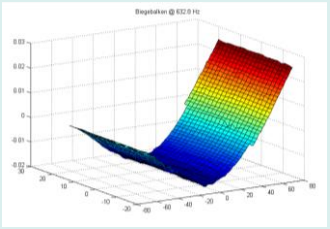
Out of plane displacement in mm



FFT Analysis



Modal Shape Analysis for 103Hz amplitude 1.2 mm



Modal Shape Analysis for 633Hz amplitude 30 µm

Dantec Dynamics' optical vibration analysis solution

- 3D image correlation of shape and deformation
- Whole areas are evaluated, not just a single point as with accelerometers or laser vibrometers
- With just a few mouse clicks the Vibration Analysis application module can show **Amplitude in Function of Time,** and can also calculate the **FFT** and **Modal Shape Analysis** for freely selectable points on the test object
- Resolution in the range of µ-meters for an A4 sized test object down to 100 nm for smaller areas
- Excellent dynamic range from µm to mm over whole measurement area
- Fully integrated DIC high–speed cameras supporting **VA up to 1 KHz** (options available up to 20 kHz) allowing synchronous, whole surface measurements
- Analyzes harmonic excitations and transient events, and is independent from the excitation method and movements of the test object
- Highly sophisticated trigger and I/O support to integrate your results with other measurement systems and sensors
- Support for VA validation with FEM tools
- Minimal preparation effort - requires only digital cameras and illumination to observe the test object
- Automated calibration for quick and efficient setup of the measurement system
- Reduces test times for experimental VA from weeks/days to just a few hours
- Compact measurement system suitable for flexible in-field or laboratory use
- Various export formats to post-process reports in company or standard compliant way
- Very attractive benefit-cost ratio

Portable Digital Image Correlation system

Q-450 High-speed Digital Image Correlation (DIC) is a full-field 3D, non-contact optical technique to measure shape, deformation, vibration and strain on almost any material or shape. Its flexible design opens a wide range of applications from microscopic investigations up to large scale civil engineering measurements.

Figure 1 - Q-450 DIC System with two cameras, trigger and I/O box and illumination

For more information contact

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