CRYSTAL INSTRUMENTS

EDM MODAL: TESTING & ANALYSIS

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EDM Modal Overview

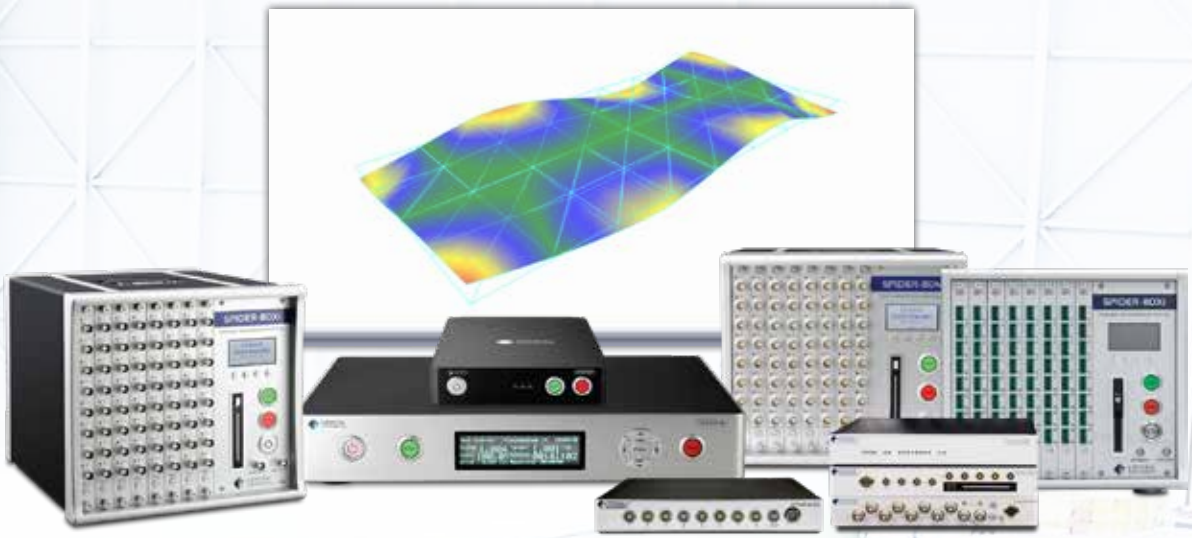
www.crystalinstruments.com/edm-modal-testing-and-analysis-software

Engineering Data Management (EDM) is a PC-based software program designed for real-time data management and processing. This easy to use, Windows-native software manages the communication between the PC and all Crystal Instruments hardware platforms.

EDM Modal is a complete Modal Testing and Modal Analysis suite for Experimental Modal Analysis (EMA). EDM Modal was developed based upon the sophisticated technologies of modern modal analysis theory and technique. With its intuitive controls and powerful features, EDM Modal is the ultimate tool for modal analysis applications. An intuitive interface allows users to manage highly complicated tests that can involve hundreds of measurement points and multiple excitations. This interface also allows for simple tests to be conducted quickly and with little effort. Regardless of how complicated the modal test is, EDM Modal provides exactly the right tools to achieve your goal.

To successfully acquire testing data, it is essential to properly book-keep the Degree of Freedoms (DOFs) of the test structure. The Geometry Editor handles all types of structure modeling and supports all types of coordinate systems. Using the concept of 'components', parts of a complicated structure can be built simply and then integrated into the geometric model. Inside the Input Channel Setup window, the measurement points and their corresponding directions can be defined. Once the test is started, the measurements will proceed through all the test points, as defined by the Degree of Freedom (DOF) information for each measurement point.

To acquire the FRF signals, there are several methods per excitation arrangement. The usual methods involve measuring the excitation along with the response signals. Included methods are hammer impact testing or modal shaker(s) testing. When using one or multiple modal shakers, the drive signal can be random or sine. Under certain circumstances, the excitation is not available or difficult to measure. In these cases, apply the response-only modal testing method or Operational Modal Analysis to take use of the ambient excitation or machinery operating status.



Crystal Instruments Spider Hardware Platforms - Scale up to 512 Channels

EDM MODAL SOFTWARE

- Geometry creation/import/export/animation
- Operational Deflection Shape analysis
- Supports Spider Systems with up to 512 input channels
- Impact hammer modal testing
- Single or multiple shaker modal testing
- Single-Input Multiple-Output swept/stepped sine modal testing
- Multiple-Input Multiple-Output swept/stepped sine modal testing
- Operational Modal testing
- Modal playback analysis with recorded data files
- Single reference modal analysis
- Poly reference modal analysis
- **Poly-X (p-LSCF)** modal analysis
- Stochastic Subspace Identification (SSI) for OMA
- Measurement data review
- Reporting to Microsoft Word

Modal Playback analysis takes use of the recorded data files and allows the analysis with detailed settings to calculate the FRF signals. This is extremely useful for the field testing cases. The recorded data files can be recalled and the structural spectrum signals can be re-calculated with any valid setup parameters.

Modal parameter identification is at the heart of modal analysis. EDM Modal employs several curve fitting methods for modal parameter identification. The Least-Squares Complex Exponential (LSCE) method is implemented for the pole (natural frequency and damping factor) identification of single-reference Frequency Response Function (FRF) cases. For multiple-reference (Multiple Input/ Multiple Output or MIMO) testing cases, the corresponding Poly-Reference Time Domain (PTD) method can be used. With the knowledge of the Modal Participation Factor (MPF) from multiple reference FRF data, closely-coupled modes can be isolated.

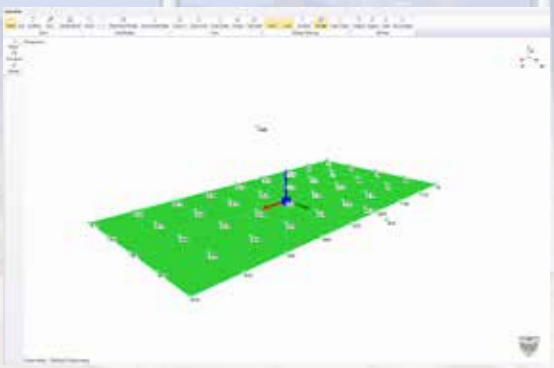
Poly-X is the poly reference Least Square Complex Frequency domain (p-LSCF) modal analysis algorithm to curve fit the FRF matrix from the SIMO/MIMO FRF testing results. Specifically for operational modal analysis, the Stochastic Subspace Identification (SSI) fitter is available.

For mode shape calculation, the renowned Poly-Reference Frequency Domain method (PFD) is used, which is very intuitive. The animation tool is a powerful visualization facility that simulates the mode shapes of the device under test, allowing users to study and understand large amounts of data through a 3-dimensional animated display. The animation module can apply color contours to the surfaces of the geometry model to help visualize deflections in a 3-dimensional space. Free-form Deformation (FFD) enhances the mode shape animation, resulting in smoother and more realistic mode shape displays. Using the same geometry model, Operational Deflection Shapes (ODS) can be displayed using measured time or spectrum operating responses.

Geometry

www.crystalinstruments.com/geometry-and-ods

EDM Modal Geometry/ODS/Animation is the primary EDM Modal software module, and is required for every EDM Modal system. This option provides fast and efficient structural model generation and full 3D visualization of test and analysis results.



The base elements (points, lines, and surfaces) can be added/deleted graphically, or through typed Model Editor entry. Components can be specified for each part of the structure. Each component can have its own origin, as well as its directions and Euler angles. The basic component library includes: line, panel, cube, sphere, cylinder and Circle. Any of these can be added to the geometry model by specifying origin, direction, dimensions, and the number of cells of the component.

The geometry model can be saved and later recalled by other tests. Also, the model can be cleared when the user wants to start over with a new geometry model for the structure under current test. Several types of format from 3rd party applications are supported for geometry model import. The Universal File Format (UFF) format of point and line models is widely used, and may be imported to EDM Modal Geometry.

Geometry view mode can be set to single Perspective View or Quad-view (Perspective/Top/Side/Front).

GEOMETRY

Features:

- Basic elements: point, line, surface; editing graphically or through editor table entry
- Coordinate system: Cartesian, Cylindrical, Spherical
- Component entry: origin, direction (Euler angle)
- Built in component library: line, plane, cube, sphere, cylinder and circle
- Geometry model save/open/clear
- Geometry model decimation
- 3D geometry model reconstruction from 2D photos
- Geometry model import: UFF (.unv), CAD (.dxf, .stl, .obj, .3ds), Nastran (.nas), and .xml
- Geometry model export: .xml, .obj, .stl, .unv
- Geometry model display: point, line, surface; point directions, point number; surface norm; origin
- Geometry view: Perspective, Quad (perspective, Top, Side, Front)

Operational Deflection Shape

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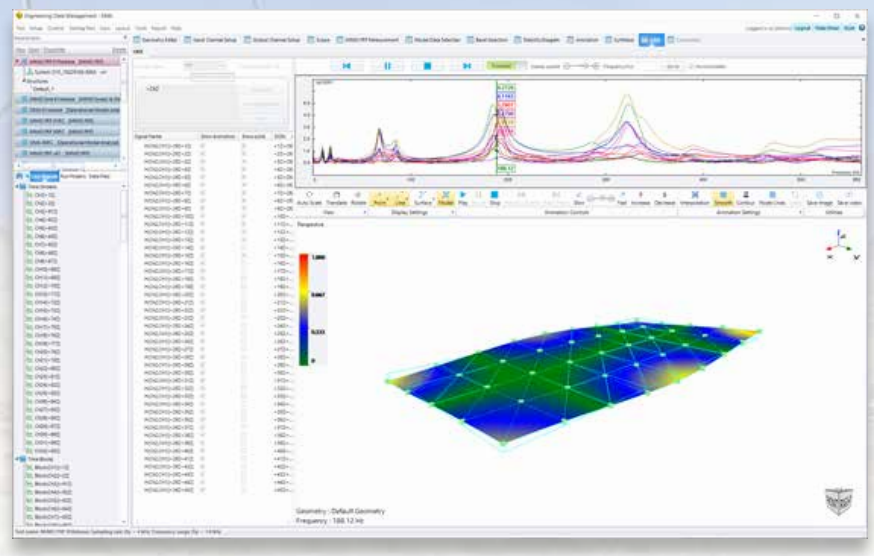

OPERATIONAL DEFLECTION SHAPE

Features:

- Data management of time domain and frequency domain
- Supported time data: block, recorded time data
- Sweep control of Forward/Backward
- Sweep speed control: -, +
- Animation amplitude normalization
- Animation of 3D geometry model with frame or contour
- Animation equation editor and animation with interpolation
- Animation amplitude control
- Animation image and video file saving

EDM Modal Operational Deflection Shape (ODS) is a feature that allows users to better visualize the deformation of the structure under test. Time domain data and spectrum data can be animated using the animation feature of the geometry model. It is an integrated feature with the Geometry and works for all types of EDM Modal testing.

The database structure of EDM makes it very easy to navigate and select data. The selected data set can be animated using the geometry model. The vibration pattern, either in time domain, or frequency domain, can be saved to image (.png, .jpg, .bmp) or video (.avi, .gif) files, too.

Hammer Impact Testing

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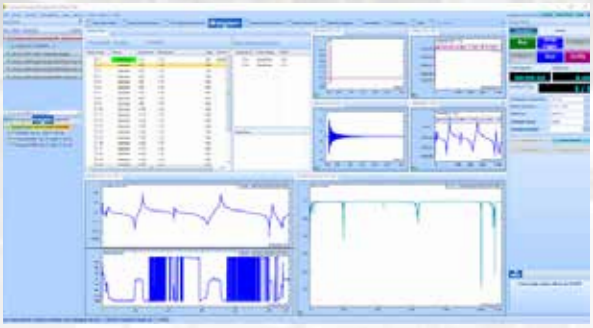


HAMMER IMPACT TESTING

Features:

- Intuitive testing process
- Geometry based testing process
- Testing plan for the process and status
- Roving hammer or response
- Auto or manual Point/Direction increment
- Manual/Auto trigger arming
- Auto trigger level; suggested bloke size
- Resizable preview window for DOFs, frame counts, impact/response waveforms
- Double hit detection on/off, auto/manual reject
- Driving point selection
- Audio/graphic feedback of test status
- H1, H2, H3, and Hv estimation

EDM Modal Hammer Impact Testing provides the necessary features for a single-operator experimental modal test. The Hammer Impact GUI features an intuitive step-by-step process, allowing a user to easily go through the setup and then the testing.

The testing process has been designed to help users quickly define acquisition parameters, so that more time can be spent on analysis. Users can define trigger behavior through the Trigger Setup; a Trigger-Preview window allows control over the trigger level and pre-trigger delay. For users that may need to review their measurements after each acquired frame, the 'Manual-Arm' trigger mode can be used. When this trigger mode is selected, acquired signals will be displayed for review and will prompt the user to accept/reject the signal. The auto-arm mode simply auto-accepts acquired measurements and automatically re-arms the trigger, helping to speed up the whole test process.

Another feature is Driving Point Selection, which will help users decide where to place the fixed excitation or response reference. The idea here is to survey several candidate driving-points, and measure their FRFs – this allows you to choose the best available DOF for the driving point. The FRF at the trial driving-point which best excites most of modes can be selected as the driving-point. EDM simplifies the data management for this important pre-test survey.

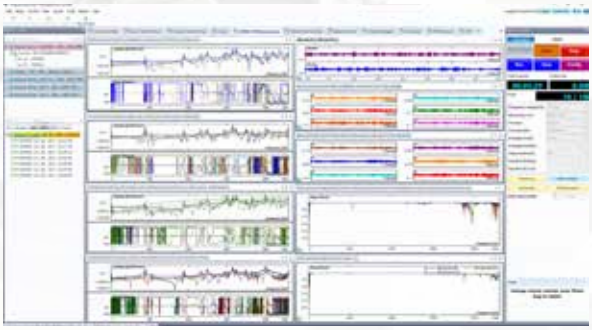
When taking measurements, the process and status are taken care using the Testing Plan. With testing plan, each measurement entry can be controlled totally by user. The status of every measurement enty is available from the testing plan too, which is updated as the test progresses.

The Trigger Preview window is optimized for your viewing experiences – featuring a resizable window and adjustable font size. The font size increases when the window itself is dragged to be enlarged. With this added flexibility of the trigger window, EDM Modal supports users with various display types- users can be far removed from their display and still be able to take measurements. Users have total control of their testing, regardless of how far they are from the computer.

One common problem associated with hammer testing is the "double hit". EDM Modal Hammer Impact software can automatically detect a double hit and give the user the choice to automatically or manually reject the double strike. Hammer impact testing is seamlessly integrated with the necessary post modal analysis inside the EDM software.

Single/Multiple-Input Multiple-Output (SIMO/MIMO) FRF Testing

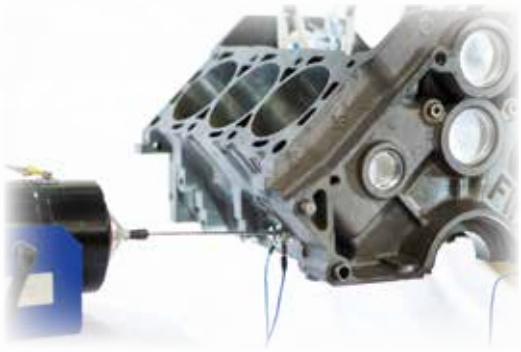
www.crystalinstruments.com/single-input-multiple-output-simo-frf-testing



EDM Modal SIMO/MIMO FRF Testing includes a dedicated test setup and operation process flow using single or multiple simultaneous shakers to acquire FRF signals. Using a large channel count data acquisition system (i.e., Spider- 80X or Spider-80Xi), this shaker excitation method provides much higher efficiency and accuracy for the FRF measurements while minimizing local stresses on the test article.

When using multiple shaker random excitation applications, the shaker-driving Source signals are guaranteed to be uncorrelated with one another. The Source Output type supports pure random (white noise), burst random, shaped random, burst shaped random, chirp/burst chirp, pseudo random, and periodic random. For periodic random types (pseudo random and periodic random), the delay block and cyclic block numbers can be set so that the structure exhibits steady-state response, allowing precise window-free analysis.

Multiple shaker excitations are useful to separate and clearly identify repeated roots and frequency-proximate modes. With more than one reference shaker, multiple columns of the Frequency Response Matrix can be measured simultaneously. Combined with the poly reference curve fitting algorithm, the modal participation factor will help to isolate the repeated and highly coupled modes.



SIMO/MIMO FRF TESTING

Features:

- Ease of use testing process
- Point/direction auto/manual increment
- One or multiple synchronized and uncorrelated excitation(s) (reference)
- Testing plan for the process and status
- Source trigger mode for synchronized acquisition and source excitation
- Random, burst random, shaped random, burst shaped random, pseudo random, period random, chirp/burst chirp output types
- Delay block and cyclic block number setting for pseudo/periodic random
- Supports Multi Resolution spectrum
- Scope tab to view channel data before measurement
- H1, H2, H3, and Hv estimation

Single/Multiple-Input Multiple-Output (SIMO/MIMO) Swept Sine Testing

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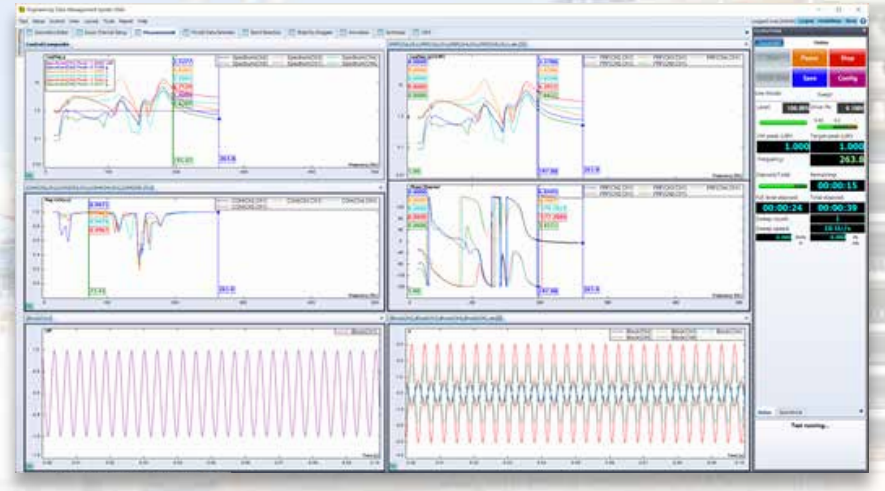

SIMO/MIMO SWEPT SINE TESTING

Features:

- Ease of use testing process
- Point/direction auto/manual increment
- One or Multiple sine excitation with sine tone (reference(s))
- Single or Multiple number of sweeps
- Different initial phase conditions for multiple sweep: +/- or random
- Testing plan for the process and status
- Specify source output level profiles; or control the amplitude of input channels
- Linear, Logarithmic sweep mode
- Filter, RMS, Mean or Peak for measurement strategy
- Fixed or proportional tracking filter, with user defined bandwidth
- User defined Start/end frequency; Number of points; Delta F (or Points/Oct); Transition speed

EDM Modal SIMO/MIMO Swept Sine Testing includes a dedicated test setup and operation process flow using single or multiple shakers outputting sine waves to acquire FRF signals. The source output type is swept sine. The sweep mode can be linear or logarithmic. The FRF signals of each measurement DOFs with respect to defined reference DOFs will be constructed. The output drive level can be defined to run the test under no control strategy, or the response of a control channel can be specified to run the test in a closed loop.

The modal analysis process is seamlessly integrated with SIMO Sine Swept Sine testing.

Single/Multiple-Input Multiple-Output (SIMO/MIMO) Stepped Sine Testing

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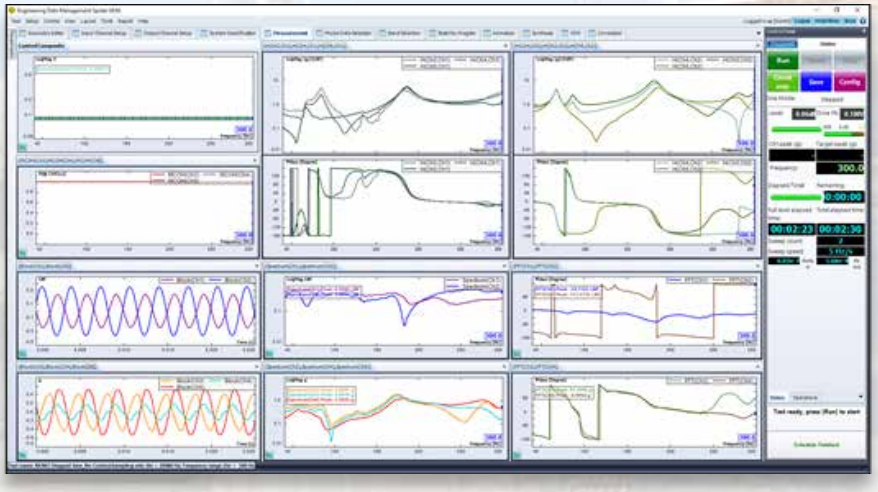

SIMO/MIMO STEPPED SINE TESTING

Features:

- Ease of use testing process
- Point/direction auto/manual increment
- One or Multiple sine excitation with sine tone (reference(s))
- Single or Multiple number of sweeps
- Different initial phase conditions for each sweep: +/- or random
- Testing plan for the process and status
- Specify source output level profiles; or control the amplitude of input channels
- Linear, Logarithmic sweep mode
- Filter, RMS, Mean or Peak for measurement strategy
- Fixed or proportional tracking filter, with user defined bandwidth
- User defined Start/end frequency; Number of points; Delta F (or Points/Oct); Transition speed

EDM Modal SIMO/MIMO Stepped Sine Testing includes a dedicated test setup and operation process flow using single or multiple shakers outputting sine waves to acquire FRF signals. The Source Output type is Stepped sine tones. The step mode can be linear or logarithmic. The FRF signals of each measurement DOFs with respect to defined reference channels will be constructed. The output drive level can be defined to operate the test in an open loop, or the response of a control channels can be specified to operate the test in a closed loop.

The modal analysis process is seamlessly integrated with MIMO Sine Swept Sine testing.

Operational Modal Testing

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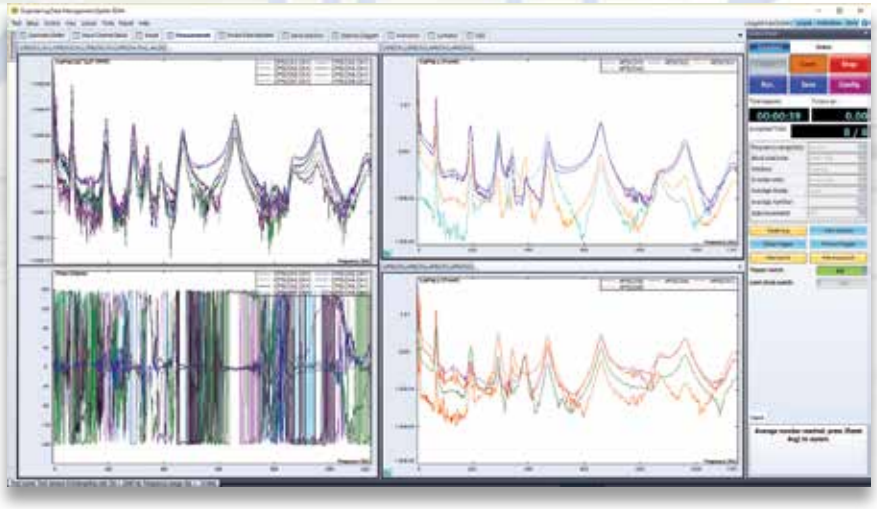

OPERATIONAL MODAL TESTING

Features:

- Ease of use testing process
- Point/direction auto/manual increment
- User defined reference channel
- Scope tab to view channel data before measurement
- Testing plan for the process and status
- Expanded cross power spectrum for all input channel vs. reference channel
- Cross power spectrum vector(S) smoothing, multiple times or cancel

EDM Modal Operational Modal Testing (OMA Testing) includes a dedicated test setup and operation process flow using ambient vibration data. Using a large channel count data acquisition system (e.g., Spider- 80X or Spider-80Xi), the excitation method provides a much higher efficiency and accuracy for FRF measurements while minimizing local stresses on the test article.

Typical modal analysis methods and procedures are based on forced excitation tests carried out in the laboratory. Frequency Response Functions (FRFs) are measured as input to modal parameter identification. However, the real loading conditions to which a structure is subjected often differs considerably from those used in a laboratory testing. In many cases, (i.e., excitation of off-shore platforms or traffic/wind excitation of a bridge,) forced excitation tests are very difficult, if not impossible to conduct; at least when using standard testing equipment. In such cases, operational vibration data is often the only resource available.

Operational modal testing is designed to measure and process ambient vibration response data, which will be ready for parameter identification. The resulting cross power spectrum vector(s) can be further smoothed by using the de-convolution method.

The modal analysis process is seamlessly integrated with Operational Modal testing.

EMA Playback Analysis

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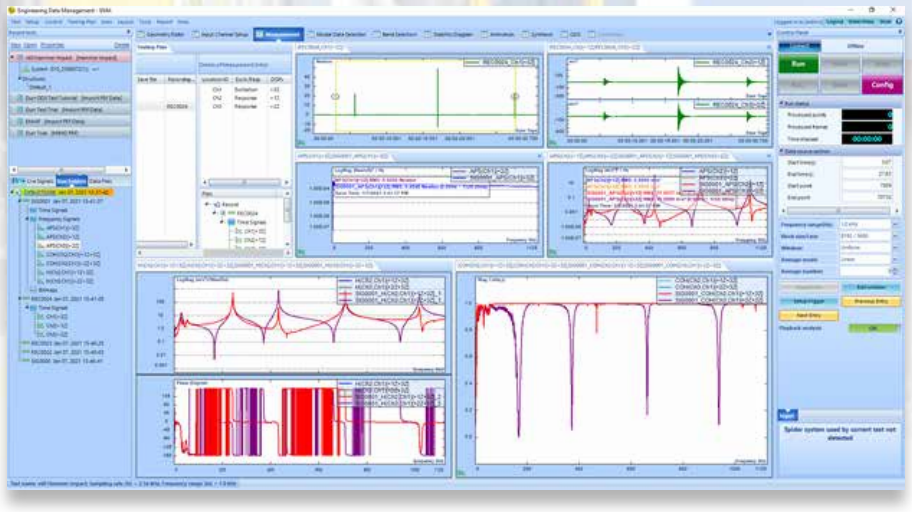


EMA PLAYBACK ANALYSIS

Features:

- Ease of use testing process
- Record and data file management through Testing plan
- Available in Hammer Impact, SIMO/MIMO FRF and OMA testing types
- Simple playback mode switch from online analysis
- Same setup as that for online analysis
- Repeatable and complete analysis for the spectrum required

Modal Playback analysis takes use of the recorded data files and allows the analysis with detailed settings to calculate the FRF signals. This is extremely useful for the field testing cases. The recorded data files can be recalled and the structural spectrum signals, i.e., FRF or CPS, can be re-calculated with any valid setup parameters.

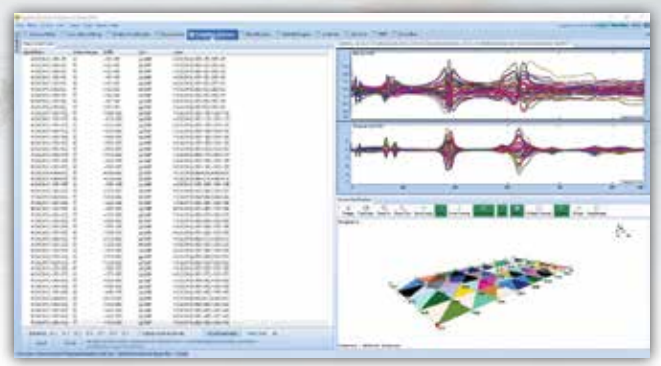
Playback analysis feature allows user to import recorded time signals and process these modal measurements to obtain the related frequency domain signals. This feature allows the user to carry out all the field measurements in a single go before post-processing and analyzing the measured data on a lab PC. This is available in the Hammer Impact, MIMO FRF and Operational Modal Analysis test types to support ambient excitation data and experimental data obtained through hammer impact or shaker excitation.

Standard Modal Analysis

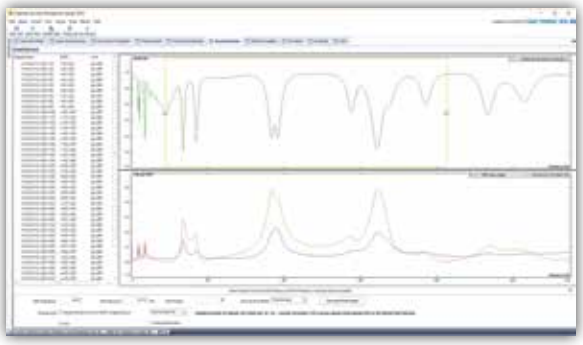
www.crystalinstruments.com/modal-analysis

EDM Modal Standard Modal Analysis provides the user with a complete arsenal of tools, from FRF data selection and parameter identification to results validation and mode shape animation.

Upon completion of the Modal testing, the set of FRF data is made available for the next step: Modal Analysis. You can also add/replace individual FRF signals. The complete set of FRF test signals can be exported or imported from other sources. These operations are managed by 'Modal Data Selection'. The FRF signals are organized for a rapid comprehensive review, one by one, or multiply in one graph window.



With one click, the Modal Parameter Identification process can be started. With the help of a Mode Indicator Function (MIF), the natural frequencies can be labeled. The Multivariate, Complex, Real, and Imaginary Sum MIFs are available. MIF indicators aide identifying repeated roots (repeated poles) and closely-space distinct roots.

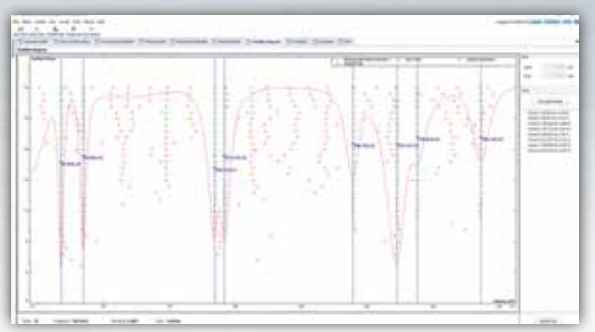


STANDARD MODAL ANALYSIS

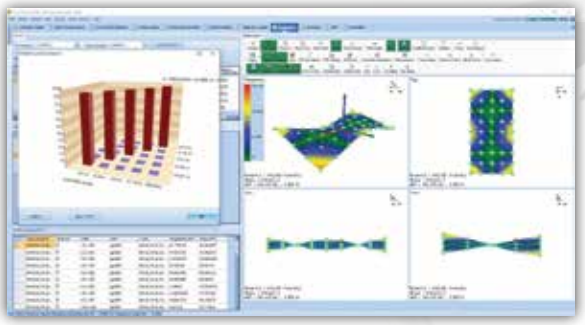
Features:

- Ease of use modal data selection
- Signal Smoothing with Deconvolution (for OMA testing only)
- MIF: Multivariate MIF, Complex MIF, Real MIF, Imag sum MIF
- User selectable frequency band for parameter identification
- Stability Diagram with Auto pole selection
- Proven curve fitting method: LSCE
- Least square frequency domain (LSFD) algorithm for mode shape calculation
- Save/append modes to the shape table
- Auto/Cross MAC calculation and display
- Import/export modes: UFF format
- Animation equation editor for unmeasured DOFs

A Stability Diagram is employed with modal parameter identification. With the Standard Modal Analysis option, the proven Least Square Complex Exponential (LSCE) fitter is implemented for pole identification. The physical poles sought are stable (as opposed to 'computational poles' sometimes produced by the LSCE) and can be selected from the Stability Diagram for the next step mode shape calculation, using the Least Square Frequency Domain (LSFD) algorithm.



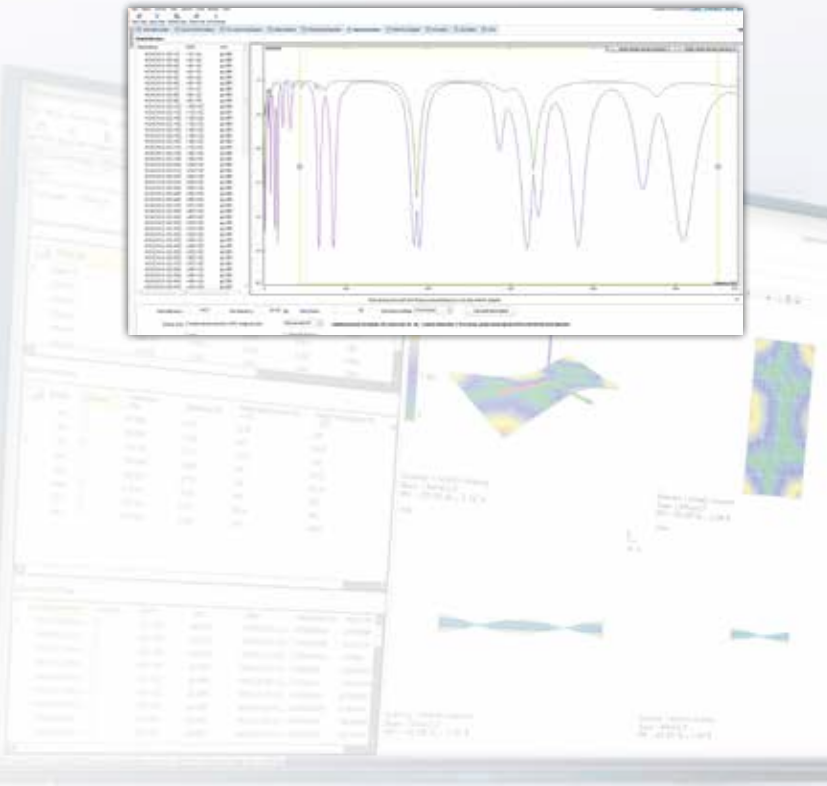
The resulting mode shape table can be saved and used for mode shape animation. Modal Assurance Criterion (MAC) function and FRF synthesis are also available. These provide means for modal parameter validation.



STANDARD MODAL ANALYSIS

Features (continued):

- Mode Shape Animation: wireframe, surface contour, FFD, animation with interpolation
- Contour edit, Contour value
- Animation smoothing
- Node lines
- Animation with un-deformed elements
- Mode Shape Animation speed control (fast, slow), magnitude control (increase, decrease)
- Animation format: Single, Left/Right, Upper/Lower
- Modal Shape video saving, graph saving
- Synthesized FRF vs. measured FRF, with Correlation and Error values



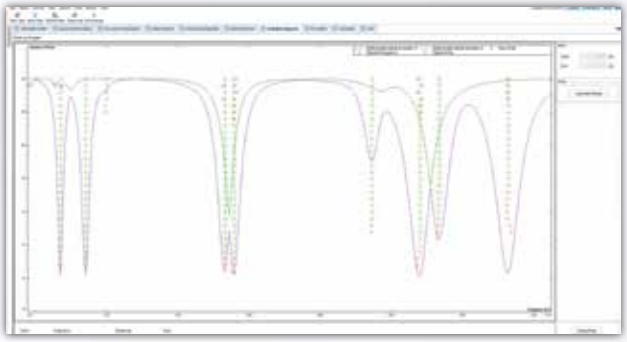
Advanced Modal Analysis

EDM Modal Advance Modal Analysis includes all the features of Standard Modal Analysis. On top, it provides the Poly-reference modal analysis algorithm to curve fit the FRF matrix from the MIMO FRF testing results. The time domain curve fitting algorithm for the pole identification is Poly reference time domain method (PTD), which is sophisticated and proven.

The selection of the curve fitting method, PTD or LSCE, is automatic based on the type of FRF signal set selected, whether it is single reference or multi reference.

Features:

- Requires all features of Standard Modal Analysis, plus,
- Poly reference time domain (PTD) curve fitting
- Auto selection of curve fitter per single or multiple reference from the FRF data set



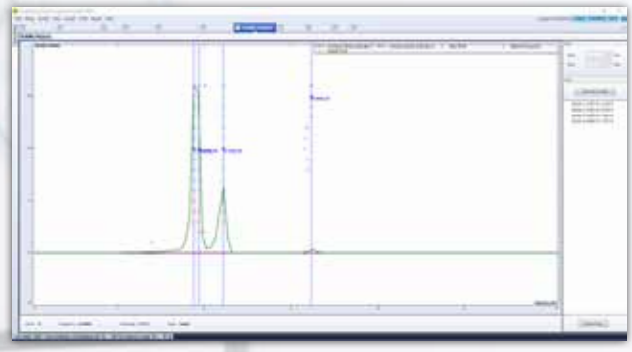
Premium Modal Analysis

EDM Modal Premium Modal Analysis includes all the features of Standard and Advanced Modal Analysis. On top, it provides the Poly-X, which is poly reference Least Square Complex Frequency domain (p-LSCF) modal analysis algorithm to curve fit the FRF matrix from the MIMO FRF testing results. This frequency domain modal parameter estimator is more efficient and neat on the stability diagram.

The selection of the curve fitting method, Time Domain or Poly-X, is available from the EDM Modal software. It applies to either single reference or poly reference FRF data sets.

Features:

- Requires all features of Standard and Advanced Modal Analysis, plus,
- Poly-X - Poly reference Least Square Frequency Domain (p-LSCF) curve fitting
- Neat Stability Diagram with emphasis on stable poles



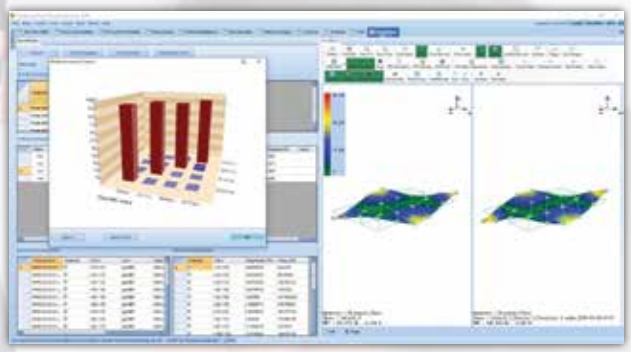
Operational Modal Curve Fitter

The modal parameter estimation method, called the Stochastic Subspace Identification (SSI) is added. This dedicated curve fitting method for Operation Modal Analysis is not only cleaner but more efficient as well.

The selection of the curve fitting method, Time Domain, Poly-X, or SSI is available from the EDM Modal software. It applies to either single reference or poly reference cross power spectrum data sets.

Features:

- Requires all features of Standard, plus,
- Stochastic Subspace Identification (SSI) curve fitting
- Neat Stability Diagram with emphasis on stable poles



Correlation Analysis

EDM Modal Correlation Analysis allows the user to correlate two modal models. The modal models can be EMA model, and/or FEA model. Comparing the experimental data with that acquired through finite element analysis helps in validating the test results. The geometry model and mode shape data from the FEA software or another set of mode shape data from EMA can be imported. A modal mapping procedure is executed to match the EMA and FEA models. After this matching procedure, the new mode shape information from FEA is interpolated and the FEA modal parameters are displayed alongside with EMA results. Finally, to observe the correlation between the results from two methods, a Cross-MAC matrix is calculated and shown.

Features:

- Import Model: .xml, .unv, .nas
- Import Mode Shape: .unv
- Modal mapping: Manually pair 3 points from each model (or more), Auto-Match
- Cross-MAC calculation and display
- Animation Comparison: Left/Right, Upper/Lower

Function	Standard Modal Analysis	Advanced Modal Analysis	Premium Modal Analysis
Modal Data Selection	√	√	√
Band selection, MIF functions	√	√	√
Stability Diagram	√	√	√
Animation, MAC, FRF Synthesis	√	√	√
LSCE (single reference time domain)	√	√	√
PTD (Poly-reference time domain)		√	√
Poly-X (Poly-reference frequency domain)			√

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