HEAD acoustics

APPLICATION NOTE

Information on this document

Contents

This document is the third in a series of four application notes on structural dynamics. The document includes an introduction to operational deflection shape analysis, providing information on possible applications and the general procedure.

Target group

This document serves as an introduction to structural dynamics and is intended for acousticians who would like to get informed about the basics of operational deflection shape analysis.

Questions?

Do you have questions? Your feedback is appreciated!
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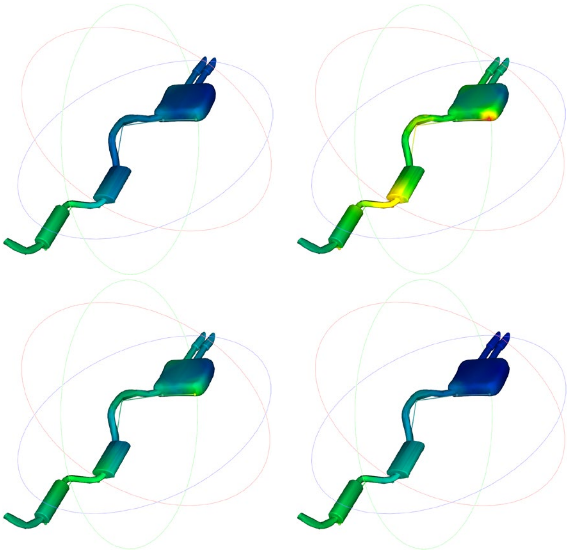
For technical questions on our products: SVP-Support@head-acoustics.com

Structural dynamics – Part 3 (ODS)

1. Introduction

What is operational deflection shape analysis?

Operational deflection shape analysis (ODS) is used to determine deflection shapes under operation loads. The result of the operational deflection shape analysis thus shows how a structure behaves dynamically under real operating conditions.
The selected operating conditions such as speed, load or temperature influence the excitation function and thus also the result. If the selected operating conditions mean that a certain frequency is not excited during the measurement, the test object cannot vibrate at this frequency. The corresponding mode shape cannot be recorded because the required excitation was lacking.



What information is obtained?

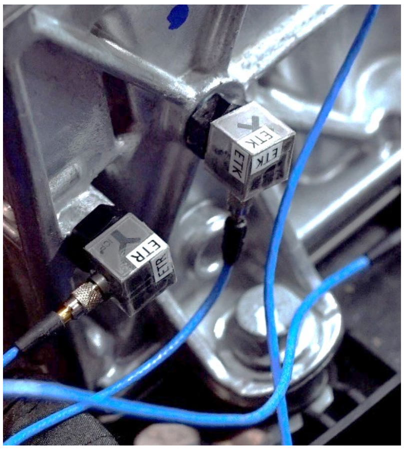
Operational deflection shape analysis therefore does not provide a mathematical model describing the system, as this is the purpose of experimental modal analysis. The measured operational deflection shapes cannot be used to draw conclusions about the system behavior under a different load situation. Nevertheless, the operational deflection shape analysis provides valuable information, e.g., on high deflections at certain frequencies. In many cases, it is best to have both operating data and modal data available when dealing with questions on structural dynamics. In this way, a statement can be made as to whether the natural frequencies found in the modal analysis are excited at all in actual operation. If they are not excited, the natural frequencies of the system usually do not pose a problem.

To determine the operational deflection shape, the vibration of the structure is measured at several points during operation. This measurement can be made using displacement, velocity or acceleration sensors. Acceleration sensors are most frequently used for this purpose.

2. Detection of accelerations

Notes on acceleration sensors

Acceleration sensors can be used to measure accelerations of the structure. In most cases, piezoelectric accelerometers are used. When attaching the accelerometers, it must be taken into account that applying additional masses to the structure causes natural frequencies to shift downward. The weight implications of acceleration sensors must not be underestimated. To reduce this effect, the sensor mass should be very small compared to the mass of the structure. Furthermore, the cable of the sensor needs to be laid in a way that disturbing influences are minimized.



Apart from the characteristics of the sensor, the attachment of the sensor to the structure also determines the detectable frequency range. As an alternative to permanent attachment by screws or connectors, the sensors can also be attached to the structure magnetically or with wax or adhesive (e.g., superglue or X60). The higher the desired frequency range, the stiffer the connections between the sensor and the structure must be.

Accelerometers usually have a measuring range between 1 and 10,000 Hz. Care must be taken to ensure that the natural frequency of the sensor is not within the desired measuring range.

Selecting the coordinate system

The alignment of the accelerometers must be adjusted to the local coordinate system of the corresponding measurement point (see also step 1 in the following chapter), as otherwise errors will occur during modal analysis. The local coordinates are automatically transformed into a global coordinate system by ArtemiS SUITE. By selecting a suitable local coordinate system, the application of accelerometers by means of mounting plates[1] can be avoided in many cases.

The perfect accelerometer

A perfect accelerometer should feature high sensitivity, a wide frequency range, and low mass. In reality, however, compromises usually have to be made: for example, high sensitivity often requires a higher mass of the sensor.

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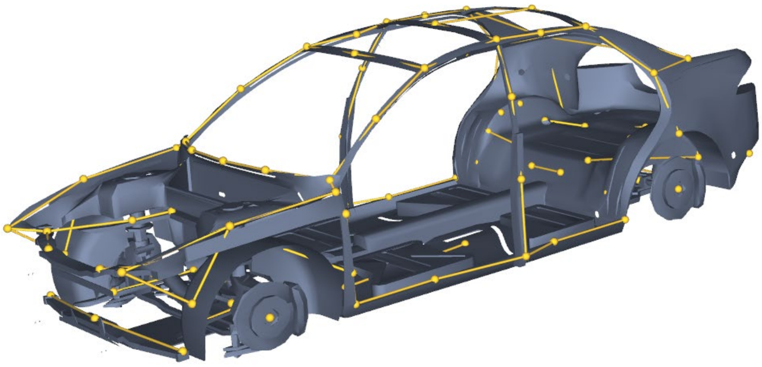
[1] Mounting plates are usually used to adapt the angle of the sensor to the global coordinate system.

Laser vibrometer

In some applications, using contacting sensors is not reasonable or is technically impossible, e.g., in case of an unfavorable mass ratio between sensor and measuring structure. In such cases, the use of a laser Doppler vibrometer as a non-contact measurement method should be considered, as this measurement method can determine the movement of the structure without applying additional mass.

3. Process of an operational deflection shape analysis

Model creation



Before measurements can be started, a model of the structrure to be investigated must be created. For this purpose, the structure is approximated with a finite number of points. It is important to use uniform coordinate systems and uniform measurement point designations for the model creation. This is the only way to ensure an error-free assignment of the measurement results during analysis. For a more realistic visualization, model points in the form of a 3D model of the measurement object can be created in ArtemiS SUITE in addition to the measurement points.

Selection of meaningful measurement points

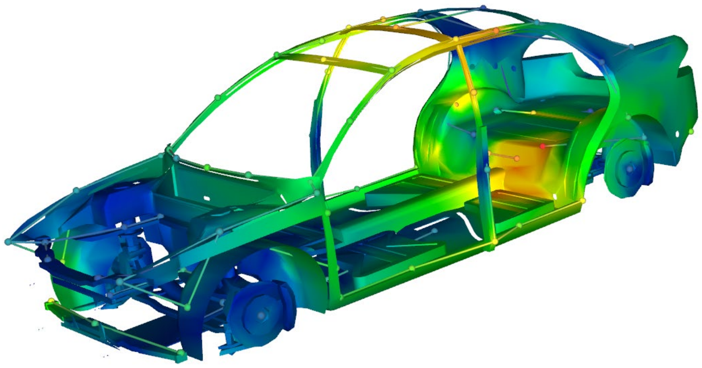
Furthermore, the number and position of the measurement or structure points must be selected during model creation in such a way that the deflection shapes in the desired frequency can actually be identified. As with the time discretization of analog signals, structural oscillations can only be validly identified if an adequate number of measurement points is considered. Otherwise, in the case of higher-frequency oscillations the corresponding deflection shapes are not correctly identified, but instead show the same spatial oscillatory patterns as deflection shapes with lower frequencies (spatial aliasing effect). In addition, it must be taken into account that a sensor that has been applied to a node of a deflection shape cannot record this shape.

Transmissibility

Instead of transfer functions, operational deflection shape analysis determines the transmissibility (ratio of measurement signal to reference signal) for each measurement point. For this purpose, the phase relationships of the measurement signals to each other must be recorded during the measurement, either by recording all measurement points simultaneously or by recording a reference channel that remains the same for each measurement. When performing repeat measurements, care must be taken to reproduce the excitation signal as accurately as possible.

Visualization

The measured time data are then spectrally analyzed for the operational deflection shape analysis. Based on these data, the mode shapes for a selected frequency can then be animated using the previously created 3D model. In contrast to modal analysis, this visualization does not show eigenmodes that are independent of the excitation, but mode shapes that are composed of the excitation function and the dynamic properties of the system.



Shape Table and MPC value

Conspicuous frequencies are detected using the frequency-dependent visualization of the measured movements. These conspicuous frequencies can be identified as mode shapes in ArtemiS SUITE and summarized in a shape table. The MPC value (Modal Phase Collinearity) can serve as an auxiliary tool for a reasonable selection of deflection shapes. This value describes the collinearity of the measured channels‘ phase at the selected frequency. The value ranges between 0 and 1, with 1 representing a high phase collinearity of the individual measurement points, i.e., the measurement points oscillate in phase or 180° in opposite directions. The greater the phase differences, the more the value tends towards 0.

Further evaluations

The results of the operational deflection shape analysis can directly be used to optimize the vibration response. By knowing critical frequencies with high amplitudes in the structural response, improvement measures can be derived. Basically, there are two possible approaches for this purpose: one possibility is to strengthen the structure by structural modification, so that an excitation at critical frequencies no longer leads to unwanted high amplitudes. The other possibility is to optimize the frequency spectrum of the excitation force, so that critical frequencies no longer exist or are less pronounced, thus causing the undesired oscillations only in a weakened form or eliminating them. Furthermore, the results of the operational deflection shape analysis can be compared with the results of a modal analysis or a numerical simulation. In ArtemiS SUITE, this can very conveniently be done with the Shape Comparison Project.

➙ *Proceed to the fourth application note on structural analysis comparing results from different structural dynamics studies.*