

ModalVIEW

Getting Started with ModalVIEW

Version R2 (Rev 2012-02)



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1. Introduction

1.1 About ModalVIEW

ModalVIEW software is designed for you easily to acquire multi-channel vibration signals from a machine, or the static or dynamic loading of a mechanical structure by utilizing data acquisition hardware. After obtaining a set of time histories, it can animate the response of a structure and show you the structure's vibration behavior at once. It helps you to extract and visualize useful modal parameters information from acquired time- and frequency-domain experimental data.

ModalVIEW software is developed under National Instruments' LabVIEW, an open environment designed to make interfacing with any measurement hardware rapidly and simple. ModalVIEW software is compatible with any dynamic signal acquisition (DSA) hardware of National Instruments including plug-in boards, USB devices, and PXI systems and speed your time to perform experimental measurement. With ModalVIEW software, you can also leverage your structural testing capabilities by utilizing existing investment in NI DSA hardware.

1.2 System Requirement

ModalVIEW runs in the Windows XP operating system or later. To use ModalVIEW, your computer must have following capabilities:

- A minimum of a Pentium IV or greater or Celeron 2 GHz or equivalent microprocessor.
- At least 2 gigabytes of RAM memory. 4 gigabytes of RAM is recommended.
- A hard disk with at least 1 gigabytes of available space.
- A mouse or other pointing device.
- A 1024*768 pixels or higher resolution graphics display.

1.3 Software Activation

You must activate ModalVIEW software before using it in accordance with its license agreement. To activate the software for your computer, you must first purchase a license or a USB dongle key. For information on purchasing licenses, please contact your sales representative. Once you have purchased a license, you can activate your ModalVIEW software by using the license manager or inserting USB dongle key to the computer.

When you run ModalVIEW for first time without USB dongle key being intalled, license manager will come out to promote you to apply a 40-character activation code previously acquired for your computer, as Figure 1-1 shows. To activate the software, click the **Activate License** button and input the activation code.

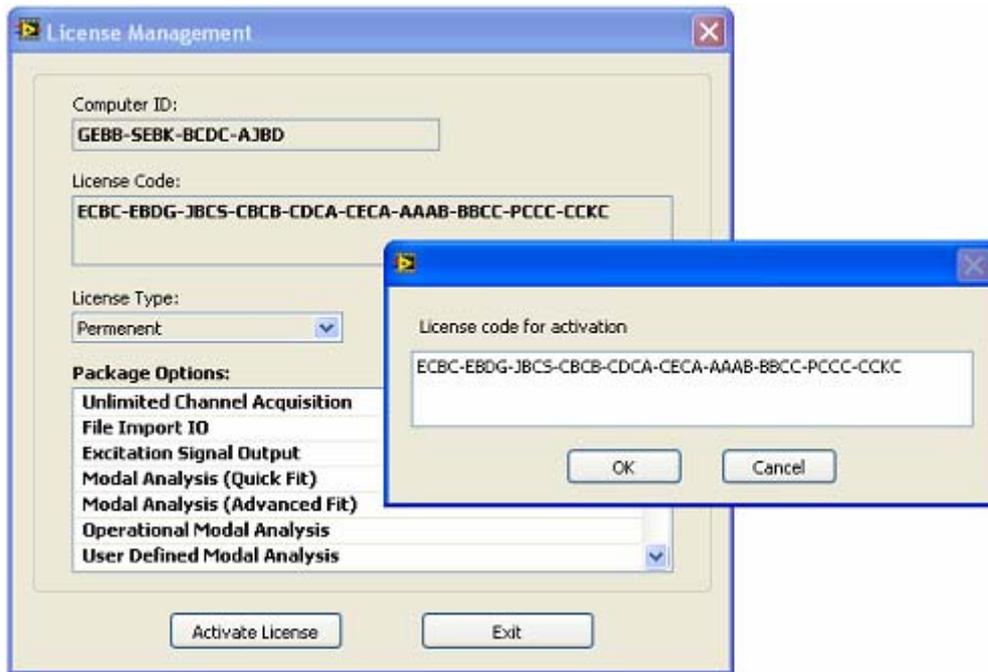


Figure 1-1 Software Activation

Upon successful activation, you can normally use your ModalVIEW software. When an installed USB dongle key being detected, ModalVIEW will be automatically activated.

2. Basic Concept

With ModalVIEW software, you can directly visualize operating deflection shapes (ODS) on 3D geometric model of the test structure based on measured time record, spectrum or frequency response function (FRF). You can also extract natural frequencies, damping ratios and mode shapes by a series modal analysis methods to analyze dynamic behaviour of the machines and mechanical structures. This section will provides a basic understanding on ODS & modal analysis.

2.1 Time ODS

Time ODS is the visualization of 3D geometric model according to the time records, which decide the motion of measured points on the machines or mechanical structures in operating state. Time ODS helps to understand the motion status or vibration pattern of the structure due to overall effect of frequency components in the time record, as Figure 2-1 shows.

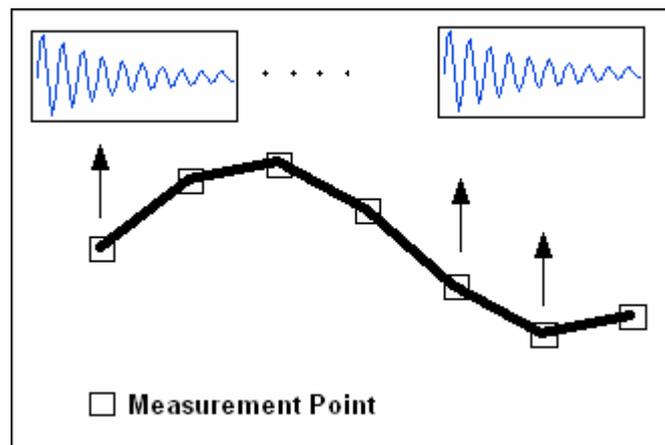


Figure 2-1 Time-based ODS

2.2 Frequency ODS

Frequency ODS is to investigate motion status or vibration pattern of the structure due to a specific frequency components. It visualizes 3D geometric model according to the frequency response functions (FRF) or other frequency domain measurements at a given frequency, as Figure 2-2 shows. It is useful to investigate if some vibration pattern of a structure is due to an inherent resonance at a specific frequency or an external force dwelling at a specific frequency.

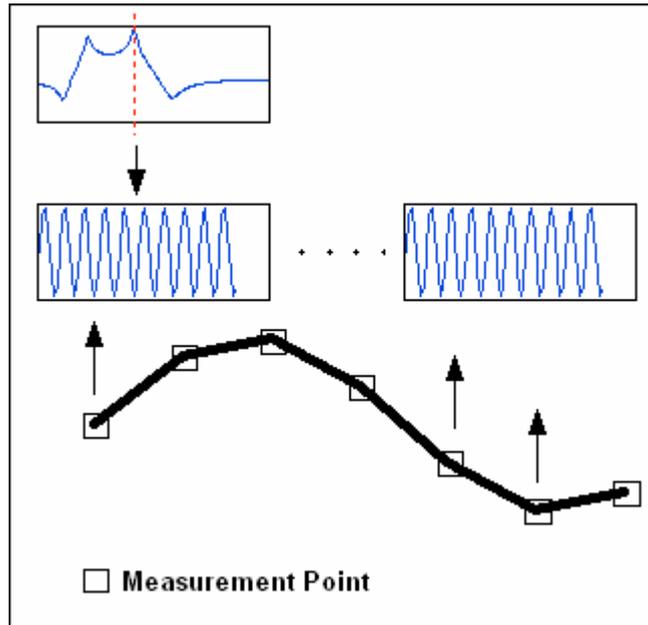


Figure 2-2 Frequency-based ODS

2.3 Order or RPM ODS

Order ODS animates the motion status or vibration pattern of a structure for a specific order component with respect to the rotational speed, as Figure 2-3 shows. Order ODS is useful for inspecting vibration behaviour of a structure due to the rotational parts of an engine.

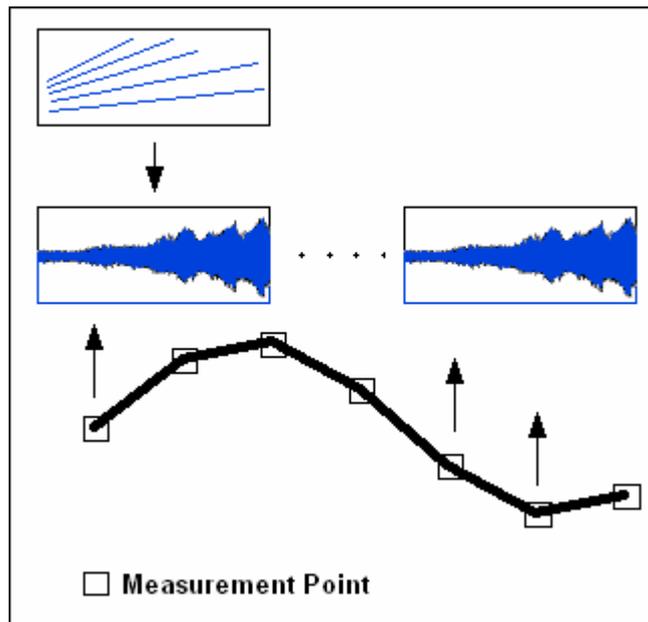


Figure 2-3 Order-based ODS

2.4 Natural frequency, Damping and Mode shape

The whole motion status or vibration pattern of a structure under free dynamic response can be reduced into a discrete set of vibration modes, as Figure 2-4 shows. One single mode is defined by three parameters: natural frequency, damping and mode shape. These parameters depend on the mass and stiffness of the structure. The modal parameters of all the modes decide complete natural characteristics or dynamic properties of structures. Mode shape reveals the deformation pattern of the structure corresponding to a natural frequency. Modal analysis is the process to find these modal parameters through analytical or experimental methods. ModalVIEW software performs modal analysis using experimental technique by curve fitting time record or frequency response function (FRF) from modal testing experiment.

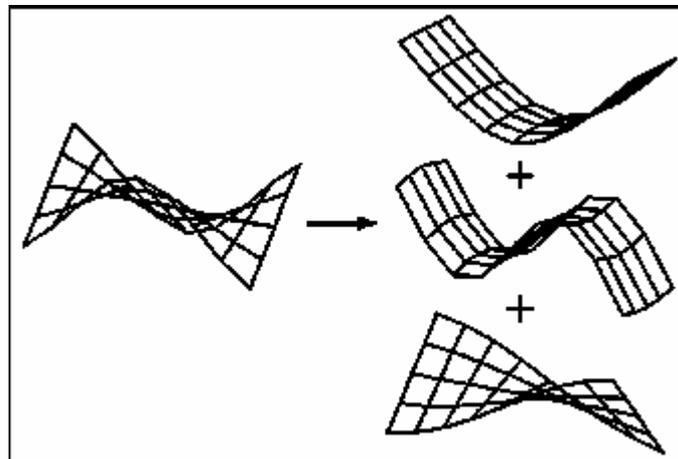


Figure 2-4 Mode Shape

The identified modal data help to tell how the structures to response when a force excites. It is a good aid to understand or predict structural behavior for trouble-shooting.

3. File Types in ModalVIEW

ModalVIEW uses a project to manage all kind of files used for modal analysis. File types contained in ModalVIEW project includes: structure file, measure config file, data file, mode shape file, report file and movie file, etc. as Figure 3-1 shows.

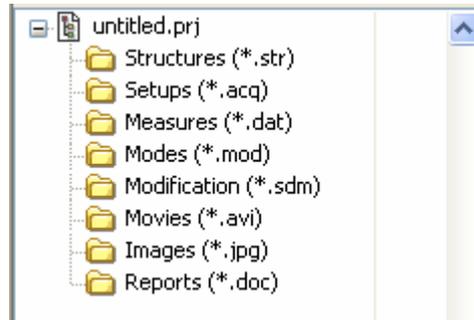


Figure 3-1 File types in project

Project file

Project file defines a collection of structure file, measure config file, data file, mode shape file, report file and movie file, which are generated during measurement and analysis operations. The data management and exchange in ModalVIEW is based on project file. The project file is typically created for a particular testing object. When project file is opened, ModalVIEW display the contained files in the tree list. The extension name for project file is .prj.

Structure file

Structure file stores nodes, lines and surfaces information, which is created to define a 3D model for a test object. When structure file is opened, ModalVIEW graphically displays the defined structure in structure viewer window. The extension name for structure file is .str.

Measure config file

Measure config file contains channel configuration for data acquisition and test settings for modal testing experiment. The extension name for measure config file is .acq.

Data file

Data file stores single or multiple time records, spectrum or frequency response function (FRF) measurements. When data file is opened, ModalVIEW graphically display the data traces in data viewer window. The extension name for data file is .dat.

Mode shape file

Mode shape file contains estimated shape table of a testing structure. The shape table includes frequency, damping and corresponding mode shapes. When mode shape file is opened, ModalVIEW display the content into spreadsheets in the mode viewer window. The extension name for mode shape file is .mod.

Report file

Report file used in ModalVIEW is generated and opened using Microsoft word.

Movie file

Movie file generated in ModalVIEW is standard AVI file format, which is opened using Windows media player.

ModalVIEW can also import universal file format (UFF), and ASCII text file containing structure definition, measurement data and mode shape.

4. Demos in ModalVIEW

ModalVIEW software offers a few built-in demo projects to show analysis process for time ODS, frequency ODS, and mode shape. These demos can be loaded from example finder by executing quick start “demo examples” in project window, as figure Figure 4-1 shows.

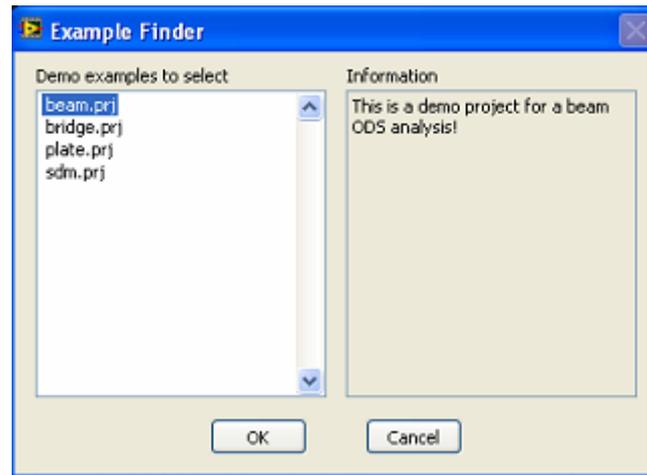


Figure 4-1 Demo example finder window

4.1 Time ODS Demo

To run time ODS demo, select **beam** demo project from example finder. The structure file “beam” and data file “time record” are contained in the project, as Figure 4-2 shows.

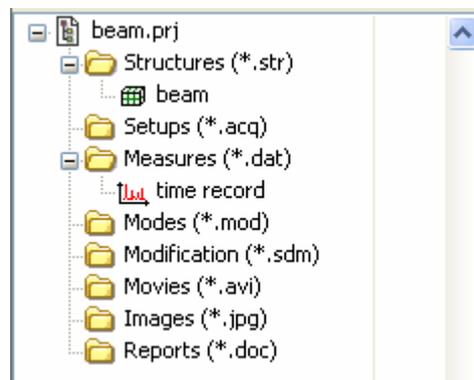


Figure 4-2 Time ODS demo project

- Click quick start item **Time or Spectral based ODS Animation** in project window, the data blocks window and structure viewer window will be opened and tiled left and right.
- Execute menu **File | Load...** in the structure viewer window, and load **beam** in the structure file list. The model structure is displayed in the window.
- Execute menu **File | Load...** in the data viewer window, and load **time record** in the data block file list. The time record with eight traces is displayed in the window, as Figure 4-3 shows.

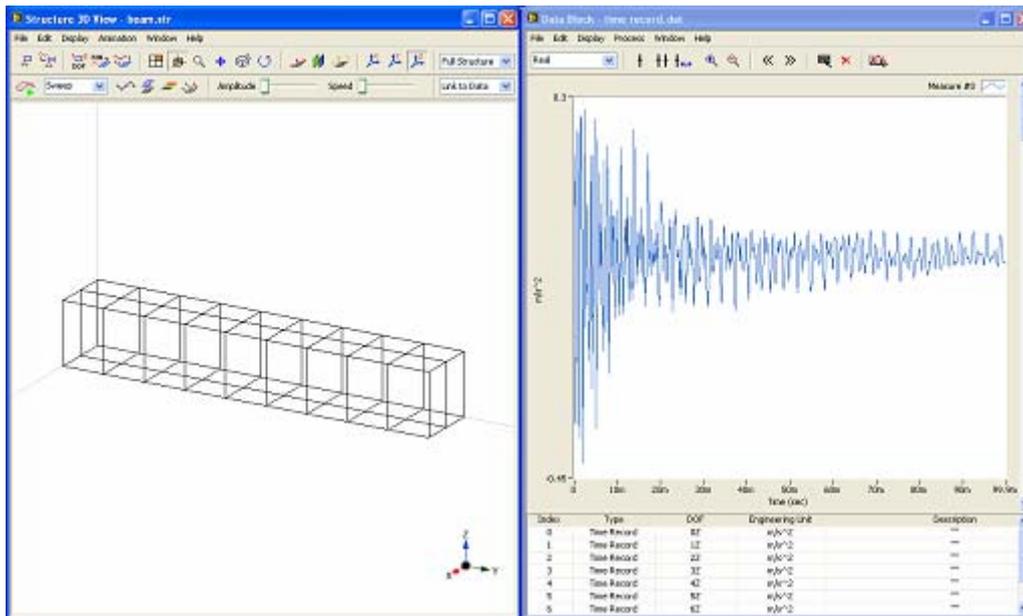


Figure 4-3 Time ODS animation

- Select animation mode as **Sweep** on the toolbar of structure viewer window.
- Click button  on toolbar of structure viewer window to start ODS animation.
- Change slider **Amplitude**  to adjust animation range.
- Change slider **Speed**  to adjust animation speed.
- Click button  to make it active. Hold left mouse button down and move mouse to change structure 3D view.

Notices that only eight measured nodes on the structure are moving now, which are corresponding to eight time records. The motion of unmeasured nodes can be computed by interpolating between measured nodes.

To enable interpolated motion of unmeasured nodes:

- Press button  on toolbar.

4.2 Frequency ODS Demo

To run frequency ODS demo, select **plate** demo project in example finder. The structure file “plate” and data file “freq response” are contained in the project, as Figure 4-4 shows.

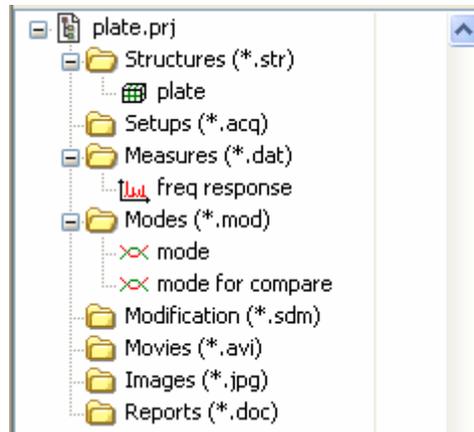


Figure 4-4 Frequency ODS demo project

- Click quick start item **Time or Spectral based ODS Animation** in project window, the data blocks window and structure viewer window will be opened.
- Execute menu **File | Load...** in the structure viewer window, and load **plate** in the structure file list. The model structure is displayed in the window.
- Execute menu **File | Load...** in the data viewer window, and load **freq response** in the data block file list. The FRF with 38 measurements are displayed in the window, as Figure 4-5 shows.

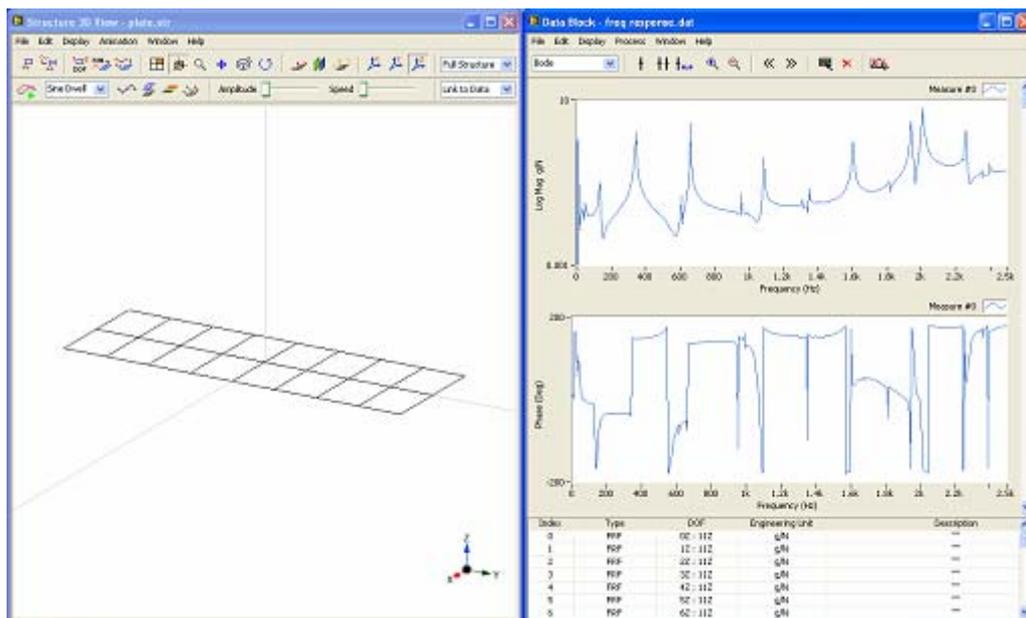


Figure 4-5 Frequency ODS animation

- Select animation mode as **Sine Dwell** on toolbar of structure viewer window.
- Click button  on toolbar of structure viewer window to start ODS animation.
- Change slider **Amplitude**  to adjust animation range.
- Change slider **Speed**  to adjust animation speed.
- Click button  to make it active. Hold left mouse button down and move mouse to change structure 3D view.

The 3D model for plate structure is now being animated with FRF data at selected frequency. The position of single line cursor indicates the selected frequency in the FRF plot.

There are some peaks in the FRF measurements, which indicate the structure resonances. The operational deflection shape (ODS) of the structure near each resonance frequency approaches to the mode shape relative to that resonance. In a situation requiring fast analysis, Frequency ODS is a good substitution for modal analysis.

To animating 3D model at a resonance

- Drag the line cursor to each peak in the FRF plot, and watch different ODS of the plate structure.

4.3 Order ODS Demo

To run order-based ODS demo, select **order oma** demo project in example finder. The structure file “rotating machine” and data file “resp1” are contained in the project, as Figure 4-6 shows.

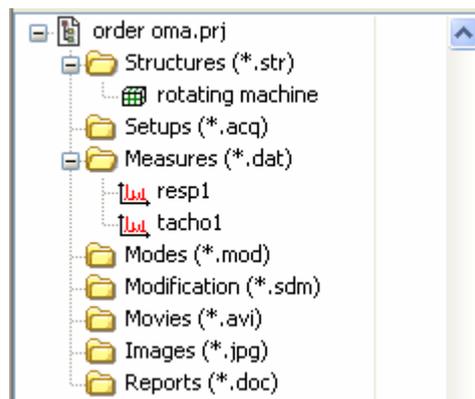


Figure 4-6 Order-based ODS demo project

- Click quick start item **Order-based ODS Animation** in project window, the operational order window and structure viewer window will be opened.

- Execute menu **File | Load...** in the structure viewer window, and load **rotating machine** in the structure file list. The model structure is displayed in the window.
- Execute menu **File | Load...** in the operational order window, and load **resp1** in the data block file list. The time-frequency spectral plot is displayed in the window, as Figure 4-7 shows.

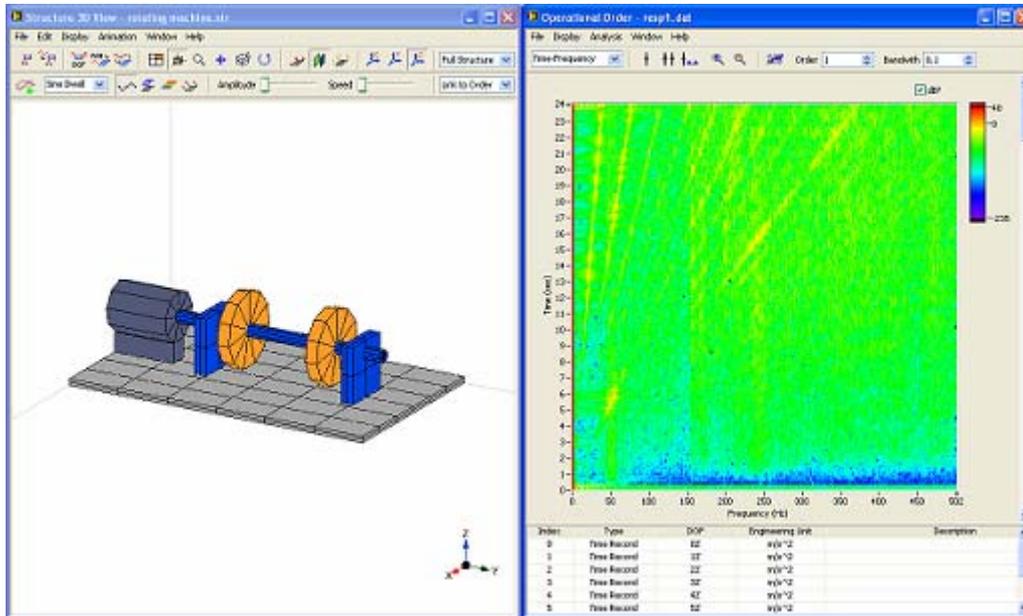


Figure 4-7 Order-based ODS animation

- Select animation mode as **Sine Dwell** on toolbar of structure viewer window.
- Click button  on toolbar of structure viewer window to start ODS animation.
- Change slider **Amplitude**  to adjust animation range.
- Change slider **Speed**  to adjust animation speed.
- Click button  to make it active. Hold left mouse button down and move mouse to change structure 3D view.

The 3D model for plate structure is now being animated with time-frequency spectral plot data at selected frequency. The position of cross line cursor indicates the selected frequency for a specific order component with respect to rotational speed.

There are some peaks in the spectral plot, which indicate the structure resonances excited by some order component. The operational deflection shape (ODS) of the structure near each resonance frequency approaches to the mode shape relative to that resonance. In a situation requiring fast analysis, Order-based ODS is a good substitution for modal analysis to inspect vibration behaviour of a structure due to the rotational parts of an engine.

To animating 3D model at a resonance

- Drag the cross cursor to each peak in the spectral plot, and watch different ODS of the rotating machine structure.

4.4 Mode Shape Demo

To run mode shape demo, select **plate** demo project from example finder. The structure file “plate” and mode shape file “modes” are contained in the project.

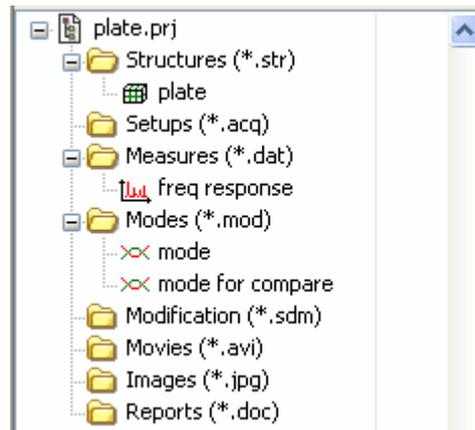


Figure 4-8 Mode shape project

- Click quick start item **Mode Shape Animation** in project window, the mode viewer window and structure viewer window will be opened.
- Execute menu **File | Load...** in the structure viewer window, and load plate in the structure file list. The model structure is displayed in the window.
- Execute menu **File | Load...** in the mode viewer window, and load mode in the data block file list. The mode table with four modes is displayed in the window, as Figure 4-9 shows.

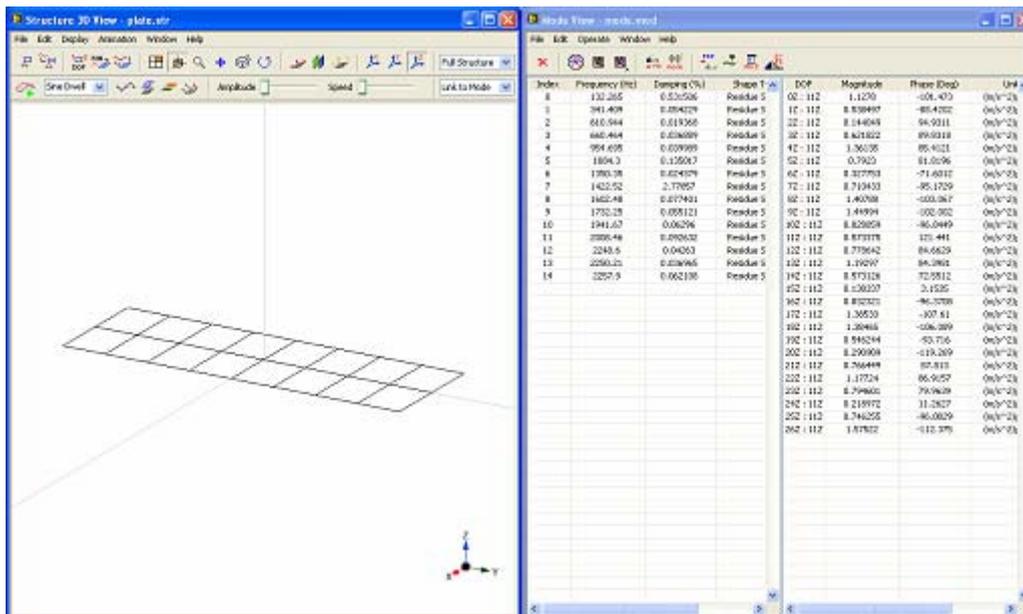


Figure 4-9 Mode shape animation

- Select interested mode in the mode shape table.
- Select animation mode as Sine Dwell on toolbar of structure viewer window.
- Click button  on toolbar of structure viewer window to start mode shape animation.
- Change slider **Amplitude**  to adjust animation range.
- Change slider **Speed**  to adjust animation speed.
- Click button  to make it active. Hold left mouse button down and move mouse to change structure 3D view.

Notices that only 15 nodes on the structure are moving now, which are corresponding to 15 measured DOFs. The motion of unmeasured DOFs can be computed by interpolation between measured DOFs.

To enable interpolated motion of unmeasured DOFs:

- Press button  on toolbar.

You can select other modes in the mode shape table to view different modal shape.

5. Performing Modal Analysis

In general, performing modal analysis for a structure involves a few steps:

1. Building a structure
2. FRF Measurement
3. Estimating modal parameters
4. Animating mode shapes of structure

Based on modal analysis example for a plate structure, operating steps are introduced in the following sections. A new project should be created before any operation for each step.

To create a new project, executes menu command **File | Project | New** in the project window of ModalVIEW. This will create a blank project for you to start with, as Figure 5-1 shows. There are a few quick start operations in the project window, which can open corresponding operating window and guide you to start your modal analysis tasks.

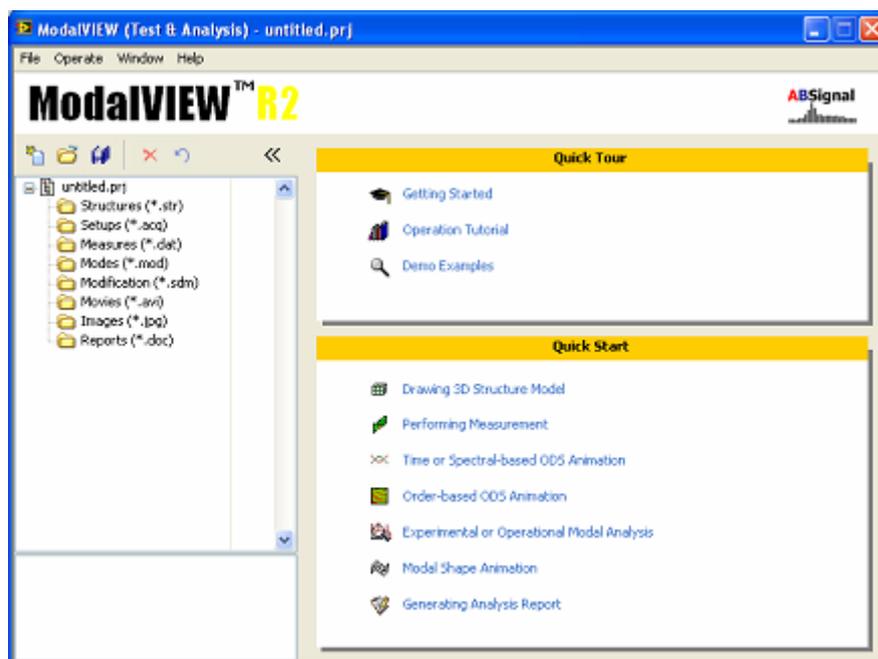


Figure 5-1 ModalVIEW project window

5.1 Drawing a plate structure

Click quick start item **Drawing 3D Structure Model**, a blank structure viewer window and structure editor window will be opened for you, as Figure 5-2 shows.

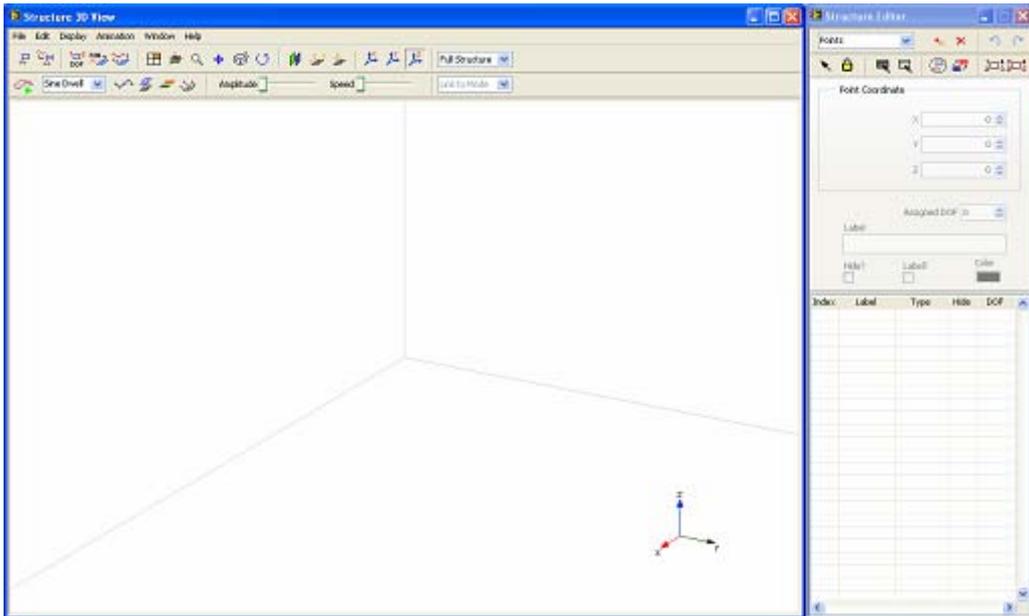
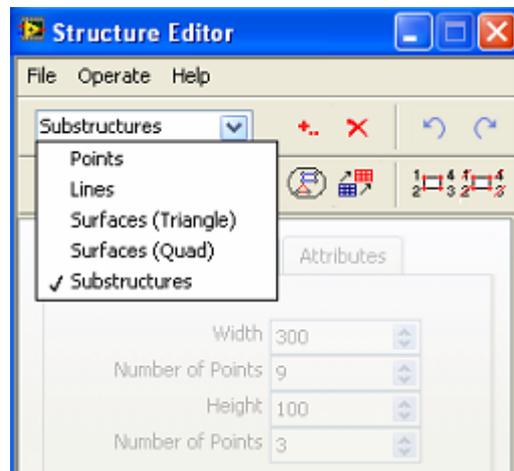


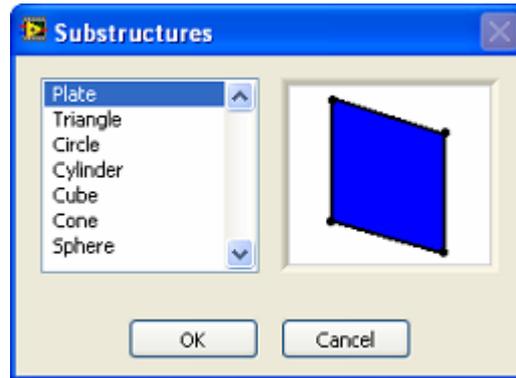
Figure 5-2 Drawing a plate structure

To draw a plate structure:

- In structure editor window, changes object selection to substructures.



- Click  to add substructures. Basic substructure blocks including plate, triangle, circle, cube, cone, cylinder and sphere are provided.



- Select **Plate** block and click **OK** button. A plate structure is listed in the spreadsheet, and displayed in structure 3D view window.
- On the **Dimensions** tab, enter **Width = 500**, **Number of Points = 9**, **Height = 150** and **Number of Points = 3**.
- On the **Position** tab, click arrow X, Y, Z, the plate rotates along X axial, Y axial and Z axial respectively. Rotates the plate to a horizontal position.
- Click button  on the toolbar to automatically number grid nodes of the plate structure.
- Close structure editor window, a horizontal plate structure drawing is finished.

Select **Zoom**, **Pan**, **Rotate** and **Reset** buttons  toolbars to adjust the view of plate structure in the structure 3D view window. Click button  to show the point numbers of the grid nodes, as Figure 5-3 shows.

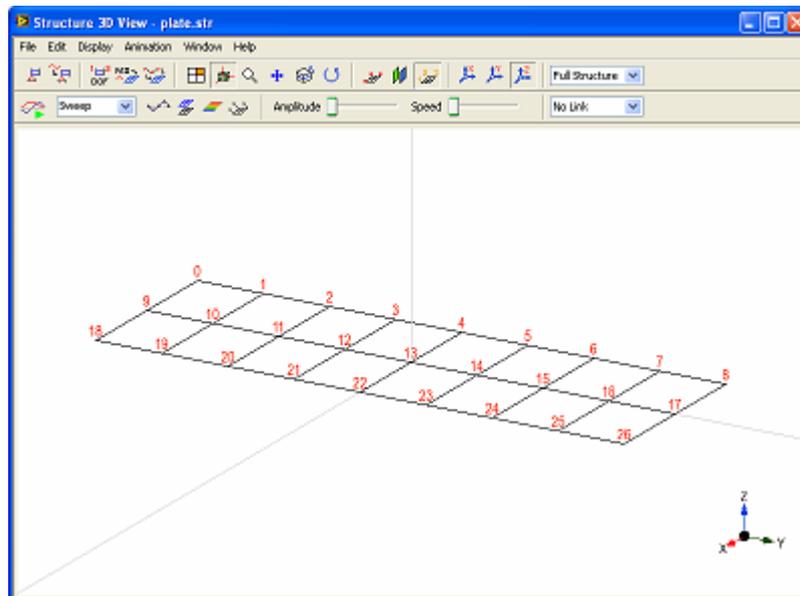


Figure 5-3 Display point number

After creating plate structure, measurement direction for each measured node on structure grid should be defined. The measurement direction is described by a set of

local axes associated with each measured node. Its origin coincides with node coordination. The directions of local axes can be rotated with respect to the global axes for the structure. The measurement direction for each measured node is selected as X, Y and Z axial direction of local axes.

A pair of point number and measurement direction is defined as one degree of freedom (DOF) for the structure. For an example, 11Z defines a DOF with the point number being 11 and measurement direction being Z axis.

To specify measurement direction for grid nodes:

- Click button  on toolbar of structure viewer window, animation equation window is opened.
- Select node in the spreadsheet of node list, the current measurement axes are displayed on the structure.
- In the **Measurement Axes** tab, click arrow X, Y, Z, the measurement axes rotates along X, Y and Z of global axes for structure respectively.

The measurement axes of nodes on plate structure are default to coincide with global axes, as Figure 5-4 shows.

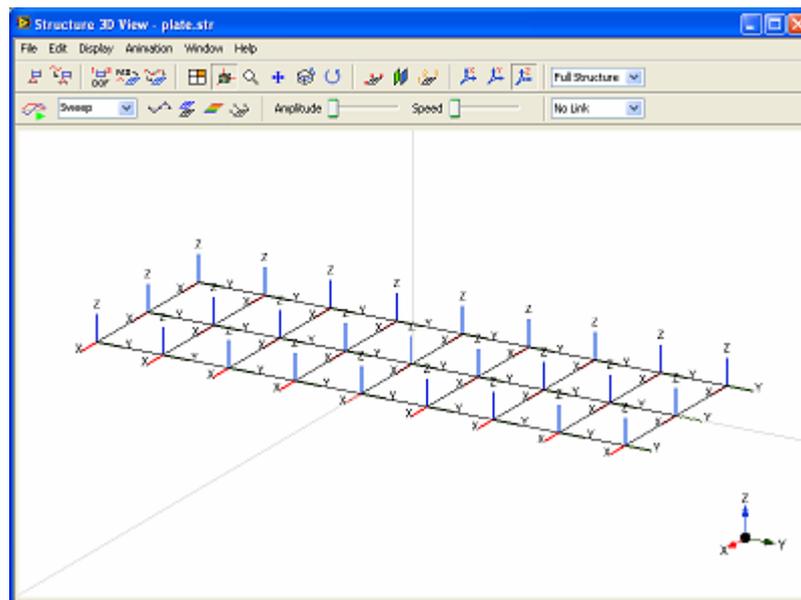


Figure 5-4 Measurement directions

Now that the plate structure is finished, executes menu command **File | Save As** in the structure 3D view window, a dialog prompt file name to save. Input file name “plate” and click **OK**.

Close structure 3D view window, and return to project window of ModalVIEW.

5.2 Measuring FRF of the structure

FRF is used as the data source for frequency-based ODS animation and for finding the modal parameters of a structure. To obtain the FRF from the plate structure, the vibration response and force excitation from different points and directions (DOFs) on the plate are simultaneously measured by data acquisition hardware, as Figure 5-5 shows.

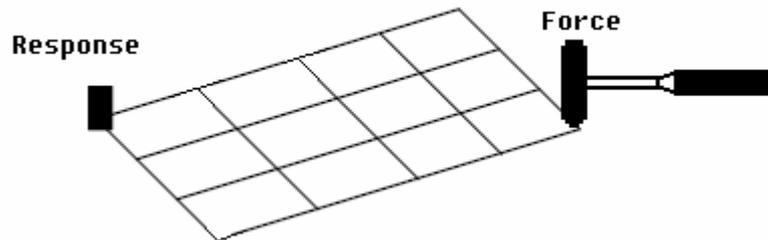


Figure 5-5 FRF measurement

In this plate structure testing, a roving hammer impact test is used. FRF measurements are obtained by impacting at different points in Z axial direction (roving DOFs) on the plate structure by using an impact hammer, and measuring the vibration response using an accelerometer fixed at point 11 in Z axial direction (reference DOF) on the plate structure.

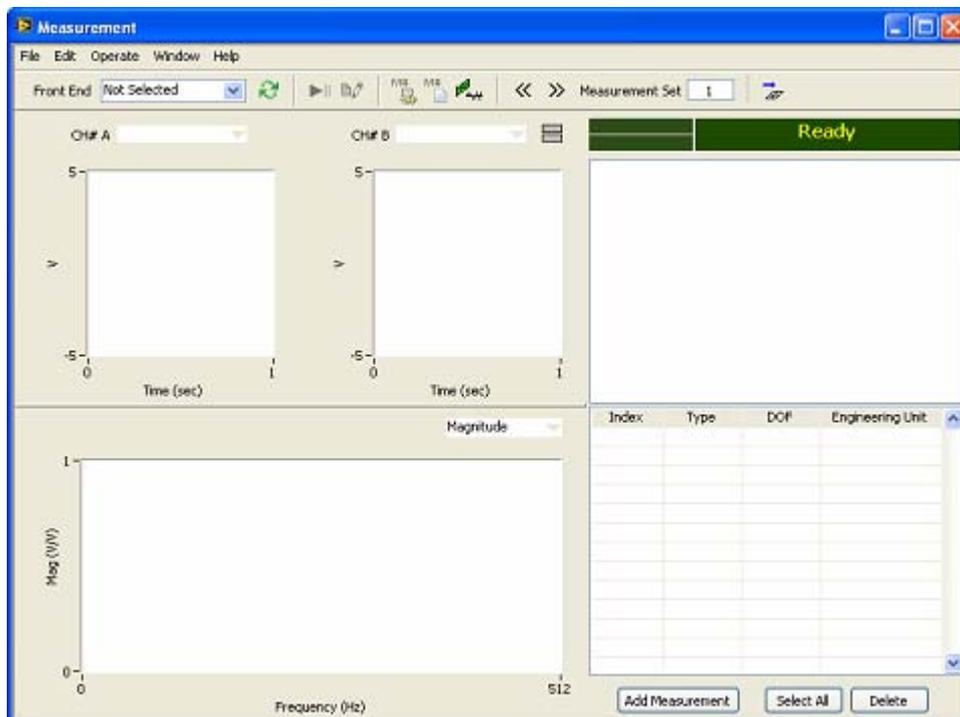


Figure 5-6 Measurement window

Measurement window in ModalVIEW allows you to perform data acquisition from multi-channel DAQ hardware (supporting all kinds of National Instrument DSA front

end). Click quick start item **Performing Measurement** in project window, measurement window will be opened for you, as Figure 5-6 shows.

Before starting measurement, you must finish the following setup:

- Select acquisition front end.
- Configure channel settings, sampling rate, triggering etc.
- Setup testing type, DOF range, and measurement sets.

To select acquisition front end and configure channels:

- Click control **Front End** in the toolbar, the available DAQ hardware will be listed. USB 4431 hardware is selected in this example.
- After front end being connected, DAQ setup button  is enabled. Click it, DAQ setup window is opened, as Figure 5-7 shows.

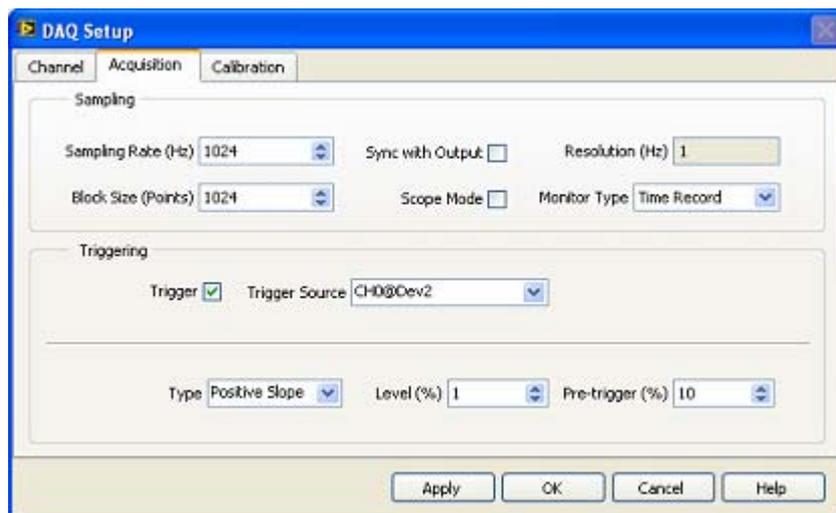
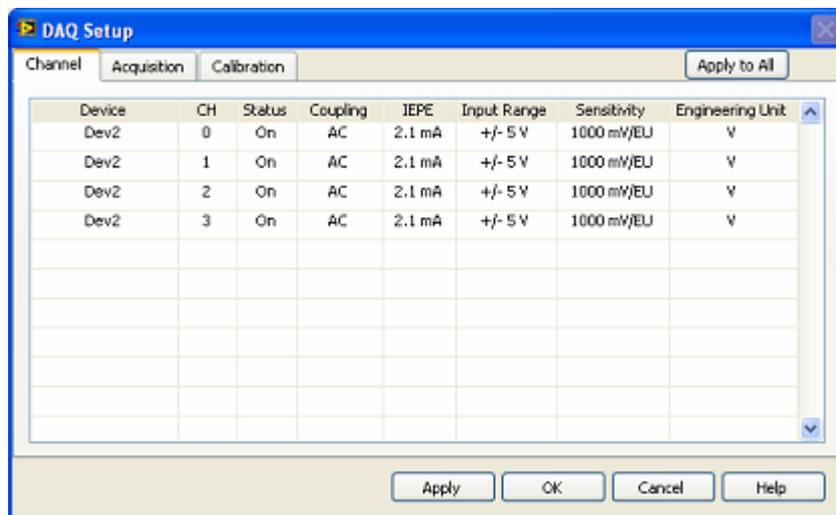


Figure 5-7 Data acquisition setup

- In the **Channel** tab, 4 channels have been displayed and enabled. Only two channels are needed in the testing, one is used for accelerometer, and the other is used for force excitation. Keeps the other two channels disabled.
- In the **Acquisition** tab, **Sampling Rate (Hz)** is set as 1024; **Block Size (Points)** is set as 1024; **Trigger** is checked; **Trigger Source** is selected as the channel for accelerometer measurement. **Trigger Type** is Positive Slope; **Trigger Level (%)** is set as 1% of input range. **Pre-trigger** is set as 10% of block size.
- After DAQ Setup is ready, close the window.

To setup measurement scheme, click test setup button , test setup window is opened, as Figure 5-8 shows.

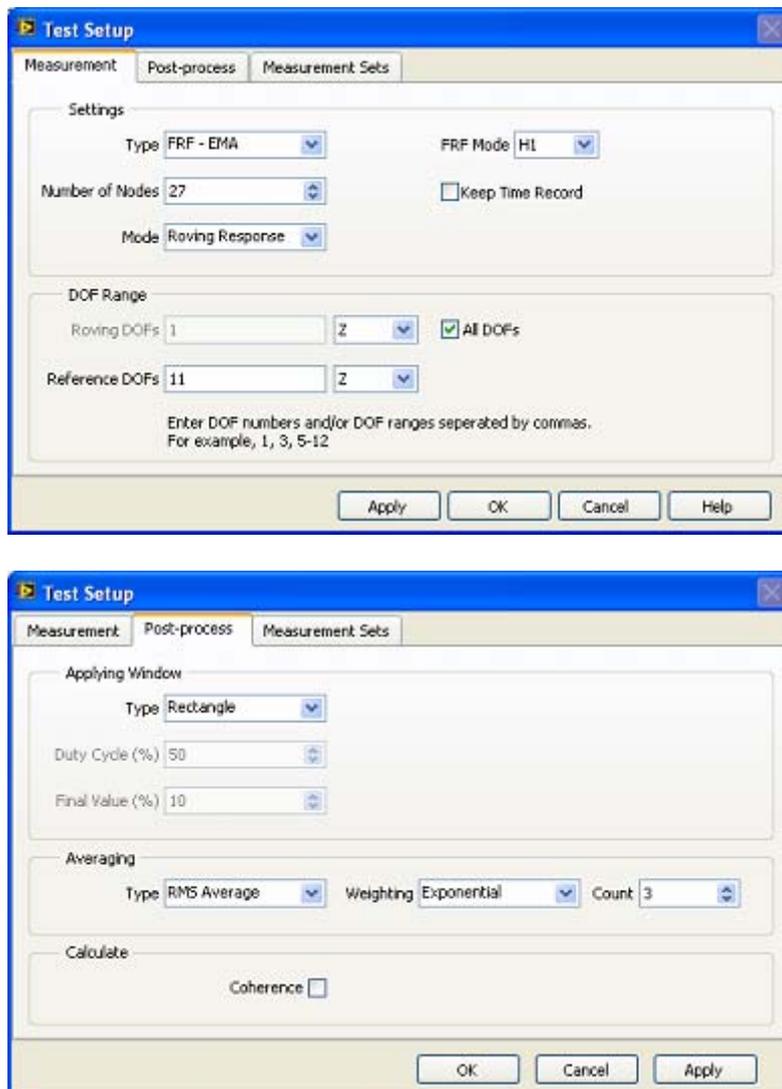


Figure 5-8 Test setup

In **Measurement** tab:

- Select measurement type **FRF – EMA**. In this type, FRF will be computed from acquired impact excitation and vibration response.

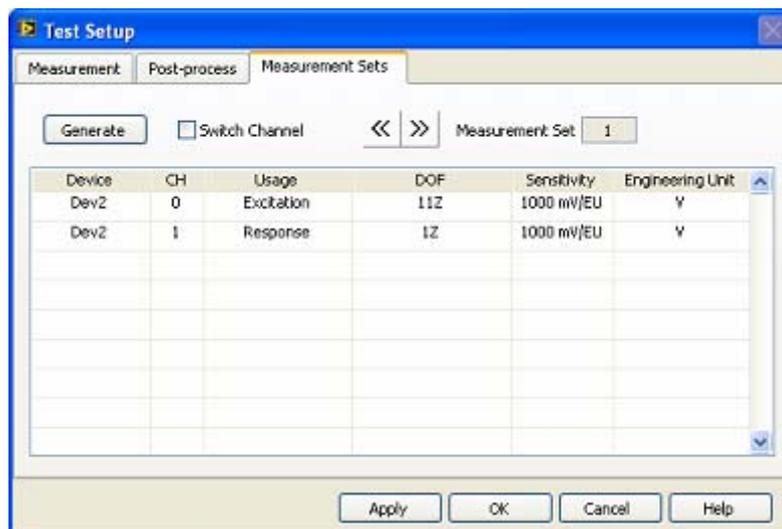
- **Number of Nodes** is set 27 according to the grid points on the plate structure surface for measurement.
- Choose measurement mode **Roving Response** for roving hammer impact test.
- Check **All DOFs** to measurement all grid points on the plate structure. The default measure direction is Z axis.
- Select point number 11 for reference DOF. The default measure direction is Z axial.

In **Post-process** tab:

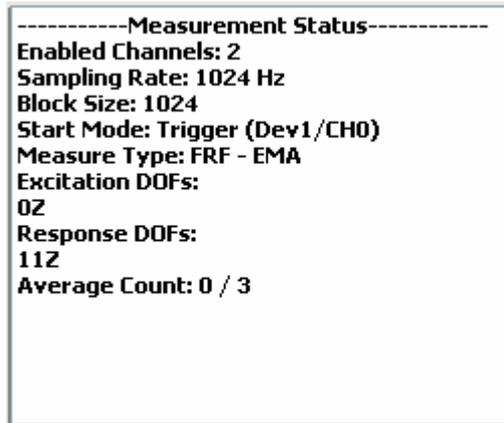
- Select window type **Rectangle** for FRF estimation.
- Averaging is needed for FRF estimation to reduce noise interference. Choose averaging mode **Exponential**. The averaging count is 3.

In **Measurement Sets** tab:

- Click **Generate** button, the measurement sets will be automatically generated according previously specified channel and test settings. Each measurement set includes channel assignment for selected roving DOFs and reference DOF measurement.
- Click browse buttons to review different measurement sets.



Now, you can begin FRF measurement for the plate structure. In measurement window, measurement status display will guide you to finish each measurement set one by one.



- Click browse buttons   in measurement window to select different measurement sets.

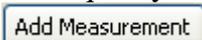
To perform testing for selected measurement set:

- Make sure force hammer and accelerometer have been correctly connected to DAQ channels.
- The accelerometer has been fixed at reference DOF on the plate structure.
- Press **Start** button  on the measurement window. The front end is in the trigger waiting state for acquisition.
- Use the hammer to give impact to the plate structure at point specified by roving DOF. This will trigger acquisition; estimated FRF will be displayed in the measurement window. The averaging count is displayed in measurement status.
- Continue to give the impact to the plate structure until averaging count is reached.

When averaging count being reached, the acquisition for current measurement set is stopped automatically. The measured FRF will be shown in the spreadsheet. To check FRF quality, select the item in the list to view the FRF curve in the measurement window.

Index	Type	DOF	Engineering Unit
 0	FRF	1Z : 1Z	V / V
 1	FRF	2Z : 1Z	V / V

If the quality of FRF for this measurement set is good enough, press button



to keep the measured FRF into data block and continue to the next

measurement set. Otherwise, press Start button  to start acquisition and perform testing for current measurement set again.

After finishing all the measurement sets, execute menu command **File | Save Measurement** in the measurement window, a dialog prompt file name to save. Input file name “freq response” and click **OK**.

Close measurement window, and return to project window of ModalVIEW.

5.3 Estimating modal parameters

Once a set of FRFs measured between a pair of DOFs on the plate structure, modal parameters (natural frequency, damping & mode shape) can be estimated by curve fitting FRFs in a specified frequency range.

Click quick start button Modal Analysis in project window, the data blocks window and mode estimation window will be opened, as Figure 5-9 shows.

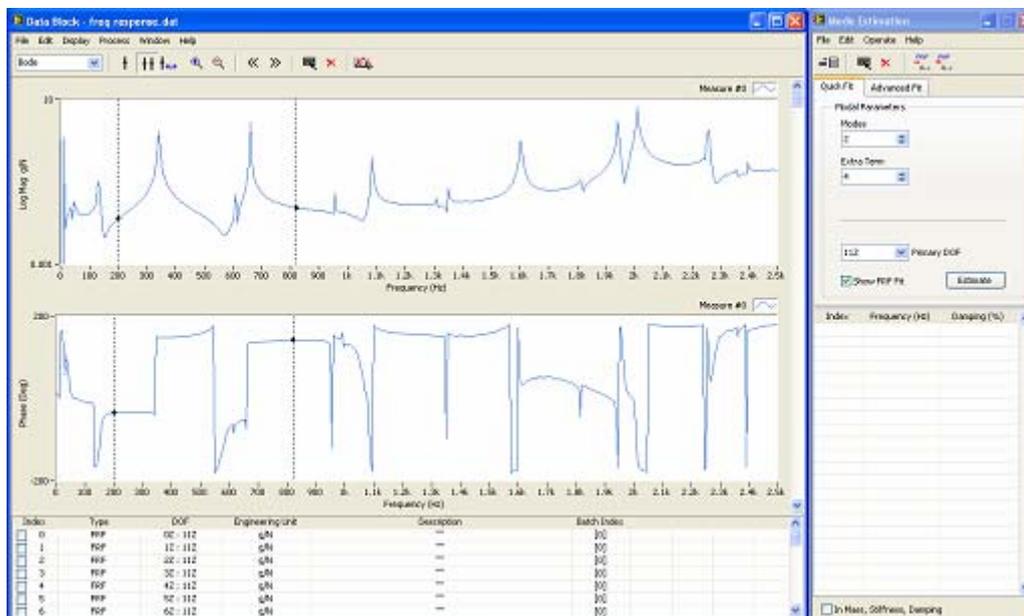


Figure 5-9 Mode estimation

Execute menu command **File | Load...** in the data blocks window, a file selection dialog prompt you to select data file. Select file name **freq response** previously saved by the step of FRF measurement. The FRF traces are displayed and listed in the spreadsheet.

To estimate modal parameters:

- Press and buttons in the data viewer window to show the band cursor and cursor values in the data graph.
- Use band cursor to specify frequency band you want to estimation modal parameters. For an example, a frequency range from 215Hz to 835Hz is selected, as Figure 5-10 shows.

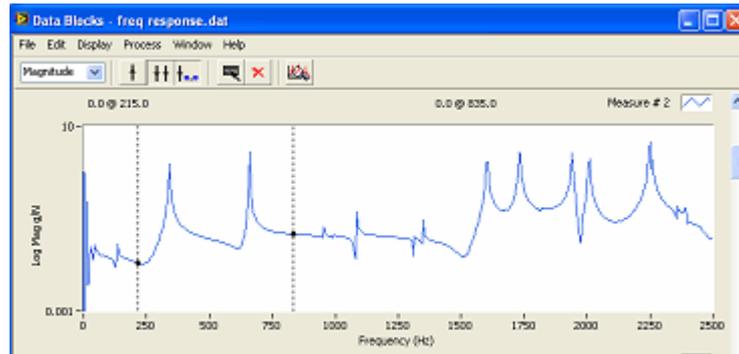


Figure 5-10 Frequency band selection

- On the **Quick Fit** tab of mode estimation window, set the number of **Modes** to fit in the specified frequency band. Each peak in FRF measurements indicates at least one mode. There are two peaks in the selected frequency range. The number of **Modes** is set two.
- Click button, the estimated modes will be listed in the modal parameter spreadsheet.
- Check **Show FRF FIT** box, the red synthesized FRFs from estimated modes are computed and overlaid with original FRFs. The synthesized FRFs should match original FRFs well if estimated modes are accurate enough, as Figure 5-11 shows.

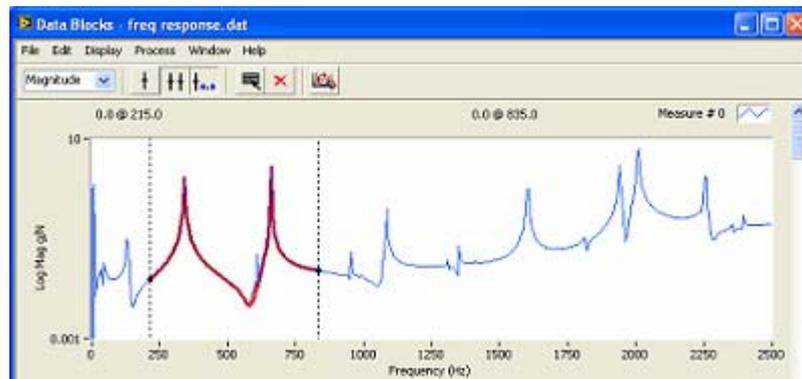


Figure 5-11 Synthesized FRF plot

If the quality of estimated modes are good enough, execute menu command **Operate | Add Fit Modes** to keep the estimated modes into modes list and continue to fit modes of interest in other frequency bands. Otherwise, adjust fitting parameters and press button to perform estimation again.

After finishing estimation for all modes of interest, execute menu command **File | Save Modes...** in the mode estimation window, a dialog prompt file name to save. Input file name “modes” and click **OK**.

Close data viewer window, and return to project window of ModalVIEW.

5.4 Animating mode shapes

Click quick start item **Mode Shape Animation** in project window, the structure viewer window and mode viewer window will be opened.

- Execute menu command **File | Load...** in the structure viewer window, a file selection dialog prompts you to select structure file. Select file name **plate** previously saved by the step of drawing a plate structure. The plate structure is displayed in the window.
- Execute menu command **File | Load...** in the mode viewer window, a file selection dialog prompts you to select mode table file. Select file name **modes** previously saved by the step of estimating modal parameters, as Figure 5-12 shows.

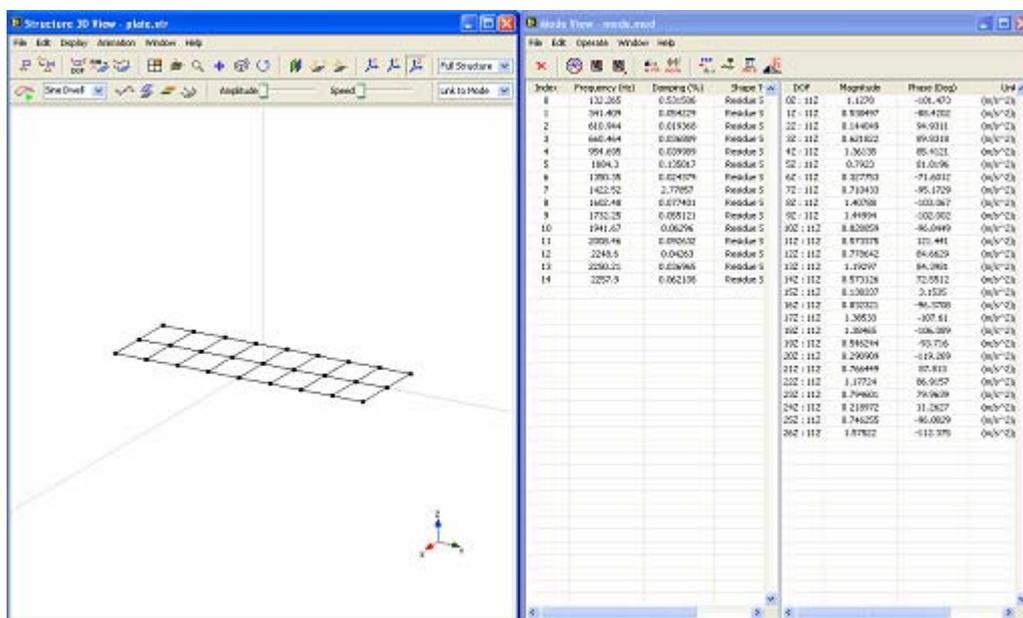


Figure 5-12 Mode shape animation

Before animating mode shapes of the plate structure, mode shape should be assigned to the points on the plate structure according to DOFs contained in the mode shape.

To match mode shape with points:

- Click button  on toolbar of structure viewer window. ModalVIEW automatically assign mode shape to node on 3D model according to the matched DOF information. After measurements being assigned, a dialog box will open to report the number of assigned measurements.



Close dialog box and mode shape is now assigned to the points on the plate structure. The plate structure is ready for animation.

To start structure animation:

- Select animation type **Sine Dwell** in the structure viewer window.
- Press  button to start animation.
- Select modes in spreadsheet list to view different mode shape animation.

