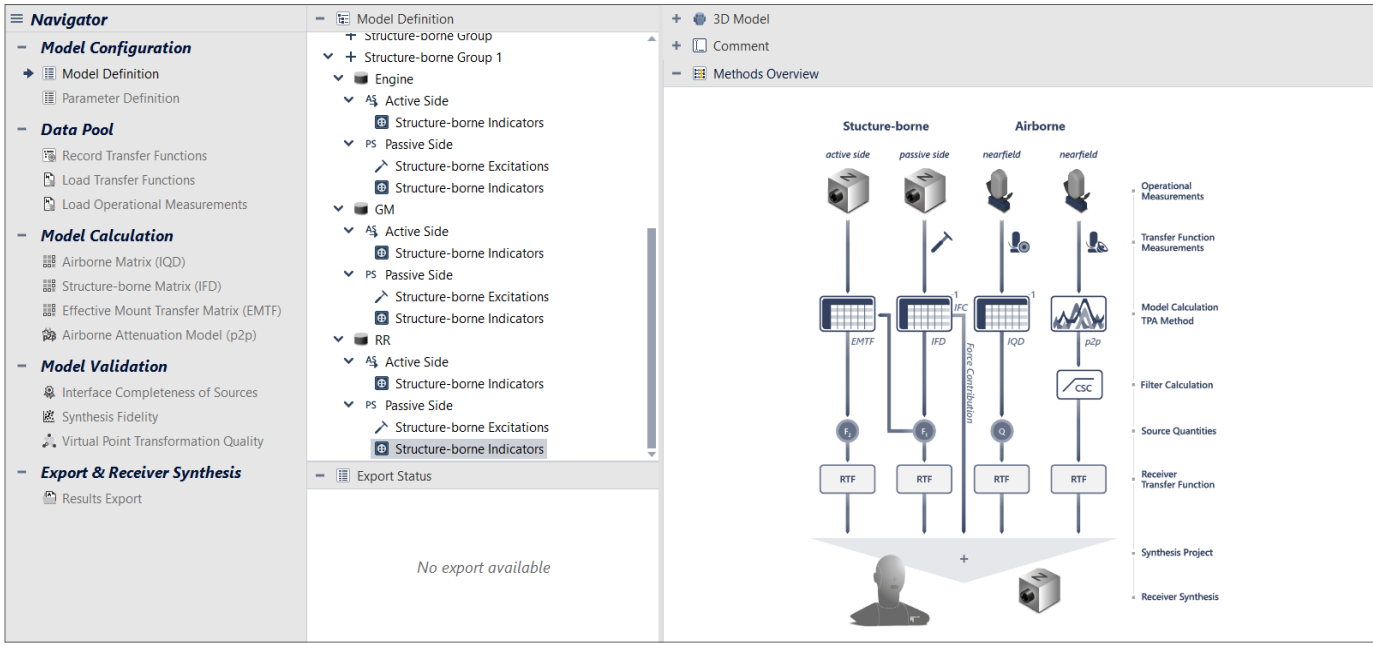
DATA SHEET



ArtemiS SUITE
PRoject

Code 50600

APR 600 TPA Project

TPA Project forms the core and workflow foundation of the TPA package of ArtemiS SUITE, enabling both classical and in-situ TPA. In combination with additional modules, it provides guidance through the complete TPA process—from data acquisition and module calculation, including the determination of the blocked forces for a standardized result exchange, to model synthesis, model validation, and the final export.

OVERVIEW

APR 600
TPA Project

Code 50600

The TPA Project enables the execution of a complete TPA, including the determination of blocked forces in accordance with ISO 20270:2019. The workflow provides structured step-by-step guidance through all required and optional processes, integrating the strengths of both experimental and numerical methods.

Multiple modules that can be seamlessly combined with each other form the TPA package:

- APR 600 TPA Project
  Core and workflow foundation of the TPA package
  - The model configuration is available, as are parts of the model calculation, validation, and the fundamental export options
- APR 610 TPA – Data Acquisition
  Performing the required measurements through
  - Structure-borne measurements using shakers and impact hammers
  - Sound pressure and volume velocity measurements
  - Measurements of the operating states
- ASP 601 TPA – Virtual Point Transformation
  Calculating forces, moments, accelerations, and angular accelerations at locations that cannot be physically measured
- ASP 602 TPA – Structure-Borne Analysis
  Procedures and analyses for structure-borne sound contributions
- ASP 603 TPA – Airborne Analysis
  Procedures and analyses for sound pressure and volume velocity contributions

KEY FEATURES

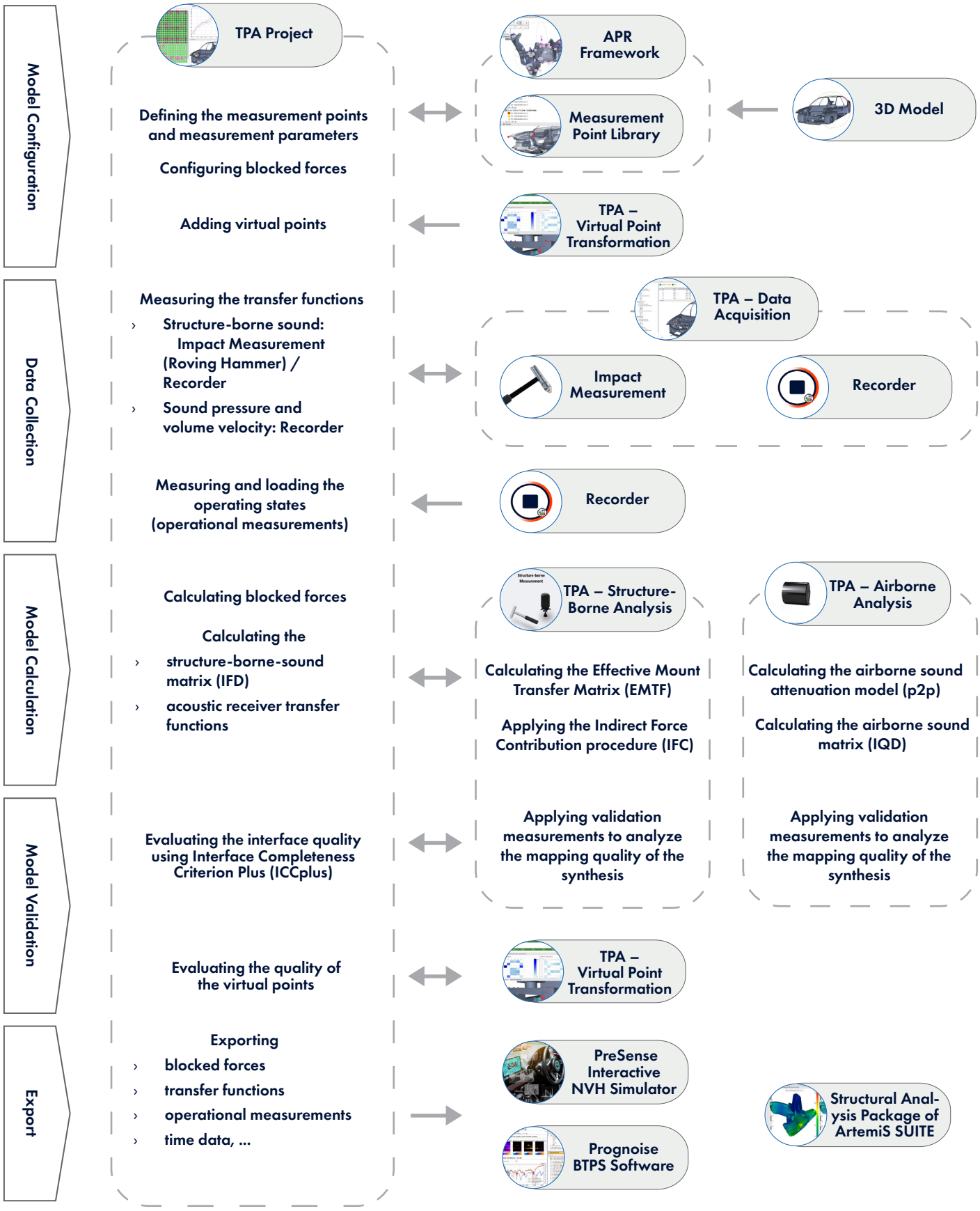
Transfer path analysis for structure-borne sound with step-by-step process guidance

- Definition of the TPA model using the Measurement Point Library and an (optional) 3D model
- Methods for model calculation and validation included in APR 600:
  - Blocked forces in accordance with ISO 20270:2019
  - Indirect Force Determination with matrix inversion (IFD)
  - Evaluation of interface quality (Interface Completeness Criterion Plus, ICCplus)
- Calculation and visualization of transfer functions, coherences, impulse response, and excitation spectrum
- Export of data for Prognoise projects and the structural analysis package of ArtemiS SUITE
- Additional methods and export options are available in combination with ASP 601, ASP 602, and ASP 603

APPLICATIONS

- Automated calculation of blocked forces and documentation in accordance with ISO 20270:2019 to enable the excange of results in a standardized format
- Use of combined simulated transfer functions and measured excitations for a hybrid TPA approach
- Detailed component-level benchmarking
- Definition of path-level targets
- Export of results for the interactive PreSense NVH simulator (ASP 602 and ASP 603 are required)
  - Auralization and experience of virtual test-drives

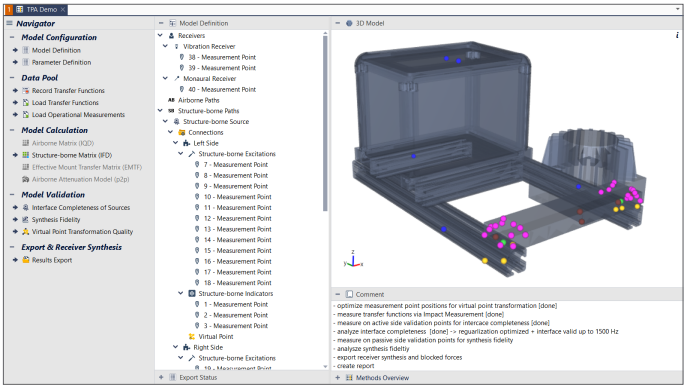
OVERVIEW: TPA WORKFLOW



DETAILS

TPA Project (APR 600)

TPA Project is designed as a process-oriented framework that provides structured, step-by-step guidance through the workflow, starting with model configuration and concluding with the export of results. In addition to the process steps provided within APR 600, further optional, license-controlled TPA modules are available, offering extended methods, analysis procedures, and export options. All modules are integrated in the TPA workflow.

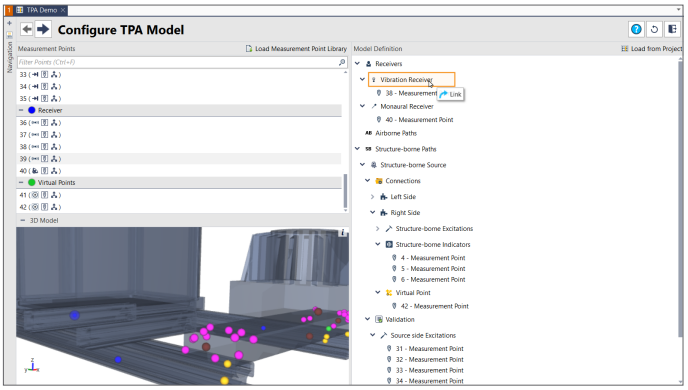


Clearly structured TPA Project

Step 1: Model Configuration

In the first step, the measurement points for structure-borne sound, sound pressure, and volume velocity are defined, and the relevant measurement parameters and blocked forces are specified. For this purpose, the Measurement Point Library (included in APR 000) is used, enabling the assignment of measurement points to the corresponding force application points, receivers, and other relevant positions of the measurement object.

Loading a 3D model enables the TPA model to be created more efficiently and with greater clarity. All visualization views are interconnected: When a measurement point is selected in the 3D model, the corresponding elements in the model tree are displayed immediately. These interconnections are subsequently adopted by the matrices, as the model tree and the 3D model interact automatically.



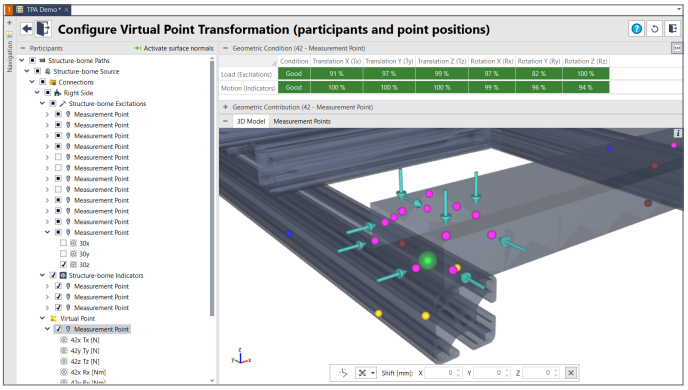
Model definition

Step 2: Virtual Points

ASP 601 TPA – Virtual Point Transformation is required

TPA – Virtual Point Transformation is an optional extension module that enables the definition of virtual measurement points on components or assemblies. Based on these points, resulting forces, moments, and both translational and rotational accelerations can be calculated at locations where direct excitation or measurement using sensors, hammers, or shakers is not feasible. Virtual points are particularly useful in hybrid models for connecting numerical simulation models with the real measurement results.

For more information, please refer to the ASP 601 data sheet.



Configuration of the virtual points

Step 3: Data Acquisition

APR 610 TPA – Data Acquisition is required.

To perform the required transfer function measurements, the TPA model workflow leads to TPA – Data Acquisition.

For the actual measurements, both the Impact Measurement (APR 430 is required) and the Recorder of ArtemiS SUITE (APR 040 is required) are available, each seamlessly integrated into the process. In this step, the Measurement Point Library and the 3D model can likewise be used to perform all tasks efficiently and with full reproducibility. Measurements performed with APR 430 are suitable not only due to the acoustic and visual feedback messages supporting the verification of the hammer impact quality; they can also be used directly within the modal analysis package of ArtemiS SUITE. Operational measurements required for the subsequent synthesis must be acquired using the Recorder, for example on test benches.

For more information on TPA – Data Acquisition, Impact Measurement, and Recorder, please refer to the APR 610, APR 430, and APR 040 data sheets.

Step 4: Model Calculation and Model Synthesis

The sum of all measured noise components—both structure-borne and airborne-induced—constitutes the overall noise, which is automatically consolidated by the TPA Project to create the TPA model.

In combination with ASP 602 and ASP 603, all transfer functions are calculated automatically:

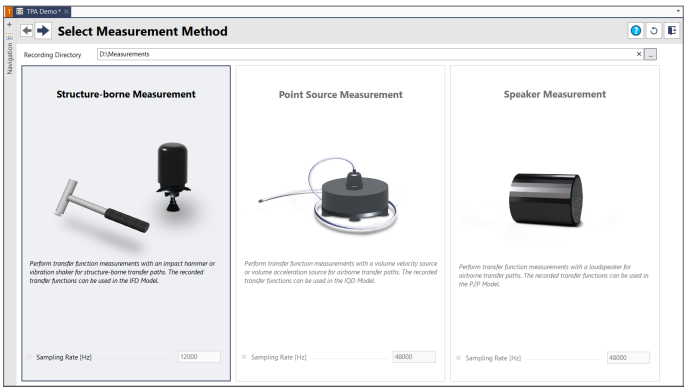
› Structure-borne-sound transfer functions: inertances, vibroacoustic transfer functions
› Airborne-sound transfer functions: acoustic impedances and acoustic transfer functions

This is followed by a matrix inversion of the inertances and the acoustic impedances.

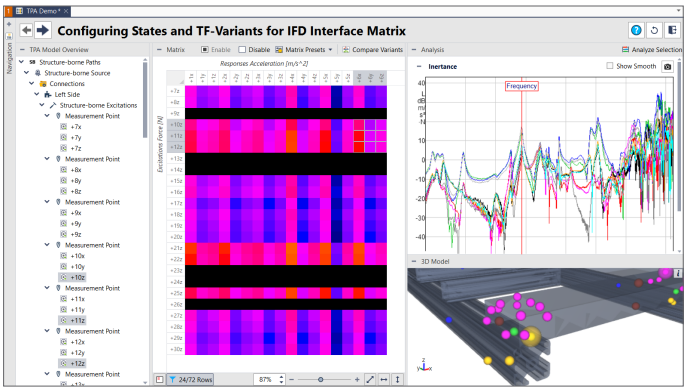
For analysis purposes, the TPA Project provides transfer functions, coherences, impulse responses, receiver excitation spectra, and acoustic masses in a clear and compact presentation.

Blocked Forces (ISO 20270:2019)

Based on in-situ measurements and operational measurements, the TPA Project determines blocked forces in accordance with ISO 20270:2019. This enables the vibroacoustic properties of excitation sources to be characterized independently of their installation conditions. A key prerequisite for this is the high quality and completeness of the interface models. To evaluate the quality and completeness of these models, the TPA Project subsequently applies the Interface Completeness Criterion Plus (ICCplus).



Selection of data-acquisition procedures



IFD Matrix: Mosaic view

Advantages of Blocked Forces

The blocked forces defined in the ISO 20270:2019 standard are determined on the basis of transfer functions and operational measurements. By determining the contributions of various transfer paths to a target quantity—independently of the specific installation conditions—blocked forces enable a seamless exchange of standardized, component-related TPA models between OEMs, suppliers, and other parties involved. Moreover, they can serve as a basis for hybrid simulation approaches and for the creation of digital twins.

Indirect Force Determination with Matrix Inversion, IFD

In the TPA Project, the operational forces are determined using the IFD method, which involves the inversion of the inertance transfer function matrix. For this purpose, the TPA Project uses

- the measured inertances (i.e., the resulting acceleration per applied force) at all relevant force application points, along with
- the operational accelerations measured on the passive side.

By using additional acceleration signals, the inertance matrix becomes overdetermined. This serves to reduce measurement noise and thus yields more stable calculation results. The inertance matrix accounts for crosstalk between the transfer paths through the off-diagonal elements of the matrix.

Procedures for Model Calculation and Model Synthesis in ASP 602 and ASP 603

- TPA – Structure-Borne Analysis (ASP 602)
  Procedure for structure-borne sound components
  - Effective Mount Transfer Functions (EMTF)
  - Indirect Force Contribution (IFC)
- TPA – Airborne Analysis (ASP 603)
  Procedure for airborne sound components
  - Airborne attenuation determination (p2p)
  - Indirect determination of the volume velocity via matrix inversion (IQD, Indirect Q-Source Determination)
  - Acoustic receiver transfer functions

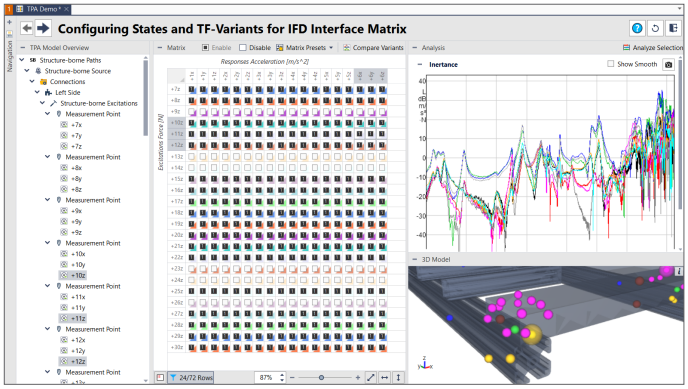
For more information, please refer to the ASP 602 and ASP 603 data sheets.

Step 5: Model Validation

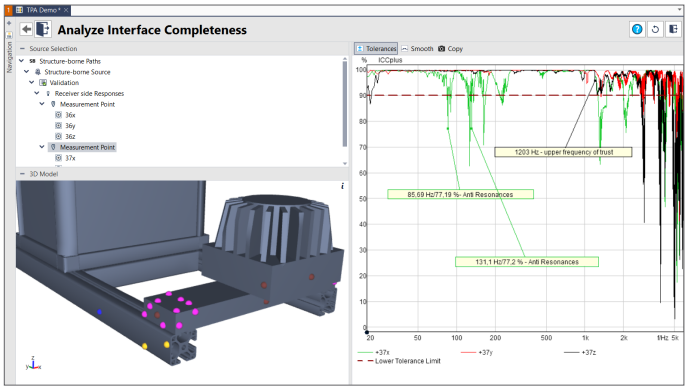
ICCplus (Interface Completeness Criterion Plus)

In this step, the completeness of the source interface is evaluated, and a comparison between the measured and the calculated transfer functions is performed.

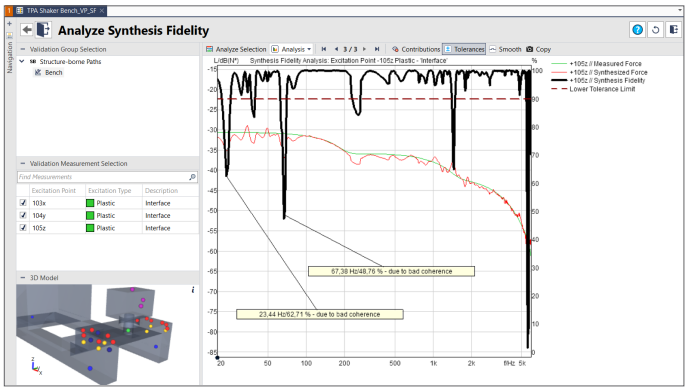
ICCplus enables a highly precise evaluation by comparing the measured transfer functions—from various excitation points on the structure-borne sound source to a receiver on the receiving structure—with the reconstructed transfer functions. If the source interface proves to be complete, the determined forces are largely independent of the receiver structure and can thus be transferred to other structures—an essential quality attribute for blocked forces. If the interface is found to be incomplete, additional validation measurements may be performed, or the interface matrix may be adjusted.



IFD Matrix



Analysis of the completeness of the source interface

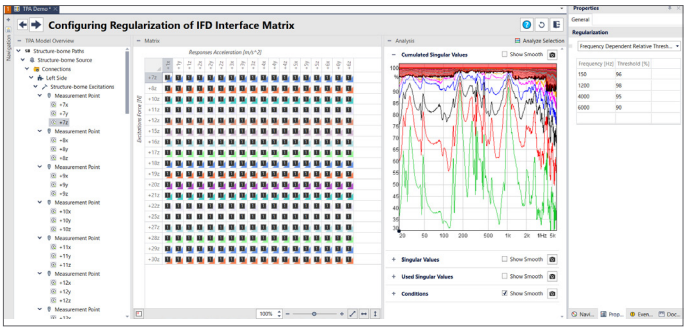


Mapping quality of the synthesis

Mapping Quality of the Synthesis

ASP 602 TPA – Structure-Borne Analysis
and/or
ASP 603 TPA – Airborne Analysis are required

The two optional modules of the TPA package can be used for validation measurements to assess how accurately the TPA model responds to unknown interface excitations. The analysis is based on comparing the measured excitation (force or volume velocity) with the synthesized excitation derived from the TPA model. If the mapping quality is insufficient, the interface matrix and the transfer functions may, for example, be adjusted.

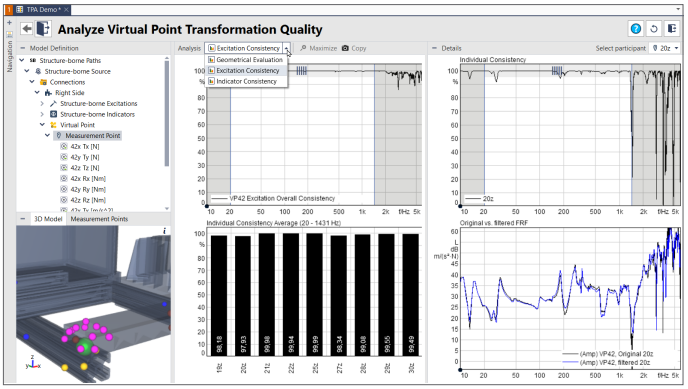


Regularization of the IFD matrix

Quality of the Virtual Point Transformation

ASP 601 TPA – Virtual Point Transformation is required

In this step, the geometric condition and the consistency of the virtual points are evaluated. The individual consistency provides information on the quality of the measurement points involved.

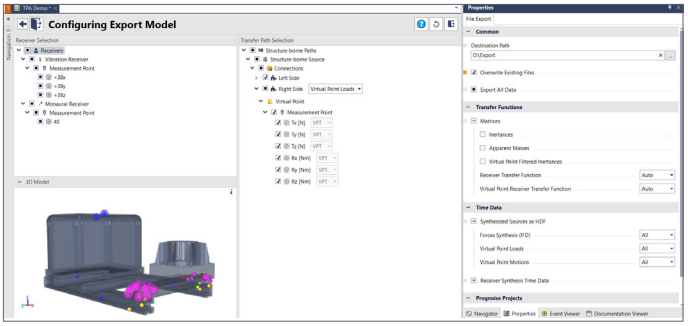


Quality of the virtual point transformation

Step 6: Export

All transfer paths and operational measurements of a TPA Project can be exported. Furthermore, individual channels and similar items may also be selected and exported separately.

- Export options with APR 600
  - Blocked forces (ISO 20270:2019)
  - Time data (IFD – blocked forces)
  - Operational measurements (e.g., individual channels)
- Export options with ASP 601, ASP 602, ASP 603
  - Synthesized sources as HDF files, volume-velocity synthesis, virtual point loads / virtual point motions, receiver-synthesis time data, summary files, overall receiver noise, group-level contributions, transfer-path contributions, transfer-path components)
  - Transfer functions (inertances, apparent masses, virtual point inertances, acoustic impedances / admittances, Effective Mount Transfer Functions, receiver transfer functions, virtual point receiver transfer functions, coherence-correction filters)
  - transfer functions
  - Prognoise projects
  - Virtual points (loads and movements)



Export

LICENSES AND OPTIONS

Required

Code	Product Name	Description
50000	APR 000 APR Framework	Basis of ArtemiS SUITE
50600	APR 600 TPA Project	Performing transfer path analyses

Optional

Code	Product Name	Description
50601	APR 601 TPA – Virtual Point Transformation	Calculating forces, moments, accelerations, and angular accelerations at points that cannot be measured physically
51602	ASP 602 TPA – Structure-Borne Analysis	Calculating the Effective Mount Transfer Matrix (EMTF) and the procedure for quantifying indirectly acting structure-borne sound contributions (IFC)
51603	ASP 603 TPA – Airborne Analysis	Indirect determination of the volume velocity via matrix inversion (IQD) and calculation of the airborne sound attenuation model (p2p)

50610	APR 610 TPA - Data Acquisition	Measuring the transfer functions required for TPA Project
50430	APR 430 Impact Measurement	Performing impact measurements (Roving Hammer / Roving Accelerometer)
50040	APR 040 Recorder	Universal Recorder of ArtemiS SUITE for all types of measurements

7600	PreSense	Interactive simulator for NVH assessments
50400 to 50430	Structural Analysis Package	Interactive examination of object vibrations
4914	Prognoise	Software for Binaural Transfer Path Synthesis (BTPS)

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