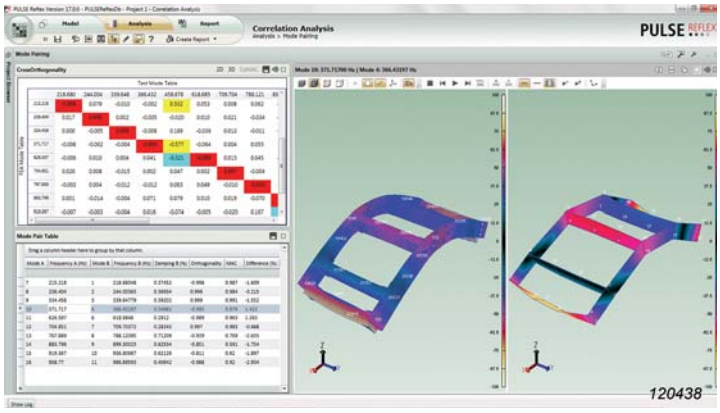
PULSE Reflex Structural Dynamics

Correlation Analysis Type 8722
Finite Element Interfaces Types 8718-A, 8718-B and 8718-C

PULSE Reflex™ Correlation Analysis is an easy-to-use post-processing application that enables you to correlate two modal models whether they are finite element models or test models. The Finite Element Interfaces software enables you to import finite element models (FEM) from Nastran™, ANSYS®, ABAQUS® or as UFF files. Accurate correlation is quickly obtained by following an intuitive, yet flexible workflow process that guides you efficiently through geometry alignment, DOF mapping, comparison, vector comparison, mode pairing and reporting.

PULSE Reflex Correlation Analysis with PULSE Reflex Modal Analysis and PULSE Reflex Structural Measurements constitutes an integrated system for modal measurements, modal analysis and model correlation.



Uses and Features

Uses

- Correlation of two modal models: FEM vs Test, Test vs Test or FEM vs FEM in order to:
  - Evaluate different test and modelling strategies
  - Identify shortcomings in modal tests
  - Identify areas of insufficient finite element (FE) modelling quality
  - Define targets and update variables for model updating
- Test planning using imported finite element analysis (FEA) results
- Import and decimation of FE models to test models to be used for experimental modal analysis
- Integrated solution from measurement to FEM correlation using PULSE Reflex Structural Measurements Type 8729-B, PULSE Reflex Modal Analysis Types 8720 and 8721 and PULSE Reflex Correlation Analysis Type 8722
- Open stand-alone application to be used with your existing data acquisition and analysis system

Features

- Efficient workflow with just a few steps to perform a complete correlation analysis
- Import of test modal models in standard formats
- Import of finite element models from Nastran, ANSYS, ABAQUS or UFF
- Easy-to-use and powerful test geometry drawing tools using built-in CAD models
- Selection and validation of test nodes from FE models for test planning
- Decimation of finite element models to test models
- Geometry alignment by scaling and orienting the two models
- DOF mapping to match DOFs from the two models
- Comparison of test and FE modal models using mode tables and mode shape animation
- AutoMAC and CrossMAC tables and 3D plots calculated in reduced test space
- AutoOrthogonality and CrossOrthogonality tables and 3D plots calculated in reduced test space
- Import of reduced mass matrix from Nastran or ABAQUS
- SEREP algorithm can be used if no reduced mass matrix is available
- Expansion of test modal vectors to FE space using the SEREP algorithm
- Pairing of modes from two modal models according to their degree of frequency correlation, shape correlation or manually
- Integrated Microsoft® Office reporting capabilities

Introduction

PULSE Reflex is the latest addition to the PULSE platform of software products. It provides real-time measurements, analysis and test-FEA integration in a modern, intuitive GUI environment and is the culmination of extensive customer surveys to resolve their most important issues when analysing sound and vibration data.

PULSE Reflex provides:

- Enhanced usability for high productivity with an intuitive user interface that puts the tools you need at your fingertips. The graphical user interface is built around a workflow model that leads you easily through any test setup, measurement and analysis process
- Open data policy that supports a wide range of native and third party formats for improved import and export of data
- Consistent user interface throughout all applications encouraging faster learning of new applications

PULSE Reflex Structural Dynamics allows you to observe, analyse and document the dynamic behaviour of structures using a single software platform covering setup, measurements, analysis and test-FEA integration. With PULSE Reflex Structural Measurements, you can set up and perform single or poly-reference hammer and shaker measurements, whereas PULSE Reflex Modal Analysis provides accurate and reliable results even in the most demanding situations using a targeted set of best-in-class mode indicator functions, curve-fitters and analysis validation tools.

Reflex Correlation Analysis adds the capability of correlating two modal models, for example, finite element model versus test model using tools such as Geometry Alignment, CrossMAC and Cross-orthogonality calculations.

The open data policy behind the PULSE Reflex Structural Dynamics suite also allows the post-processing applications to be used as stand-alone applications together with your existing measurement and analysis system.

Geometry

PULSE Reflex Correlation Analysis contains powerful tools for working with geometries. It allows you to create test geometries, import test and finite element geometries, decimate finite element geometries to test geometries and align test and finite element geometries.

Geometry Creation and Import

Test geometries can be created from scratch using the embedded drawing tools. You can work with various elements like points, lines, triangular and quad surfaces and you can create various 2D and 3D CAD models and mesh them. The geometry can also be created from table entries. Alternatively, test geometries can be imported in standard data formats like UFF and CSV.

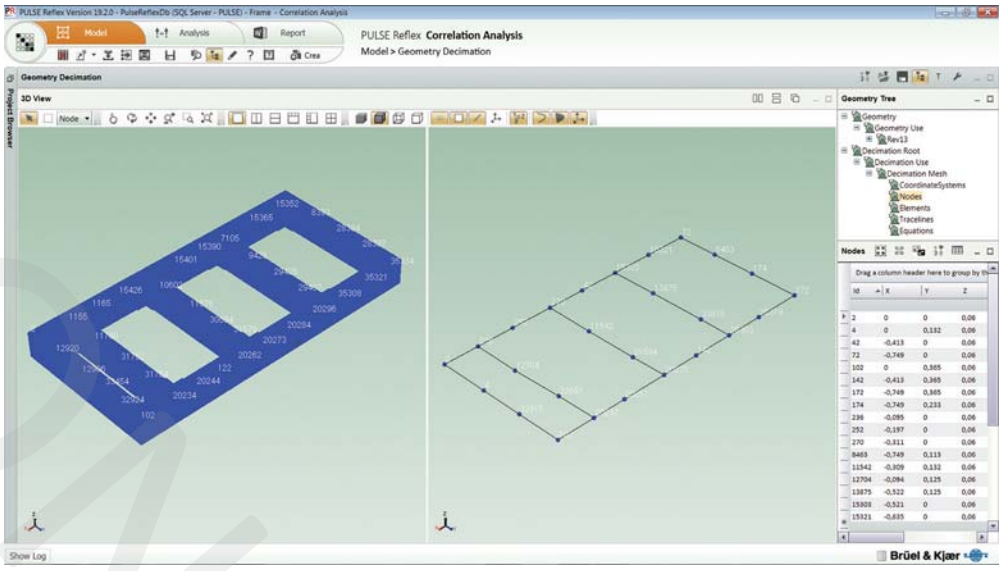
Finite Element (FE) models can be imported as UFF files or from NASTRAN, ANSYS and ABAQUS. Import of FE models can include, apart from geometry data and modal data, also reduced mass matrices (NASTRAN or ABAQUS). This allows for animation of the FE modes as well as correlation of Finite Element Analysis (FEA) results with test results.

Geometry Decimation

Imported FE geometries can be decimated to test geometries for use in, for example, PULSE Reflex Structural Measurements, PULSE Modal Test Consultant or PULSE ODS Test Consultant. The decimation can be done graphically by clicking on the nodes of the FE geometry to keep. Lines and optional surface elements like triangles or quads connecting the points, are automatically drawn on-the-fly.

You can also select nodes on a FE model and investigate how the AutoMAC builds up for the reduced geometry consisting of the selected nodes. This helps determine which nodes on the FE model to include in a test geometry to identify and separate modes of interest.

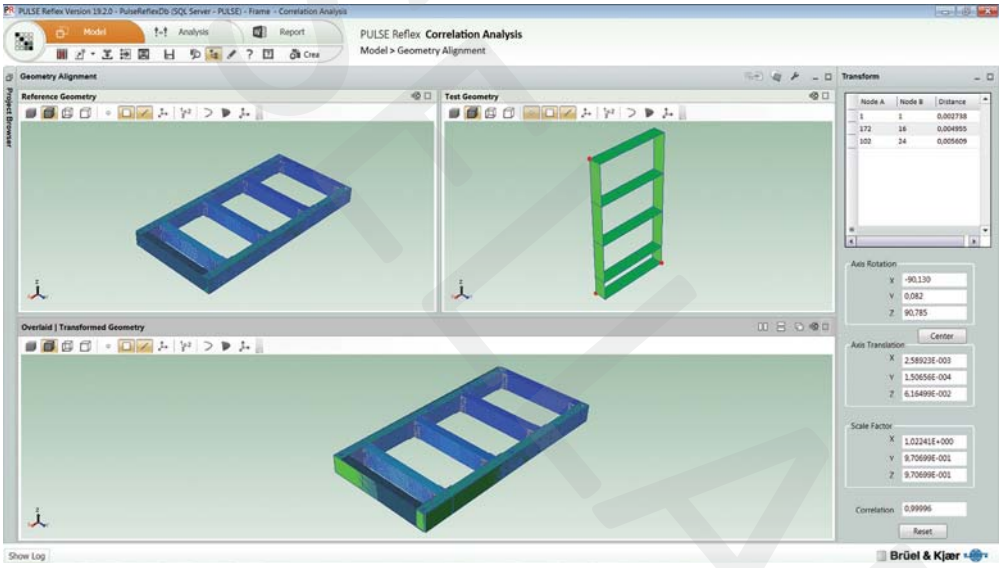
Fig. 1
Geometry Decimation. Simple test geometries can easily be created from FE models



Geometry Alignment

Before two modal models can be correlated, their respective geometries must be aligned in space as regards orientation and scaling. This is obtained by selecting, graphically or using a table, three or more pairs of points to be aligned on the two geometries.

Fig. 2
Geometry Alignment. Alignment can be performed by selecting three or more point pairs on the two geometries



Analysis and Reporting

By logically grouping features and display of results, PULSE Reflex Correlation Analysis allows you to do a complete correlation analysis in just five main steps:

- Geometry Alignment
- DOF Mapping
- Comparison
- Vector Comparison
- Mode Pairing

In addition, a User Defined Layouts task is available.

Extensive live reporting can be done at any time during the analysis process in Microsoft® Word, Excel® or PowerPoint® using integrated reporting functions.

DOF Mapping

The nodes and directions of the two models are mapped based on the DOF information in the two mode tables and the geometry alignment previously performed. The distance between the mapped pairs of nodes and the relation between directions on the two models are displayed in a table. Also the two models' geometries and mode tables are shown.

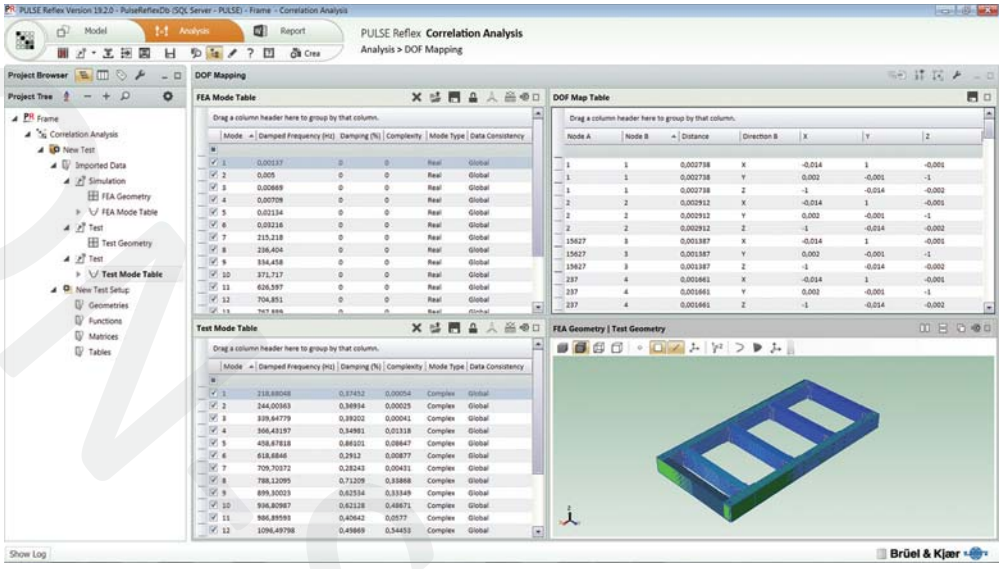


Fig. 3
DOF Mapping. Nodes and directions of the two models are mapped

Comparison

The Comparison task allows you to further investigate the two modal models. This includes mode shape animation, where the two models can be shown in various different layouts including side-by-side, top-bottom, overlaid or differenced.

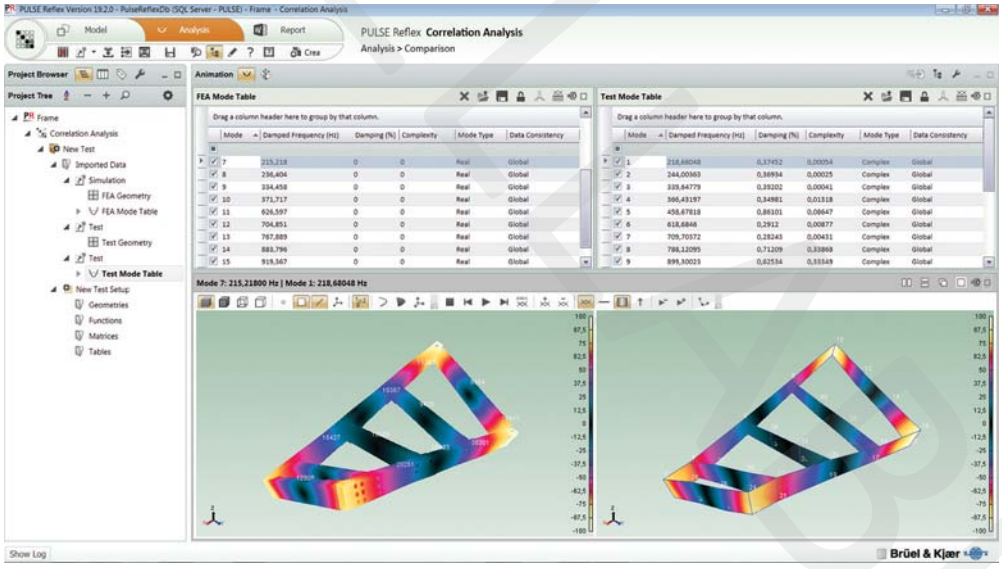


Fig. 4
Comparison. Comparing 1st torsional mode from FEA and test

Vector Comparison

Vector comparison can be done by calculating AutoMAC, CrossMAC, AutoOrthogonality and CrossOrthogonality tables and 3D plots in reduced test space. The AutoOrthogonality and CrossOrthogonality results are calculated using a reduced mass matrix. If a reduced mass matrix does not exist, the SEREP algorithm can be used for orthogonality calculations. Expansion of test modal vectors to FE space can be done using the SEREP algorithm.

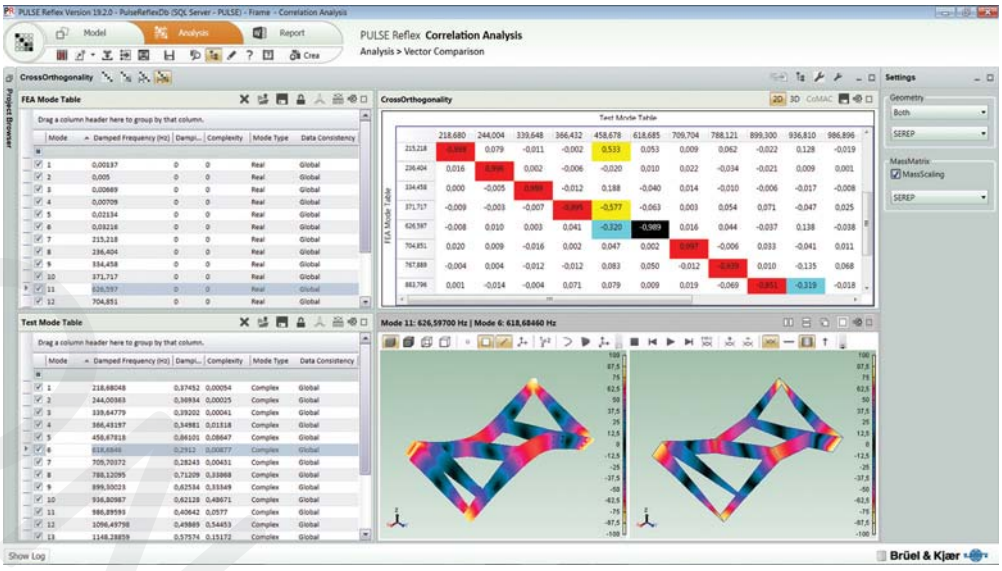


Fig. 5
Vector Comparison. CrossOrthogonality comparing the mode shapes found using FEA and test. The mode pair selected is automatically animated

Mode Pairing

Modes can be paired according to their degree of frequency correlation, mode shape correlation based on CrossMAC or CrossOrthogonality calculations or manually.

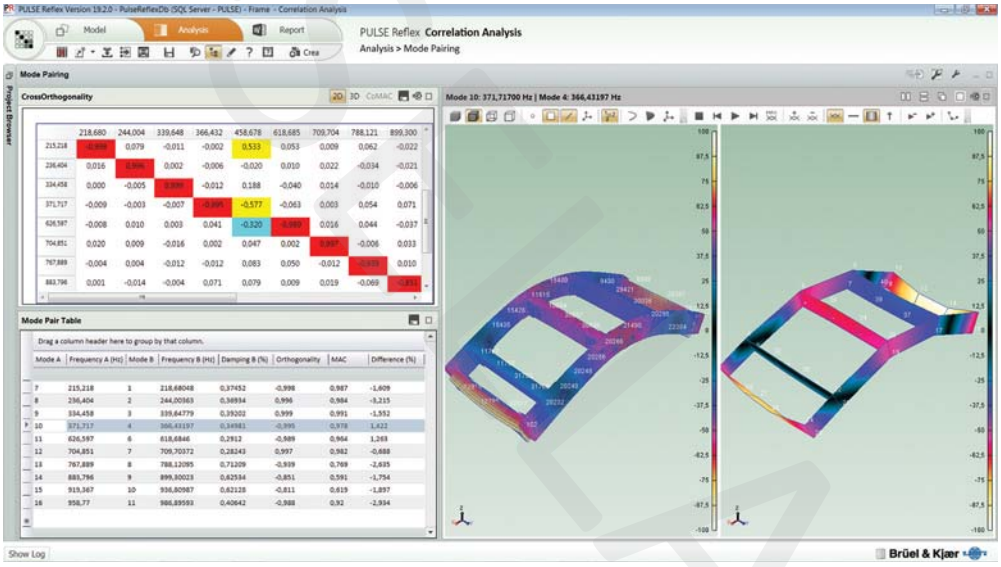


Fig. 6
Mode Pairing. Pairing the modes from FEA and test based on CrossOrthogonality. Selected FEA-Test mode pair (Mode 10: 372 Hz and Mode 4: 366 Hz) is shown animated

Reporting

The Report task enables reports to be prepared in parallel with the analysis process, linking important results as they are produced. Store geometries, displays, tables and text in the Project Browser as report elements so when you are ready, you only need to generate and save the report. Generated reports can be based on standard embedded templates, customised templates you define, or on-the-spot.

High-quality, active or static reports are easily created directly in Microsoft® Word, Excel® or PowerPoint®.

User-defined Layouts

The User Defined Layouts task enables you to create customized layouts consisting of graphs, geometries (with or without animation), shape tables, MAC tables/plots and complexity plots. Data can be linked between displays in the layout so that source data in one display is reflected in a result display. For example linking a mode table to a geometry – changes to the mode table will be automatically updated in the geometry. This allows for fast and flexible data viewing and ad hoc analysis.

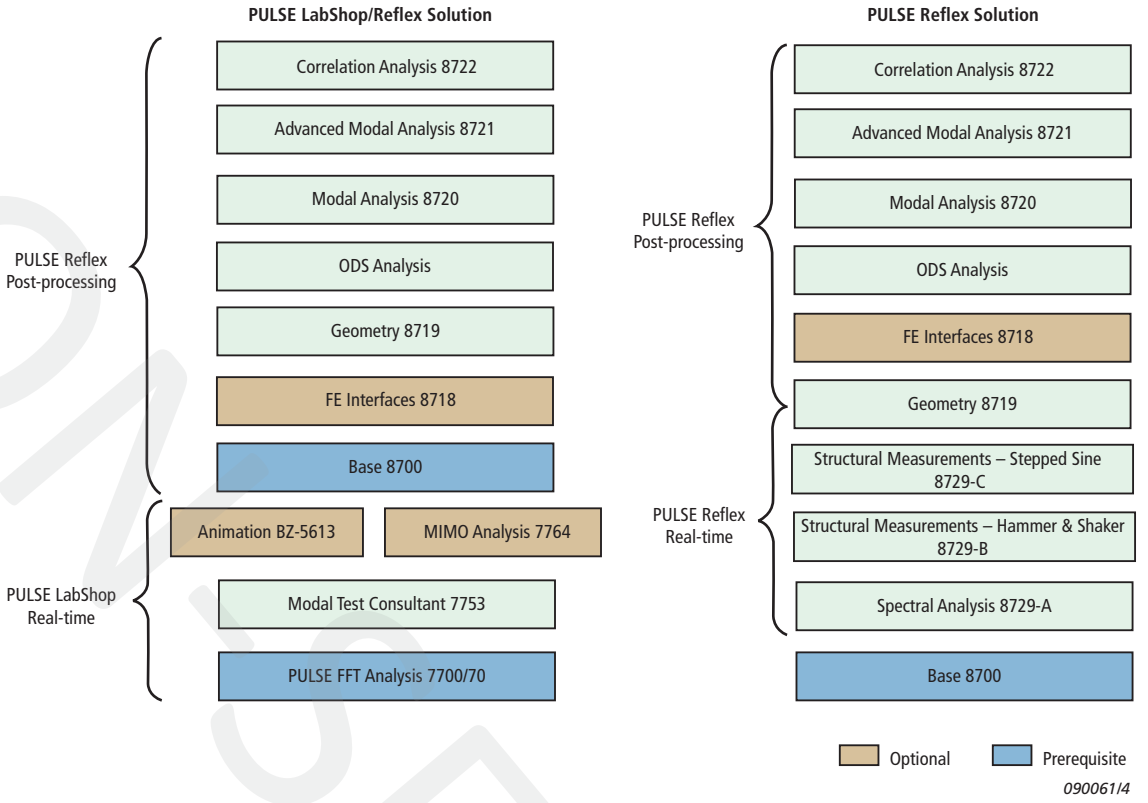


Fig. 7
PULSE structural dynamics product structure – from modal measurements to analysis and test-FEA integration. Real-time measurements can be performed in the PULSE LabShop environment (left), or completely integrated in the PULSE Reflex environment (right)

PULSE Reflex Base Type 8700

PULSE Reflex Base provides the framework, including Project Browser, Reporting, Notes and Help system. The Base module must be installed to run any PULSE Reflex application.

PULSE Reflex Measurements Type 8729

Spectral Analysis Type 8729-A

This is the prerequisite for measurements in PULSE Reflex. It provides the Hardware Matrix, the Hardware Setup Table and the Level Meter as well as the Transducer Manager and the Transducer Verification tasks.

Structural Measurements – Hammer and Shaker Type 8729-B

Structural Measurements adds dedicated setup and measurements tasks for hammer and shaker testing, including measurements for MIMO analysis. Geometry-guided measurement setup, execution and validation is supported.

Structural Measurements – Stepped Sine Type 8729-C

Type 8729-C adds dedicated setup and measurement tasks for single and multi-shaker stepped sine testing. Geometry-guided measurement setup, execution and validation is supported.

For information on PULSE Reflex Structural Measurements, see Product Data BP 2518.

Geometry Type 8719

Geometry allows the importation and creation of geometries and is used across the various PULSE Reflex Structural Dynamics solutions. FE models can be imported using UFF and decimated to test models.

A variety of animation types are supported including wire frame, surface contour, point and arrow animation as well as overlaid, difference, top-bottom, and side-by-side animation in single, dual or quad view format. The animations can be recorded as AVIs and included in Word and PowerPoint reports.

FE Interfaces Type 8718
FE Interfaces enables you to import FE models from Nastran, ANSYS® and ABAQUS®.

Modal Analysis Type 8720
An application designed for single-reference modal analysis with a basic, yet comprehensive, set of mode indicator functions (MIFs), curve-fitters and analysis validation tools. For use with single shaker FRF data and single reference hammer testing data.

For more information on PULSE Reflex Modal Analysis Type 8720/21, see Product Data BP 2257.

Advanced Modal Analysis Type 8721
Advanced Modal Analysis adds polyreference modal analysis capabilities and advanced MIFs, curve-fitters and analysis validation tools to the Modal Analysis application. For use with shaker MIMO (Multiple Input Multiple Output) FRF data, polyreference hammer testing data or for advanced analysis and validation of both single and polyreference data.

ODS Analysis
With Type 8700 and 8719 licenses installed, a PULSE Reflex ODS Analysis application is available for frequency-based spectral ODS post-processing analysis or for viewing modal analysis results.

Correlation Analysis Type 8722
Correlation Analysis adds the ability to correlate two modal models: FEM vs Test, Test vs Test or FEM vs FEM.

Other Modules
For more information on PULSE Reflex Base Type 8700, see Product Data BP 2258.
For information on Modal Test Consultant Type 7753, MIMO Analysis Type 7764 and Animation Option BZ-5613, see Product Data BP 1850.

For an overview of PULSE LabShop's software platform, see PULSE Software System Data BU 0229.

Complete Measurement Chain

With Brüel & Kjær's complete and fully integrated measurement chain, including accelerometers, impact hammers, force transducers, modal exciter systems, data acquisition front-ends and measurement and post-processing software, you can select the optimal solution for your structural dynamics needs. The openness and flexibility of the PULSE Reflex Structural Dynamics applications support your needs today and in the future. You are never limited to a vendor specific system configuration and can easily assemble the system of your choice.

Correlation of two modal models with Cartesian coordinate systems

SYSTEM REQUIREMENTS
- PULSE v.21 or later
- Microsoft® Windows® 8.1 Pro or Enterprise (x64), Windows® 8.1 Pro or Enterprise (x64), or Windows® 7 Pro, Enterprise or Ultimate (SP1) (x64) operating system
- PC requirements for PULSE Reflex Base Type 8700 must be fulfilled

RECOMMENDED PC FOR USE WITH FE MODELS
Intel® Core™ i7, 3 GHz or better with 16 GB RAM or more. This will support test-FEA correlation analysis of FE models up to 1 M nodes

SOFTWARE REQUIREMENTS
- PULSE Reflex Base Type 8700
- PULSE Reflex FE Interfaces Type 8718: To import NASTRAN, ANSYS and ABAQUS models and results
- PULSE Reflex Geometry Type 8719: For all geometry functionality
- PULSE Reflex Modal Analysis Type 8720: To run Type 8721

Geometry

GEOMETRY CREATION AND EDITING
- Basic geometries using nodes, tracelines, triangle and quad elements
- Geometries based on built-in CAD models:
  - Curves: Circle, Circular Arc, Ellipse, Elliptical Arc, Hyperbolic, Parabolic, Line, Polyline, Interpolation Spline and Control Points Spline
  - Surfaces: Circular, Circular Arc, Ellipse, Elliptical Arc, Hyperbolic, Parabolic, Triangular, Rectangular, Polygon, Interpolation Spline and Control Points Spline
  - Solids: Cylinder, Hemisphere, Sphere, Box, Cone and Conical Frustum
- CAD models with selectable colour and transparency
- Move (translate, rotate) and copy (linear, radial) operators for CAD models and meshes using interactive handles or manual entry
- Definition of locations with three directions on a CAD model (Sites)
- Meshing of CAD models
- Extrusion of CAD models: Curves can be extruded to surfaces. Plane surfaces can be extruded to solids. Preselection of colour is possible
- Hierarchical geometry tree view with subfolders for Coordinate Systems, Nodes, Elements, Tracelines and Equations
- Tables for Coordinate Systems, Nodes, Elements, Tracelines and Equations with sorting, filtering, multiple selection and editing
- Support of Cartesian, Cylindrical and Spherical coordinate systems. Local and Global coordinate systems
- Automated point numbering. Partial or complete semi-automated point renumbering
- Visual link between sections made in Geometry 3D View and Geometry Tree

GEOMETRY IMPORT FORMATS
UFF data set types 15, 18, 82, 2411, 2412, 2416 or 2431; Microsoft® Excel® (*.csv); UFF FE models; Nastran (MSC, NX, NEi), ANSYS and ABAQUS FE models (requires Type 8718)

GEOMETRY EXPORT FORMATS
UFF data set types 15, 18, 82 or 2412 and Microsoft® Excel® (*.csv)

NODE SELECTION
Select test node locations on a FE model until a satisfactory FE AutoMAC is created.
A-set nodes from an imported Reduced Mass Matrix or Reduced Stiffness Matrix from MSC Nastran (.op2) are automatically selected for validation and potential modification.
Nodes selected are automatically high-lighted in the Geometry Decimation task for connection with trace lines and/or elements

DECIMATION
Imported FE models can be decimated to test models by manually selecting nodes on the FE model or by entering the nodes directly in a table.
Selected nodes can be connected with trace lines and/or elements

ALIGNMENT
Two modal models can be aligned as regards orientation and scaling using three or more node pairs. Graphical and tabular methods available

DYNAMIC POINT NUMBERING
Show more point numbers (IDs) when zooming in on parts of the geometry (user-definable). Also supported during animation

GEOMETRY VIEWS
- Single, Side-by-Side, Top-Bottom and various Quad views
- Definition of front, back, left, right, top and bottom view axis
- Isometric view
- Perspective, orthographic and stretched projections of geometry
- Hidden lines and transparency
- Pan, zoom and rotate options for viewing geometries
- Symbols for shaker, impact hammer, force transducer and accelerometer positions shown on geometry with customized colours and sizes

CUTTING PLANES
Cut through a geometry in three user-defined 2D planes to view the interior or exclude viewing parts of the geometry. Also supported during animation

ANIMATION
- Deformed and undeformed animation with Max. Deformation
- Single, overlaid and difference animation
- Wireframe, contour (solid, solid edge), point and arrow animation
- Animation of non-measured DOFs using interpolation equations
- AVI file generation with selectable codec

DOF Mapping

- Map DOFs from two aligned geometry models, their mode shape tables and DOF node and DOF direction tolerances
- Mapped DOFs shown with resulting node distance and direction relationship
- Nodes on Geometry B (typically a test geometry) can be re-numbered to the same node IDs as the nodes on Geometry A (typically a FE model)

Comparison

General comparison of two modal models. Mode tables contain the modal models in terms of natural frequency, damping and mode shapes. Comprehensive documentation of modal results including:
- Mode number, Mode Description, Estimation Method, Mode Complexity, Mode Type, Mode Shape Scaling, etc.
- Columns with Sorting and Filtering

Selected mode pairs are automatically animated

Vector Comparison

Vector (mode shape) comparison of two modal models:
- AutoMAC, CrossMAC, AutoOrthogonality and CrossOrthogonality with animation of selected mode pairs
- AutoMAC and CrossMAC tables and 3D plots calculated in reduced test space
- AutoOrthogonality and CrossOrthogonality tables and 3D plots calculated in reduced test space
- Import of Nastran or ABAQUS reduced mass matrix. SEREP algorithm can be used if reduced mass matrix is not available
- Expansion of test modal vectors to FE space can be done using the SEREP algorithm

Mode Pairing

- Pairing of modes from two modal models according to their degree of:
  - Frequency correlation
  - Mode shape correlation based on CrossMAC or CrossOrthogonality calculations
  - Manual pairing
- Mode Pair table includes
  - Mode number, frequency and damping for each mode
  - CrossOrthogonality, CrossMAC and Frequency Difference (%) for each mode pair
- Animation of selected mode pairs

User-defined Layouts

For user specific definition of layouts
Supports geometries with animation, function data, tables (DOF pairing, mode pairing, mode shapes, MAC and Orthogonality), plots (Complexity, MAC and Orthogonality), etc.

Reporting

Integrated live reporting using Microsoft® Word, Excel® and PowerPoint®
Reports can be prepared in parallel with the analysis process and generated at any time

Ordering Information

Table 1 *Ordering information for PULSE Reflex Structural Dynamics suite software*

Item No.*	Description
Type 8700-X	PULSE Reflex Base
Type 8718-A-X	PULSE Reflex Nastran Interface
Type 8718-B-X	PULSE Reflex ANSYS Interface
Type 8718-C-X	PULSE Reflex ABAQUS Interface
Type 8719-X	PULSE Reflex Geometry
Type 8720-X	PULSE Reflex Modal Analysis
Type 8721-X	PULSE Reflex Advanced Modal Analysis
Type 8722-X	PULSE Reflex Correlation Analysis
Type 8729-A-X	PULSE Reflex Spectral Analysis
Type 8729-B-X	PULSE Reflex Structural Measurements – Hammer and Shaker
Type 8729-C-X	PULSE Reflex Structural Measurements – Stepped Sine
Packs	
Type 8720-A-XS	PULSE Reflex Modal Analysis Pack
Type 8720-B-XS	PULSE Reflex Modal Acquisition and Analysis Pack
Type 8721-A-XS	PULSE Reflex Advanced Modal Analysis Pack
Type 8721-B-XS	PULSE Reflex Advanced Modal Acquisition and Analysis Pack

* "X" indicates the license model, either N: Node-locked or F: Floating

Table 2 *Overview of PULSE Reflex Modal Analysis packs (modal analysis packs and modal acquisition and analysis packs)*

	Packs			
	8720-A	**8720-B**	**8721-A**	**8721-B**
	Modal Analysis	**Modal Acquisition and Analysis**	**Advanced Modal Analysis**	**Advanced Modal Acquisition and Analysis**
Comprises:				
PULSE Reflex Base Type 8700		•		•
Geometry Type 8719 (incl. animation)	•	•	•	•
Modal Analysis Type 8720	•	•	•	•
Advanced Modal Analysis Type 8721			•	•
Modal Test Consultant Type 7753		•		•
MIMO Analysis Type 7764*				•
Animation Option BZ-5613†		•		•

* Type 7764 is required for measuring MIMO FRFs in PULSE Modal Test Consultant Type 7753. Type 7764 is not required for polyreference curve-fitting in PULSE Reflex.
† For FRF animation in PULSE Modal Test Consultant Type 7753

Table 3 *Ordering information for PULSE Reflex Structural Dynamics suite's maintenance and support agreements*

Item No.*	Description
M1-8700-X	Software Maintenance & Support for Type 8700
M1-8718-A-X	Software Maintenance & Support for Type 8718-A
M1-8718-B-X	Software Maintenance & Support for Type 8718-B
M1-8718-C-X	Software Maintenance & Support for Type 8718-C
M1-8719-X	Software Maintenance & Support for Type 8719
M1-8720-X	Software Maintenance & Support for Type 8720
M1-8721-X	Software Maintenance & Support for Type 8721
M1-8720-A-XS	Software Maintenance & Support for Type 8720-A-XS
M1-8720-B-XS	Software Maintenance & Support for Type 8720-B-XS
M1-8721-A-XS	Software Maintenance & Support for Type 8721-A-XS
M1-8721-B-XS	Software Maintenance & Support for Type 8721-B-XS
M1-8722-X	Software Maintenance & Support for Type 8722
M1-8729-A-X	Software Maintenance & Support for Type 8729-A-X
M1-8729-B-X	Software Maintenance & Support for Type 8729-B-X
M1-8729-C-X	Software Maintenance & Support for Type 8729-C-X

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BP 2395 – 17 2016-09

Brüel & Kjær Sound & Vibration Measurement A/S
DK-2850 Nærum · Denmark · Telephone: +45 77 41 20 00 · Fax: +45 45 80 14 05
www.bksv.com · info@bksv.com
Local representatives and service organizations worldwide

Brüel & Kjær