Modal analysis with ASM 18

Using modal analysis, you can examine the inherent dynamic properties of your mechanical components. The resonance frequencies and damping values in combination with the associated mode shapes of the test object allow targeted measures to be derived for improving an object’s vibration behavior and thus also its acoustic characteristics.

In order to perform a modal analysis, the dynamic transfer properties of the test object have to be measured, i.e., you must determine the transfer functions. ArtemiS SUITE allows you to acquire these measurements easily using an impact hammer and an accelerometer.

After exporting the measurement results to the BLK format, the versatile tools of the analysis software ME’scopeVES™ from Vibrant Technology can be used for an animated representation of the modes of oscillation and for advanced structural dynamic analysis (see figure 1).

Figure 1: Determining the modal parameters and displaying the animated modes of oscillation in ME’scopeVES™

Requirements and application areas of ASM 18

For a quick and convenient measurement of the required data, ArtemiS SUITE (version 5.1 or later) provides the function Impact Measurement. This function is contained in the Online Analysis Module (ASM 18) of ArtemiS SUITE. Furthermore, you need a front end as well as sensors and an impact hammer. The following front ends are supported by the Impact Measurement function of ArtemiS SUITE: SQobold, SQuadriga, SQuadriga II, labCOMPACT12, labCOMPACT24, HEADlab and DATaRec.

The function was specifically developed for users primarily dealing with acoustic tasks (sound quality, sound design), who, however, repeatedly face questions related to the transfer behavior of measurement objects. This tool is particularly suited for users who already own an ArtemiS SUITE license and, e.g., a SQuadriga II and do not want to invest in an additional measurement and analysis system for their occasional structural analysis tasks.

1 The descriptions in this Application Note are based on version 9.0 of ArtemiS SUITE. The general procedure also applies to other versions. However, there may be differences in the scope of functions and in the user interface.
2 Please note the footnotes of the “Summary” chapter regarding possible limitations as well as the required ArtemiS SUITE versions and licenses for the different front ends.
One application area is in the automotive supplier industry, where suppliers are increasingly obligated by vehicle manufacturers to guarantee certain parameters of the mounting structure of a component. At the same time, it must be assured that components will not exhibit unfavorable vibration behavior. Furthermore, the function is suitable for all users working in the area of acoustic troubleshooting who need a mobile, easy-to-use measurement system. These users can perform pre-examinations with the software and hardware products from HEAD acoustics in order to quickly identify potential problems. Subsequently, structural analysts can make specific further examinations. Since such pre-examinations are often performed on test tracks or in production facilities, the mobile measurement systems like SQobold and SQuadriga II with their compact size and built-in battery offers many advantages. With its straightforward guidance through all necessary steps, and the possibility to have almost all parameters determined and checked automatically, the function Impact Measurement allows even inexperienced users to quickly and efficiently perform a structural analysis with little effort and low risk of errors. The function focuses on easy and straightforward handling allowing the user interface to be compact and manageable.

**Overview of the function**

You can start the function Impact Measurement via Start -> Data Acquisition -> Impact Measurement. As of version 9.0 of ArtemiS SUITE, two methods are available for impact hammer measurements: Roving Hammer and Roving Accelerometer.

For the Roving Hammer method, you initially specify one or several static reference channels and then excite the structure point by point with the impact hammer. This method is suitable for troubleshooting purposes. In the Roving Accelerometer method, you have only one fixed excitation point, which you can excite with an automatic hammer, for example. The sensors (accelerometers) are repositioned after each measurement. This method is suitable in cases where excitation with an impact hammer is not possible due to space restrictions in some of the positions to be examined.

For both methods, several steps must be performed for the configuration and the actual measurement in order to determine the transfer characteristics. ArtemiS SUITE will guide you through these steps. Once a step is completed successfully, you can proceed to the next one by clicking on the ➔ button. This concept is deliberately different from the “free-style” way of working, e.g., with a Pool Project.

**The individual steps**

The text below briefly describes the individual steps for the Roving Hammer method. A detailed description, e.g., of the possible configurations in the Properties window, are available in the Help System of ArtemiS SUITE. In the Help System you will also find a description of the steps for the Roving Accelerometer method, which differ from the steps described here in some points.

In the first step, you specify the project name and the data storage location. If you have already started a measurement before, you can also select the name of the existing project and continue the measurement.

In the second step, you can enter User Documentation for the project. You can use the suggested default template or a different documentation template. If you want to add the User Documentation later, you can skip this step by clicking on the ➔ button. If you do not need any User Documentation for this project at all, you can remove the displayed documentation template with a click on the X button and proceed to the next step.

In the third step, you select a suitable coordinate system for your measurement object (cartesian, cylindrical or spherical). Instead of the spatial directions (e.g., X, Y, Z), you may use colloquial names (e.g., left, up, back, see figure 2). This facilitates the subsequent orientation of the sensors (particularly when using triaxial accelerometers) and the impact hammer. Furthermore, in this step you specify a list of the measurement points to be excited with the respective directions of impact.
If you have already created a structure model, e.g., in a ME’scope project, you can import it via the button. The positions specified in the model will then be displayed in the list, making the manual specification of the measurement points described above unnecessary. The supported import file formats and other requirements are described in the Help System of ArtemiS SUITE.

In the fourth step, you select the front end and specify the channels for the impact hammer and the references. You have to define your sensors in a Sensor Library to be able to connect sensors to the different channels. For more information about defining and administrating Sensor Libraries, please refer to the Help System of ArtemiS SUITE. If you have imported a structure model in the previous step, you can view it now via the 3D Model tab. Besides the model, ArtemiS SUITE also visualizes the connected sensors in order to facilitate their correct positioning and orientation for you.

The fifth step easily leads you to the correct parameters for the impact measurements, i.e., sampling rate, window size and windowing function, pre-trigger for the hammer, threshold for triggering the hammer, as well as the appropriate measurement range. For this purpose, you simply strike a measurement point several times, e.g., the first one. Colored status icons indicate whether the parameters were correctly determined (see figure 3).
**Figure 2:** Determining the parameters for the impact measurements: the screen shows the time domain signal of the hammer stroke, the time domain signals of the references and the FFT spectrum of the stroke, as well as the status icons for the various parameters.

The quality of the stroke is checked during this configuration step, e.g., if a double stroke is detected. In this case, this stroke has to be repeated. When all parameter status icons are green, you will get a visual and acoustical feedback.

Advanced users can also enter some or all parameters manually in the Properties window. If you specify a parameter (such as the sampling rate) manually, it will no longer be included in the automatic functionality. In the **Configuration** section of the display area, the status display for this parameter is then grayed out. In the Properties window of this step, you can also enable the option **Make Reciprocity Check** to insert an additional verification step into the sequence.

In this optional **sixth step**, you can verify whether your structure behaves reciprocally. For this purpose, you measure two positions on your structure, which should be as distant from each other as possible. First, excite point A and measure at point B, then relocate the acceleration sensor to point A and excite point B. The display area will now show the averaged curves (averaged transfer function, calculated coherences, and auto spectra of the impact hammer) jointly for both directions. By means of these superimposed curves, you can identify any nonlinear behavior of your measurement setup and take appropriate countermeasures. Information on how to interpret the result curves can be found in the Help System of ArtemiS SUITE.

The **seventh step** comprises the actual measurement of the transfer function. You are guided, point by point, through the list of measurement points you had previously defined. The current measurement point to be struck with the hammer and the striking direction are clearly displayed on the screen. The number of strokes to be averaged in order to determine the transfer function can be specified in the Properties window of this step.
This step, too, includes automatic quality control, which checks for double strokes, too high or too low signal levels of the time domain signal of the hammer stroke, and for coherence between the hammer signal and the reference signal. In automatic mode, a measurement is discarded if one of the quality criteria is violated. Violation of criteria is visualized by colored status icons in the upper area of the display. Advanced users are free to configure the different quality control functions in the Properties window so that only a warning is displayed and no automatic rejection takes place, or to disable quality control altogether. In such cases, the user decides whether a stroke should be discarded and when an averaged transfer function should be saved. In a measurement step, four diagrams are displayed: the time signal of the impact hammer, the time signals of the reference channels, the coherences between the excitation signal and the references and the averaged transfer functions (see figure 4).

![Strike to Acquire Transfer Functions](image)

**Figure 3:** Display of the time domain signal of the impact hammer, the time domain signals of the references, the coherence and the transfer function averaged over the individual strokes of this measurement step

Once all strokes for a measurement point are done, an HDF file is saved. For each measurement point, one file with an averaged transfer function for each reference channel is created. Furthermore, you can determine in the Properties window that additional data are stored as HDF files. You can save the time signals of the impact hammer and of all reference channels, the averaged coherences between the excitation signal and the reference signals as well as the averaged auto spectrum of the excitation signal.

In the **eighth** and last step, you decide how you want to analyze your data subsequently. It is possible to visualize the transfer function in a Data Viewer or in a report (see figure 5) directly in ArtemiS SUITE. Or you can export the averaged transfer functions to the BLK format with a click of the mouse and use the analysis software ME’scopeVES™ from Vibrant Technology (see figure 1) for further analysis. Furthermore, UFF export and XLS export are available.
**Application examples**

- Transfer behavior of pipeline mounting points to the pipeline
- Transfer behavior of mounting points of a car back door when the car body is excited
- Vibrations of a wheel rim (bending or torsion)
- Acoustic sensitivity of a gearbox mounting (microphone in the car interior recording hammer strokes on the mounting)
# Summary

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<th>ArtemiS SUITE version 5.1 or later</th>
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<td>Required licenses</td>
<td>ASM 00, ASM 18</td>
</tr>
<tr>
<td>Recommended licenses</td>
<td>ASM 02 (results display in report), ASM 23 (for export to UFF format)</td>
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<td>Supported front ends</td>
<td>HEADlab(^3), labCOMPACT12(^4), labCOMPACT24(^4), SQuadriga II(^5), SQuadriga(^6), SQobold(^3) und DATaRec 4(^7)</td>
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<tr>
<td>Required hardware</td>
<td>Impact hammer</td>
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<td>Acceleration sensor(s)</td>
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<td>Target group</td>
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Do you have questions or suggestions?  
Please contact us at imke.hauswirth@head-acoustics.de.  
We look forward to your feedback!

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3 Using a HEAD/lab system is supported as of ArtemiS SUITE 6.0. The channel number is not limited to a fixed value. A computer that complies the minimum requirements described in the data sheet allows e.g. the use of 60 channels (with the following parameter setting: 24 kHz sampling rate, 32,768 samples window size, 10 averagings). According to the performance of your computer and the parameters effectively used more or less channels can be applied in practice.

4 Using this front end is supported as of ArtemiS SUITE 7.0.

5 When using a SQuadriga II the channel number is limited to 6 Line/ICP® channels.

6 When using a SQuadriga (I), only channels 1+2 or channels 3+4 can be used.

7 For measurements with a DATaRec 4 you additionally need license ASM 28 (ArtemiS SUITE Data Acquisition Support for DATaRec 4). Using a DATaRec 4 is supported as of ArtemiS SUITE 7.0.