IMAT™ v9.0 | Bringing the Power of MATLAB to Your Engineering Analysis and Test Data

Overview

IMAT is a toolbox for use with MATLAB®, offered by ATA Engineering, Inc. (ATA). Designed for test and analysis engineers, it provides a framework for easily importing finite element (FE) simulation data and measured test data into the MATLAB environment to leverage the versatile programming, visualization, and mathematical strengths of MATLAB. With the IMAT toolbox, test and simulation data such as mode shapes, time histories, spectra, and other functions can be viewed and manipulated in MATLAB while preserving all of the native data attributes.

IMAT facilitates the manipulation of test and simulation data in MATLAB by defining datatypes that contain descriptive attributes as well as the data. Numerous methods within IMAT allow powerful and complex operations to be performed directly on these datatypes while preserving the data's descriptive attributes. Selection filters coordinate traces, and groups make selecting, sorting, filtering, and partitioning the datasets straightforward.

Operations such as matrix multiplications and repetitive data calculations can be performed in the powerful MATLAB matrix language. Many capabilities are available to perform advanced processing in simple steps.

FEA entities such as coordinate systems, nodes, elements, and tracelines can also be imported into MATLAB. IMAT allows the user to perform coordinate transformations and plotting, providing the ability to display and animate mode shapes making sharing results easy by creating AVI or animated GIF files of your mode shape animations. You can also generate contour plots of stress and other data quantities.
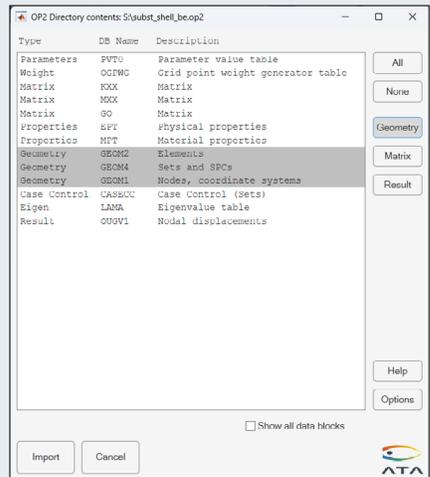
IMAT Extended Capabilities

IMAT offers several add-on toolboxes that are organized according to the capabilities they offer. These toolboxes greatly expand IMAT's core capabilities. The toolboxes include IMAT+FEA, IMAT+Modal, and IMAT+Signal.

IMAT+FEA allows users to import simulation data from Nastran, Abaqus, Femap, or I-deas and then operate on that data using the full capabilities of MATLAB. Nastran users can read data directly from binary Output2 database, ASCII bulk data, ASCII or binary Output4, or ASCII Punch files. I-deas and NX users can import and export associated data files (ADF) or Universal files. Result data from Abaqus simulations are read directly from output database files, allowing the user to process Abaqus results independent of Abaqus/Viewer. Femap users can import from and export to the Neutral file format or directly to a Femap session. IMAT+FEA also provides a bidirectional interface to the Femap API, so MATLAB users can communicate directly with Femap via COM. IMAT+FEA is a powerful extension to any CAE application.
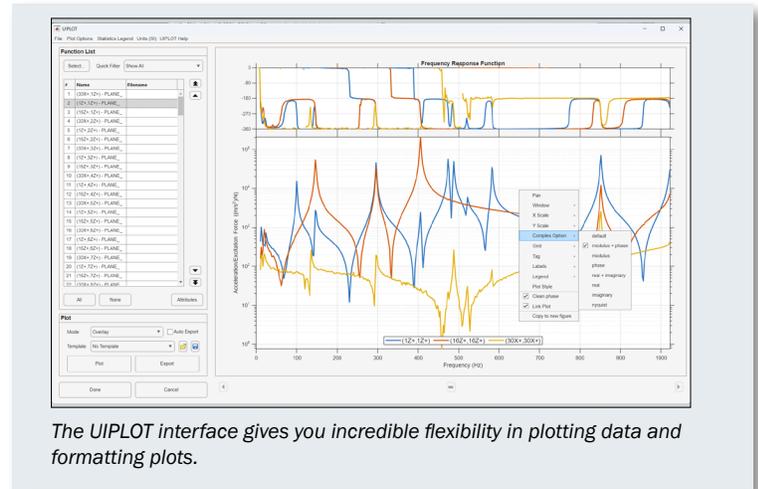
The UIPLOT interface gives you incredible flexibility in plotting data and formatting plots.

Selectively import Nastran Output2 data into IMAT, previewing the Output2 contents.

IMAT+Modal offers significant functionality that extends IMAT's capabilities for the modal test engineer. IMAT+Modal is a collection of utilities that aids in test planning and postprocessing of test data. It includes methods for pretest analysis, allowing users to optimally select accelerometer locations for a modal test, as well as procedures for reducing a full finite element model (FEM) to the test-measured degrees of freedom, and it also provides parameter estimation utilities for extracting mode shapes from the test data. The IMAT+Modal toolbox comprises several components, including the Test-Analysis Model Toolkit (TAMKIT), the Modal Test Kit (MTK), and two accelerometer selection capabilities: the Genetic Algorithm (GA) and selectASET. Users can perform modal parameter identification with OPoly using a Laplace and z-domain orthogonal polyreference algorithm as well as with SDOFit using a single-degree-of-freedom method. MIFODS extracts operating deflection shapes (ODSs) from mode-indicator functions (MIFs). The functionality provided by IMAT+Modal makes the entire modal test process more efficient.

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IMAT+Signal extends IMAT's functionality into signal processing, which involves processing data from the time domain into the frequency domain. IMAT+Signal provides graphical interfaces that greatly simplify the task of processing this data. spFRF (signal processing for frequency response functions) is a GUI application for computing power spectral density (PSD) and cross spectral density (CSD) functions from time histories and creating frequency response functions (FRFs) from spectral functions. spVIEW facilitates viewing and comparing different measurement datasets in the time and frequency domains. In addition, Rotating Test Kit (RTK) is a GUI that facilitates the analysis of rotational events. IMAT contains the most advanced implementation of order-based Vold-Kalman filtering available in a commercial software product. The IMAT+Signal GUI controls are provided as command-line functions such that any task can be easily scripted within MATLAB.

Display and animate your mode shapes, change the mode shape view, and export your animations to an animated GIF file.

Toolbox Components

- ➤ Core IMAT provides the basic functionality leveraged by each advanced toolbox
  - ➤ Includes data types for XY functions, function filters, coordinate traces, mode shapes, results (stress, strain, etc.), FEM connectivity, groups, and substructures (mass, stiffness, and back-expansion matrices)
  - ➤ Includes many methods for math operations, manipulation, and some visualization of the IMAT data types
  - ➤ Import and export associated data files (ATI, AFU, and ASH)
  - ➤ Import and export Universal files written by I-deas, LMS, B&K, ME'Scope, and others
- ➤ IMAT+FEA interfaces with several analysis software packages
  - ➤ Import Nastran bulk data, Punch, Output2, and Output4 files
  - ➤ Export Nastran Output2 files and limited bulk data
  - ➤ Import Abaqus ODB files
  - ➤ Import and export Femap Neutral files
  - ➤ Bidirectional connectivity to the Femap API via COM
  - ➤ Powerful FEM and result visualization using VTK, the Visualization Toolkit (www.vtk.org)
- ➤ IMAT+Modal provides tools for the modal test engineer and analyst
  - ➤ Optimal accelerometer selection for modal tests using different methods
  - ➤ Test-analysis model (TAM) generation in Nastran
  - ➤ OPoly and SDOFit modal parameter estimation GUIs
  - ➤ MIFODS generates ODSs from MIFs
  - ➤ Many utilities for processing, validating, and comparing modal test results
- ➤ IMAT+Signal provides tools for the signal processing engineer
  - ➤ spFRF GUI for processing time-domain signals to the frequency domain
  - ➤ RTK GUI for processing order-tracked data from rotating equipment using Vold-Kalman filtering
  - ➤ spVIEW GUI for comparing multiple measurement datasets
  - ➤ Command-line functions for calculating power and cross-spectral densities, frequency response functions, and shock response spectra, as well as Vold-Kalman filtering
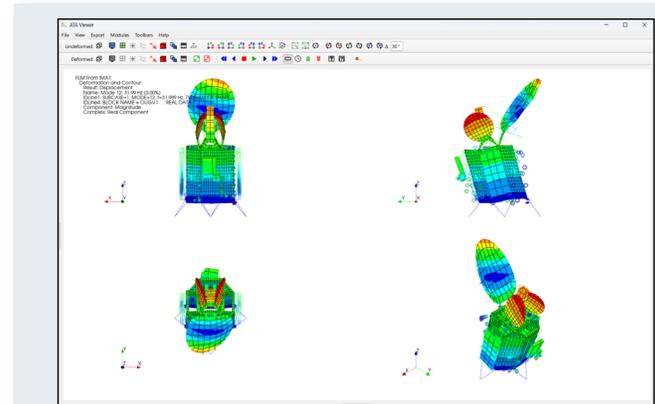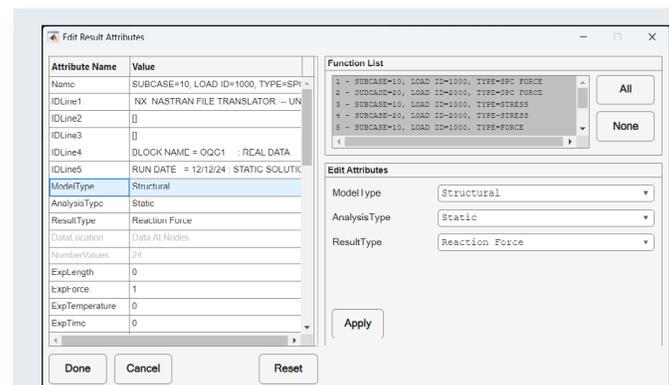
Easily review shape, function, and result attributes with the convenient edit_attributes graphical interface.

New Features in IMAT v9.0

- ➤ For use with MATLAB R2023b and higher
- ➤ Supports Femap 11.3.x through 2512 using the COM interface
- ➤ Supports Abaqus 2024 on Windows
- ➤ VTKPLOT has been replaced by ATAViewer, which has increased capability
- ➤ Added support for importing HBK's PK Connect/Pulse function data
- ➤ Enhanced Nastran import capabilities, supporting many new datablocks including improved nonlinear and composite data import
- ➤ Enhanced functionality for working with Nastran output transformation matrices
- ➤ OPoly, MIFODS, and spFRF accommodate processing fixed base correction data and also using cross spectra for operational modal analysis
- ➤ Many other enhancements

Hardware Platforms

The IMAT toolbox was written primarily in the MATLAB language. Versions are available for 64-bit Windows, 64-bit Linux, and 64-bit Mac platforms. MATLAB R2023b (or higher) is a prerequisite for IMAT v9.0. Some capabilities of IMAT (notably time-domain filtering and RTK) require the MATLAB Signal Processing toolbox.

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IMAT+Modal™ | Advanced Utilities for the Test Engineer

Overview

IMAT is a toolbox for use with MATLAB®, offered by ATA Engineering, Inc. (ATA). Designed for test and analysis engineers, it provides a framework for easily importing finite element (FE) simulation data and measured test data into the MATLAB environment to leverage the versatile programming, visualization, and mathematical strengths of MATLAB. With the IMAT toolbox, test and simulation data such as mode shapes, time histories, spectra, and other functions can be viewed and manipulated in MATLAB while preserving all of the native data attributes.

IMAT+Modal extends the core capabilities of IMAT by providing additional functionality for the modal test engineer. IMAT+Modal includes methods for pretest analysis to allow users to optimally select accelerometer locations for a modal test, provides procedures for reducing a full finite element model (FEM) down to the test-measured degrees of freedom (DOFs), and provides modal parameter estimation routines for extracting shapes from the test data. The IMAT+Modal collection of utilities significantly aids in test planning and postprocessing.

The IMAT+Modal toolbox comprises several components, including the Test-Analysis Model Toolkit (TAMKIT), the Genetic Algorithm (GA), selectASET, the Modal Test Kit (MTK), the Orthogonal Polyreference (OPoly) GUI application, and MIFODS, which is used to extract operating deflection shapes from mode-indicator functions (MIFs).

Prepare and Plan Modal Tests with IMAT+Modal

The Test-Analysis Model Toolkit (TAMKIT) is intended for structural dynamics engineers who perform pretest analysis and posttest correlation of modal survey tests. It provides procedures for selecting the instrumented degrees of freedom and for reducing the FEM matrices to these DOFs. It is implemented as a set of Nastran DMAP alters, with MATLAB functions used to read and interpret the Nastran output. It also includes procedures for comparing two similar models and for comparing test and analysis modes after completion of a modal test.

The Genetic Algorithm (GA) allows users to optimally select accelerometer locations for a modal vibration test. The GA will efficiently select optimal accelerometer locations to maximize the linear independence of test-measured mode shapes. The software can accommodate multiple FEM configurations, simultaneously selecting the best accelerometer locations for multiple-configuration modal tests to minimize the test setup time. GA can also optimally select triaxial accelerometer locations and gives the user the option of manually including or excluding specific degrees of freedom from the final DOF set.
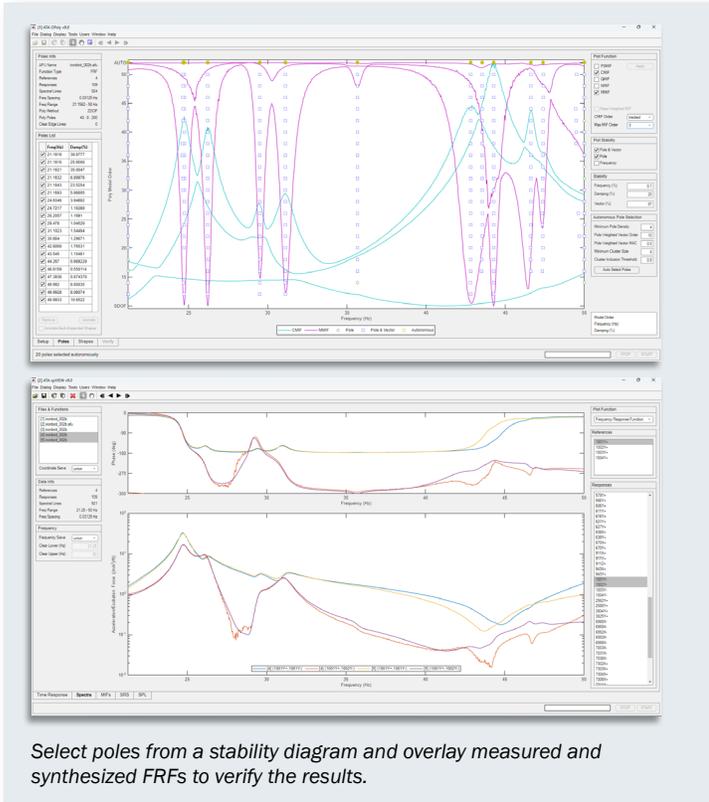
selectASET is an alternative method to select accelerometer locations. It uses a "brute force" approach to select accelerometers by iteratively removing the least important DOFs from a candidate set of accelerometer locations to achieve the user-defined objective. Like GA, selectASET can accommodate multiple FEM configurations, can operate on individual DOFs or triaxes, and can be set to manually include or exclude DOFs/triaxes from the final set.
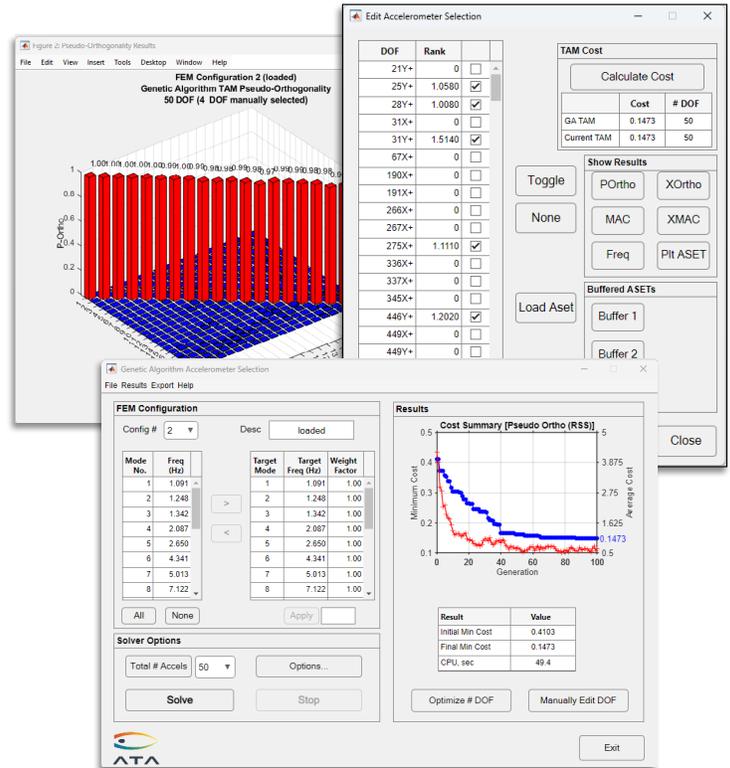
Select optimum test accelerometer locations and review selection quality for multiple configurations quickly using the Genetic Algorithm.
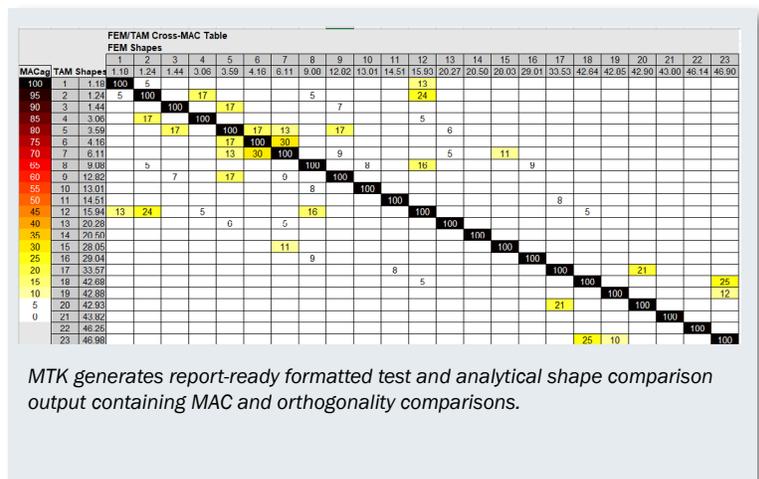
MTK generates report-ready formatted test and analytical shape comparison output containing MAC and orthogonality comparisons.

Select poles from a stability diagram and overlay measured and synthesized FRFs to verify the results.

The Modal Test Kit (MTK) is a toolbox for use with MATLAB that contains routines for placing sensors and exciters, extracting modes from test data, verifying shape extractions through FRF synthesis comparisons, providing shape independence and completeness checks, and other useful routines for analyzing modal survey test data. One such useful routine is the ability to select and display shaker locations and orientations for optimal target mode excitation during a modal test. FEM entities such as coordinate systems, nodes, elements, and tracelines can also be imported into MATLAB. Several utility functions provided with IMAT allow for coordinate transformations and plotting, allowing you to display and animate mode shapes. You can even create AVI files of your mode shape animations.

Estimate Modal Parameters with IMAT+Modal

OPoly stands for "Orthogonal Polyreference" and refers to a type of multi-reference modal parameter estimation method. ATA Engineering developed OPoly as the implementation of a robust and proven modal parameter estimation technique that has been extensively used in the field by ATA's test group. OPoly provides the choice of using either a Laplace domain or a z-domain orthogonal polynomial algorithm. In addition, SDOFit is a single-degree-of-freedom companion technique to OPoly.

The OPoly GUI guides users through the process of identifying modal parameters (natural frequency, damping, and shape coefficients) in a step-by-step manner. Users import frequency response functions (FRFs) with the GUI, solve for poles, and identify the valid poles with the help of autonomous pole selection. Shapes are then extracted, and the results are verified by overlaying various measured and synthesized mode indicator functions. Once the shapes have been verified, they can be exported for further analysis.

IMAT+Modal Key Features

IMAT is a prerequisite for IMAT+Modal.

Key features of TAMKIT:

➤ Select instrumented DOFs and reduce FEM matrices to specified DOFs
➤ Reduce FEM matrices using several reduction methods
➤ Evaluate test-analysis model (TAM) quality
➤ Compare between two similar models
➤ Compare between test and analysis modes

Key features of the Genetic Algorithm and selectASET:

➤ Works with multiple FEM configurations; simultaneously select accelerometer locations on multiple FEM configurations
➤ Use industry-standard pseudo-orthogonality or self-MAC cost functions to rank the effectiveness of a set of accelerometer locations
➤ Export orthogonality, MAC, and frequency comparisons to Excel-compatible XML format to document results
➤ Select degrees of freedom that must be included or excluded from the final target DOF set
➤ Optimally select triaxial locations if desired

Key features of the MTK toolbox:

➤ Pretest activities including exciter selection (single or multiple configurations) and pretest results summary in a formatted XML file or XLSX file for import into Microsoft Excel
➤ Single and multiple reference mode indicator functions
➤ Modal parameter estimation utilities including the OPoly GUI, single reference, and enhanced FRF extraction methods
➤ Perform operational modal analysis using MIFs or cross-spectra
➤ Process fixed base correction data
➤ FRF synthesis from modal parameters
➤ Test mode shape verification
  ➤ Independence and completeness checks based on MAC or orthogonality
  ➤ Test vs. FEM comparison tables
  ➤ Test summary XML and XLSX files
  ➤ Advanced tools such as grid point energy checks
  ➤ Computation of mode shapes from TAM matrices
➤ Supplemental routines
  ➤ Sorting of modes from multiple extractions to generate final mode set
  ➤ Removal of bad sensors from TAM matrices
  ➤ Back expansion of mode shapes and frequency response functions to test display model for viewing

Hardware Platforms

The IMAT toolbox was written primarily in the MATLAB language. Versions are available for 64-bit Windows, 64-bit Linux, and 64-bit Mac platforms. MATLAB R2023b (or higher) is a prerequisite for IMAT v9.0.

About ATA

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IMAT+Signal™ | IMAT Signal Processing Toolkit

Overview

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IMAT+Signal extends IMAT's functionality into signal processing, which involves processing data from the time domain into the frequency domain. IMAT+Signal provides graphical interfaces that greatly simply the task of processing this data. spFRF (signal processing for frequency response functions) is a GUI application for computing power spectral density (PSD) and cross spectral density (CSD) functions from time histories and creating frequency response functions (FRFs) from spectral functions. spVIEW facilitates viewing and comparing different measurement datasets in the time and frequency domains. In addition, Rotating Test Kit (RTK) is a GUI that allows the analysis of rotational events using Vold-Kalman filtering. IMAT contains the most advanced implementation or order-based Vold-Kalman filtering available in a commercial software product. The IMAT+Signal GUI controls are provided as command-line functions such that any task can be easily scripted within MATLAB.

Stationary Signal Processing with spFRF

spFRF™ stands for "Signal Processing for Frequency Response Functions." The primary purpose of this application is to process time response data into spectral functions such as frequency response, coherence, auto-spectra, and cross-spectra. spFRF can read time response functions from ADF files, Universal files, or from the MATLAB workspace, and can write time response and spectral functions to the same. spFRF can process continuous measurements, as well as triggered measurements with the ability to preview, and accept or reject, each frame. Although the name implies that spFRF produces frequency response functions, it can also generate the auto-spectra of response-only datasets and can be used for principal component analysis.

Key features of spFRF:

➤ Process time histories into FRF and spectra
➤ Access features from the GUI or directly through a command-line interface
➤ Write your own extensions with plugin capability

Plotting Measurements with spVIEW

spVIEW™ is a companion to spFRF for plotting the spectra function results from multiple datasets of measurements. spVIEW can also plot time response, mode indicator, and sound pressure level functions in separate tabbed modules.
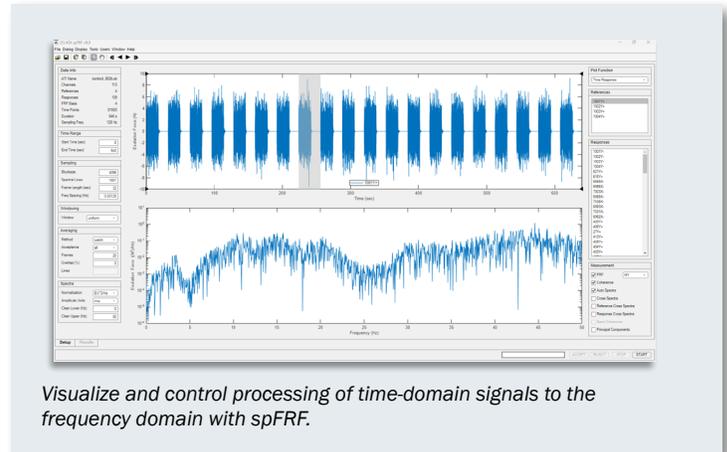
Visualize and control processing of time-domain signals to the frequency domain with spFRF.
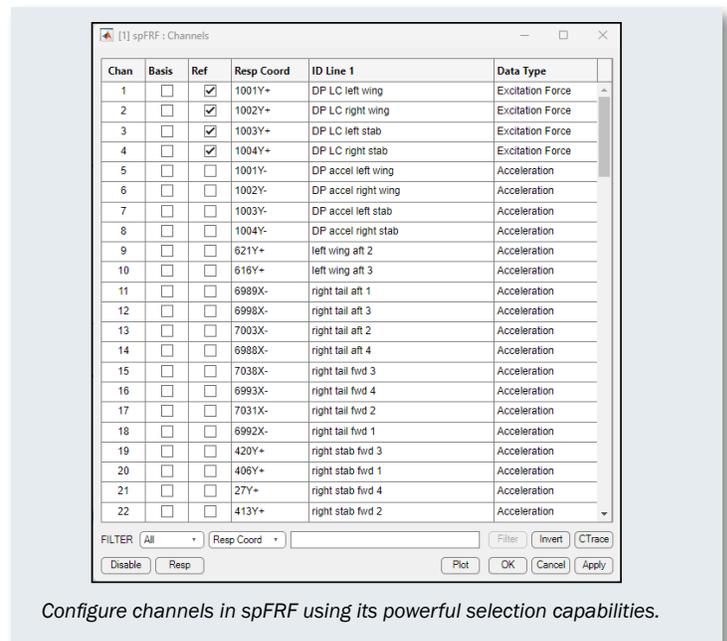
Configure channels in spFRF using its powerful selection capabilities.
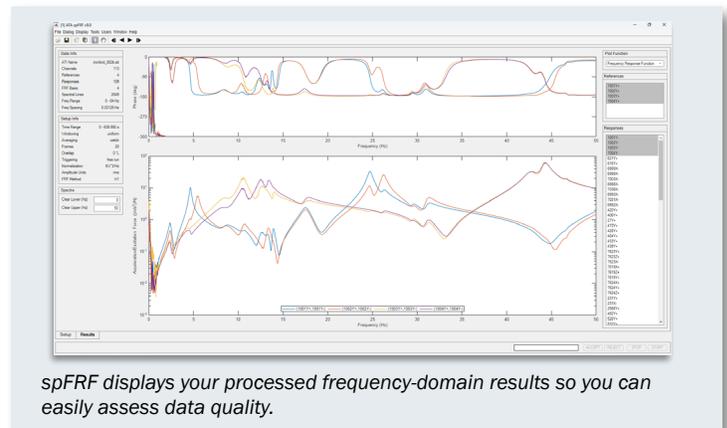

spFRF displays your processed frequency-domain results so you can easily assess data quality.

And while the modules are mostly independent, some functions can be sent between the modules. For example, FRFs in the Spectra module can be used to compute mode indicator functions that are then sent to the MIFs module. spVIEW can read time response and spectral functions from ADF files, Universal files, or from the MATLAB workspace, and can write sieved and truncated datasets of functions to the same. spVIEW's primary purpose may be plotting measurements, but it also has some signal processing and computational capabilities, such as filtering, resampling, decimation, and octave band reduction.

Key features of spVIEW:

➤ Interactive viewing of many types of measurements
➤ Send datasets to and from spFRF and OPoly
➤ Access features from the GUI or directly through a command-line interface
➤ Write your own extensions with plugin capability
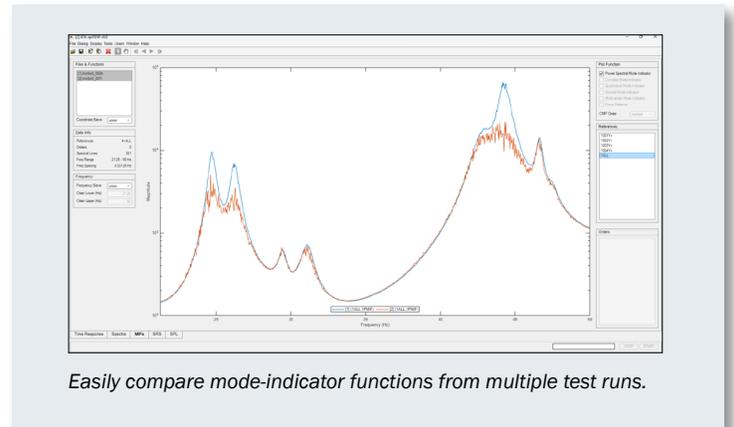
Easily compare mode-indicator functions from multiple test runs.
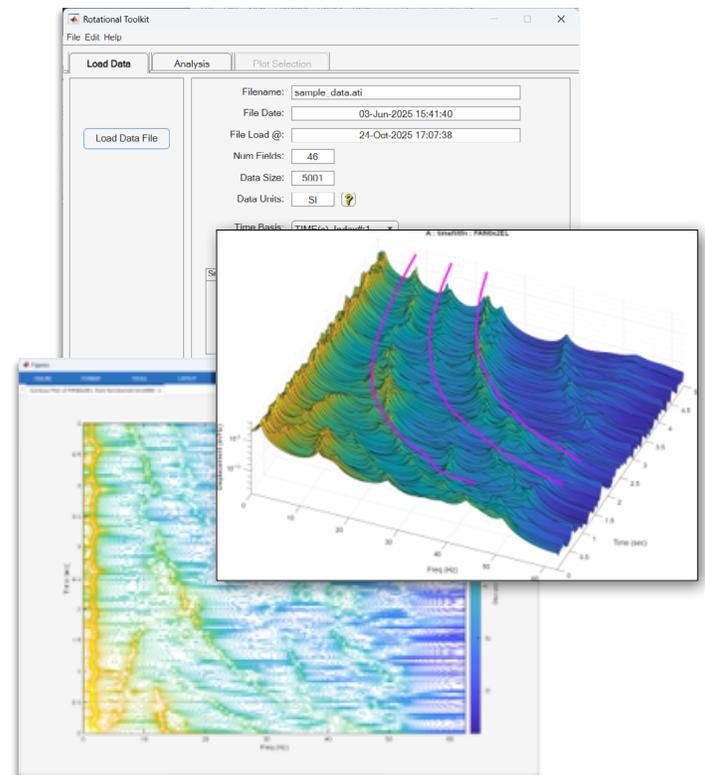
Order Tracking with RTK

The Rotational Toolkit (RTK) in IMAT+Signal is designed for jet engine and rotating equipment engineers. The RTK application is used for applying the Vold-Kalman filtering technique to order tracking of rotational events. The Vold-Kalman filtering capability included in IMAT is the most advanced capability available in any commercial software product. It can track multiple tachometer signals simultaneously in large datasets. RTK is a very easy-to-use GUI with three simple steps: load the data, run the analysis, and plot the results.

The application uses time history data files from simulations or real-time data collection to process and visualize the spectral properties of events. This tool facilitates the processes of obtaining response characteristics and finding insights into the mechanics of rotating events. Users are able to view results as a contour plot of the data, a 3D waterfall plot, or an "X-Y" plot that allows the user to select single or multiple items from all available results. This third plot option will also allow the user to filter items from the results produced.

Key features of RTK:

➤ Perform order tracking on results in a user-friendly GUI
➤ Visualize order-related vibrations from non-order-related vibrations using contour plots
➤ Use advanced function plotting utilities designed specifically for rotating equipment
➤ Import comma-separated variable (CSV) files that contain time, speed, and forcing functions

Command-Line Utilities

IMAT+Signal also provides a number of command-line utilities for performing various signal processing tasks:

➤ Computing PSD, CSD, FRF, and coherence from time-domain signals
➤ Time-domain IIR and FIR filtering
➤ Robust and powerful Vold-Kalman order-tracked filtering, including support for multiple tachometers
➤ Creating and plotting spectrograms without using the MATLAB Signal Processing toolbox
➤ Computing shock response spectra (SRS) from time-domain signals
➤ Generating time-domain signals from SRS or PSDs

Access powerful order-tracking plotting capabilities with RTK.

Hardware Platforms

The IMAT toolbox was written primarily in the MATLAB language. Versions are available for 64-bit Windows, 64-bit Linux, and 64-bit Mac platforms. MATLAB R2023b (or higher) is a prerequisite for IMAT v9.0. The RTK user interface of IMAT+Signal also requires the MATLAB Signal Processing toolbox.

About ATA

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# IMAT+FEA™ | IMAT Finite Element Analysis Interface

Overview

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IMAT+FEA extends the core capabilities of IMAT by providing significant additional functionality to manipulate simulation data. IMAT+FEA can directly access CAE data from many different analytical solvers, including Nastran, Abaqus, Femap, and I-deas. IMAT organizes this data into easy-to-use data types within MATLAB, allowing analysts to combine results, specify custom failure criteria, calculate margins, and otherwise evaluate CAE data using the power and flexibility of MATLAB.

IMAT+FEA provides a powerful FEM, result, and coordinate trace visualization capability that utilizes the Visualization Toolkit developed by Kitware, Inc. This allows you to display very large datasets (greater than 1 million nodes) and visualize results on a deformed mesh with advanced visualization capabilities such as selective entity display (by element type, material, physical property, and/or group), transparency, and shaded or line display. Animate your shapes, interactively label elements and nodes, and "fly" through your FEM using VTK's advanced dynamic translation and rotation in Perspective display mode.

IMAT+FEA Key Features

➤ Nastran
  ➤ Import bulk data (including DMI and DMIG), Output2, Output4, or Punch files
  ➤ Select a subset of results to import
  ➤ Import results into MATLAB in native ("raw") OP2 format and use the provided datablock interpreter to translate the entire content of the results
  ➤ Export to OP2 (then import into your CAE postprocessing tool)
  ➤ Write bulk data entities such as DMIG, MPC, and some FEM entities such as coordinate systems, nodes, and several different element types and their associated physical and material properties
➤ Abaqus
  ➤ Import xyData, step histories, and field data from ODB
  ➤ Select a subset of results to import
➤ Femap
  ➤ Supports Femap 11.3.x through 2412
  ➤ Import select datasets from Femap Neutral file
  ➤ Export to Femap Neutral file or directly to Femap via COM
  ➤ Access the Femap COM API for bidirectional communication with Femap
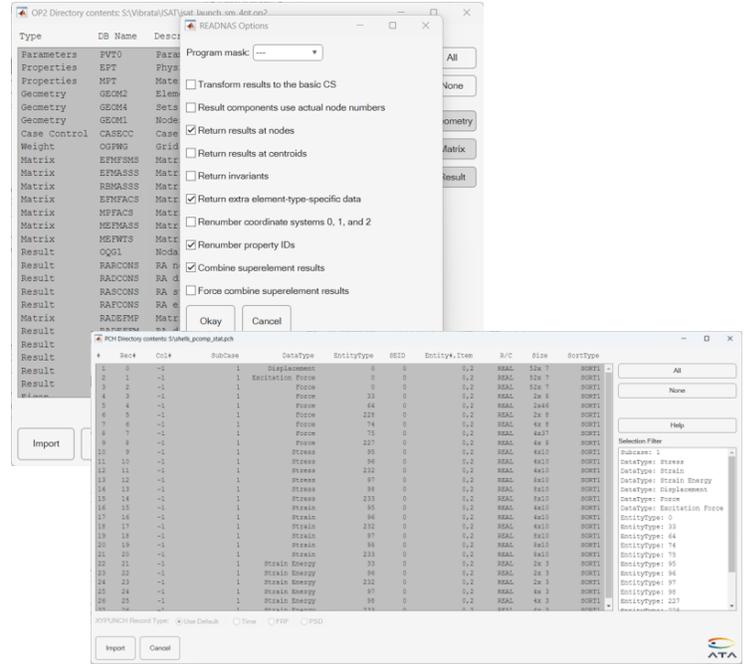
Selectively import data from OP2 or PCH files using the readnas utility in IMAT+FEA.
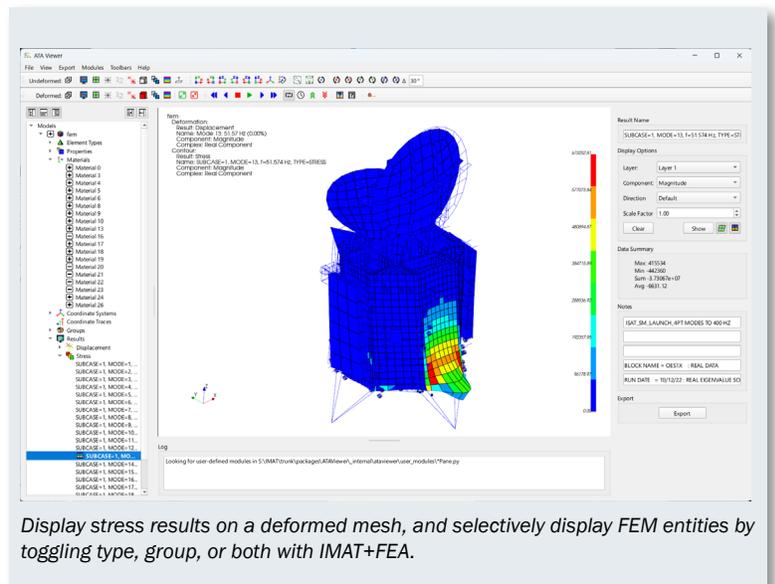
Display stress results on a deformed mesh, and selectively display FEM entities by toggling type, group, or both with IMAT+FEA.

➤ Data Visualization
- ➤ Display extremely large FEM datasets (millions of nodes)
- ➤ Overlay multiple FEMs and results in the same display window
- ➤ Visualize deformed and contour results
- ➤ Display coordinate traces

Hardware Platforms

The IMAT toolbox was written primarily in the MATLAB language. Versions are available for 64-bit Windows, 64-bit Linux, and 64-bit Mac Silicon platforms. MATLAB R2023b (or higher) is a prerequisite for IMAT v9.0.

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Visualize coordinate trace locations and orientation on your FEM using IMAT+FEA.

Animate your mode shapes with a multi-view capability using ATAViewer.

Compare two sets of mode shapes (in this case, test and analysis) side by side.