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RS TWR – A module of RS LabSite®

Time Waveform Replication

INSTRON® STRUCTURAL TESTING SYSTEMS

RS TWR
Accelerating the Durability Testing Process

A key challenge in durability testing is the ability to accurately reproduce test track loading histories on the test rig. RS TWR (Time Waveform Replication) software was developed by two partners from The Durability Alliance (Instron® Structural Testing Systems (IST) and LMS), with the specific objective of achieving this goal in the shortest possible time and with maximum accuracy.

RS TWR is part of IST´s RS LabSite® application suite, and the integrated Durability Alliance solution for environmental durability simulation. It accurately reproduces measured (or synthesized) reference time signals on multi-channel Hydropuls® testing facilities. New tools based on advanced technologies, reduce the time required to optimize the drive signals - work that previously took a week is now finished within a day.

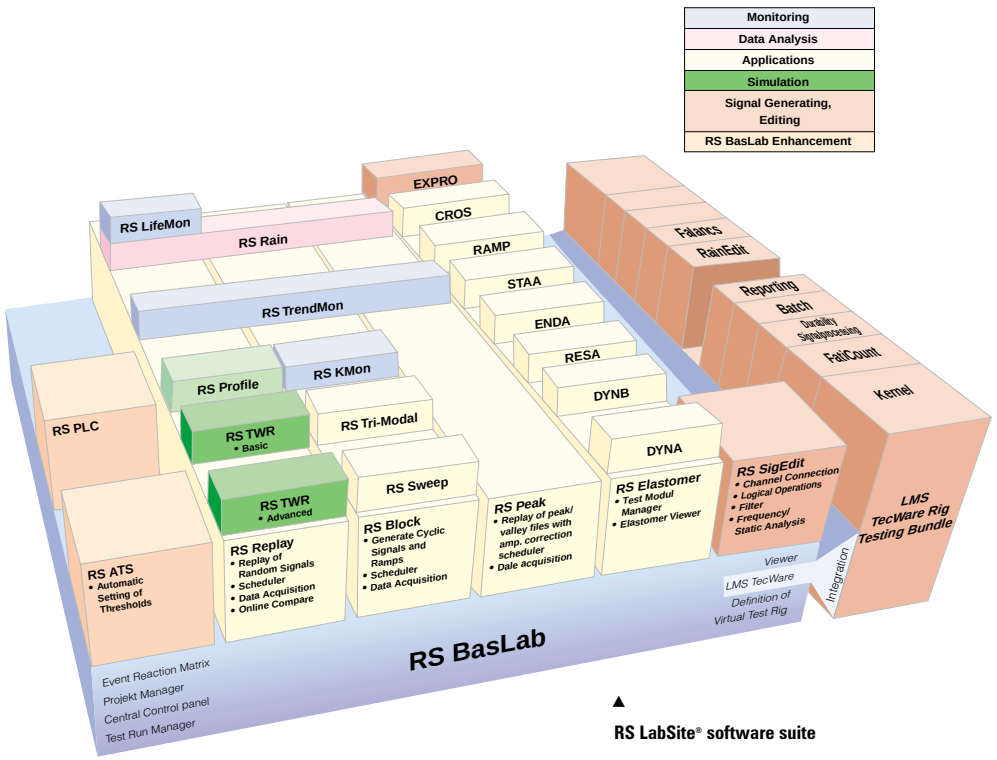
Getting High Quality Results Faster

Innovative approaches help save time in several key areas. For example, Time Waveform Replication technology is significantly faster in terms of test rig system identification; it also uses a new approach for the iteration process that is more automated and accurate than traditional iterative methods. The control algorithms are applicable to a wide range of test rig systems. There is no limitation on test rig complexity - TWR installations range from uni-axial component tests to the most complex test rigs ever built.

Flexible Automation

Technology based on frequency response function modelling as typically used for drive file development is mature and proven for complete automation of the drive file development process. Automation tools allow you to run your test rig - without operator intervention while ensuring safe operation. For example, you can split your test track into different sections and adapt a different iteration strategy for each section. Sequencing will then automatically execute the different sections of the test track, while checking against pre-defined convergence criteria. An optimized iteration strategy for the different test track sections results in less time spent on the iteration process, and increased testing efficiency.

Quote DaimlerChrysler - Mr. Bruno Seufert:
"We have reduced the time needed to ensure the signals used to drive the laboratory tests match the providing ground data by about one-third. The process of generating our fatigue test programs now is much less an art and more of a science"



RS LabSite® software suite

Ease-of-Use

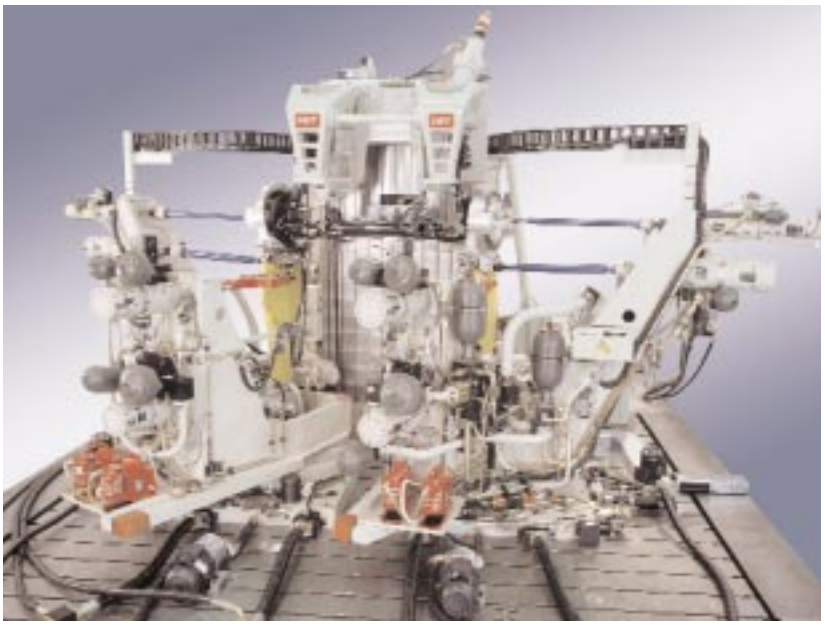
Running complex test rigs typically involves assistance from engineers to set-up and adapt a drive file development test to the specific needs of the structure under test. Transferring this knowledge to operators or technicians is often not easy. RS TWR introduces a template concept and focuses on workflow support.

A process-driven graphical user interface guides the operator through the different process steps typically needed to execute a drive file development job. Templates capture test rig-specific knowledge and standardize your laboratory on processes to follow. As a result, the process of generating fatigue test programs becomes much less an art and much more a science.

▲
Full vehicle testing system

Delivering Engineering Insights

Considerable time is typically spent on post-processing the results of a drive file development test. Often, due to physical constraints of your test rig, measured road signals cannot be perfectly reproduced. To evaluate simulation quality it is therefore important that the drive file development tool can not only quickly create overlay plots of time domain signals but also can compare test rig and measured road data in Durability or NVH relevant views. It is even possible to standardize your laboratory on the type of plots you want to evaluate by using the automated report generation tools embedded in the software.



◀
16-Channel axle test rig

Integrated Database Concept

RS TWR includes an integrated database concept that organizes all set-up and time/ frequency data collected during a TWR process. This allows the test engineer to concentrate on achieving the best possible simulation quality without having to worry about finding files, models, and set-up parameters, thereby reducing the number of errors. RS TWR will always store, retrieve, and invert matrices when required and calculate new drives with a simple push-button action. Pre-configured compact displays are supported by this database concept, allowing the test engineer to analyze Frequency Response Functions (FRF) and coherences instead of searching for correct data sets.

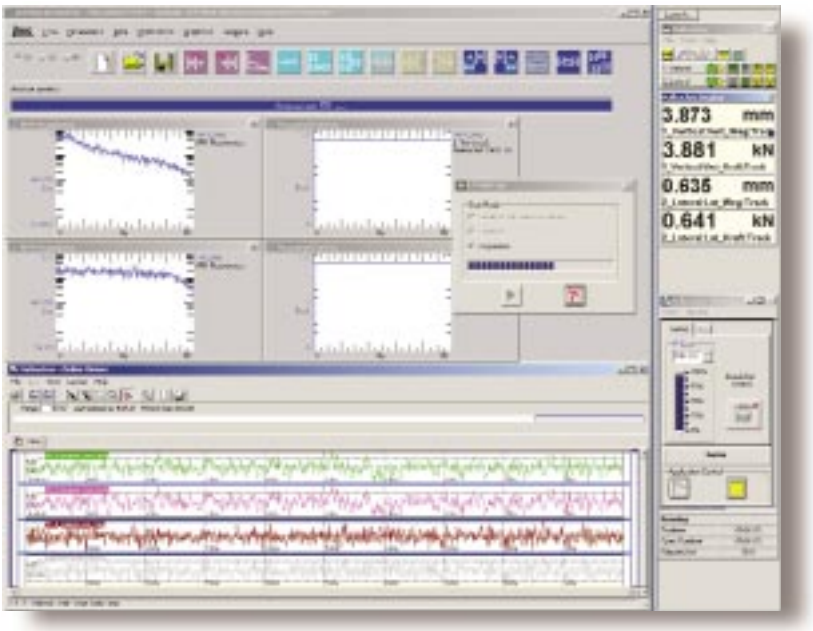
Finally, in case it is necessary to step back in the iteration process, the RS TWR database automatically retrieves all relevant data and set-up parameters.

System Identification

Proven Test Methodology

Reproducing time histories on multi-channel Hydropuls® testing facilities remains a special art in many organizations. Very often, the drive file generation process takes too long. All too often, engineering intuition and years of experience are required to gain control of the rig.

RS TWR was developed by IST and LMS with the specific objective to make drive file development possible in the shortest possible time and with maximum accuracy. The dedicated graphical user interface steps the user through the different phases of the drive file development process. In the first phase (system identification) a system model is made which models the test rig and test structure.



▲ **During multi-shaker excitation, you receive immediate feedback on time histories, statistics, FRF model and coherence functions.**

Quick and Easy Set-ups

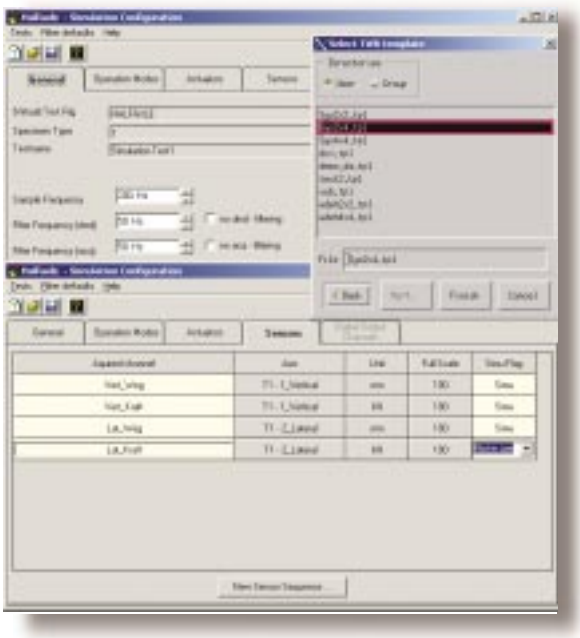
As RS TWR is fully integrated into RS LabSite®, all set-up information required for a drive file iteration process (number of control channels, channel names, number and name of actuators, sampling rate, etc.) is directly transferred to RS TWR from the RS LabSite Simulation Configuration Tool. Road surface time series and drive files are exchanged automatically, with only the iteration specific parameters still to be refined.

- Data management of .twr databases based on RS BasLab Project Manager
- RS LabSite Simulation Configuration Tool for digital transfer of set-up parameters
- Templates allow pre-configuring and saving specific test set-ups

Automated System Modeling

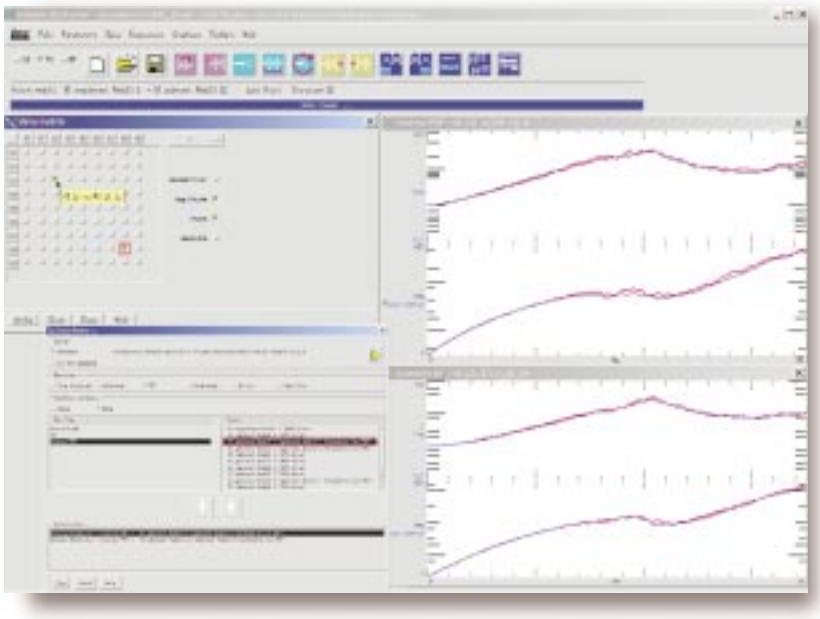
Technologies developed by LMS, such as modal system identification, have been incorporated in RS TWR, allowing quick identification of high quality frequency domain FRF models. In addition, RS TWR offers tools for automatic calculation of synthetic drive signals adapted to the road profile to be reproduced. This allows identification of more accurate models and results in a faster iteration process.

- Fast and accurate system identification with realistic excitation signals
- MIMO (multiple input-multiple output) FRF model (frequency response function model)



◄ **This acquisition set-up for an RS TWR test is defined in the RS LabSite Simulation Configuration Tool, while identification parameters are loaded from predefined user templates.**

Smarter, Deeper, More Accurate



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FRF models can easily be compared to models of predecessor tests. A dedicated viewer allows easy navigation through the different elements of the FRF matrix.

On-line Visualization of Processed Results

RS TWR is designed to allow on-line processing and visualization of results. Its tight integration with the IST Labtronic™ 8800 digital controller allows functions such as FRF, coherence, and autopower to be calculated and visualized on-line while data is being acquired on the rig. This allows immediate feedback to the test engineer on possible faulty measurements. Loose accelerometers, badly connected wheel force transducers, or broken strain gages could otherwise only be detected upon completion of the measurement and loss of valuable test time on the rig.

Inspecting System Model Quality

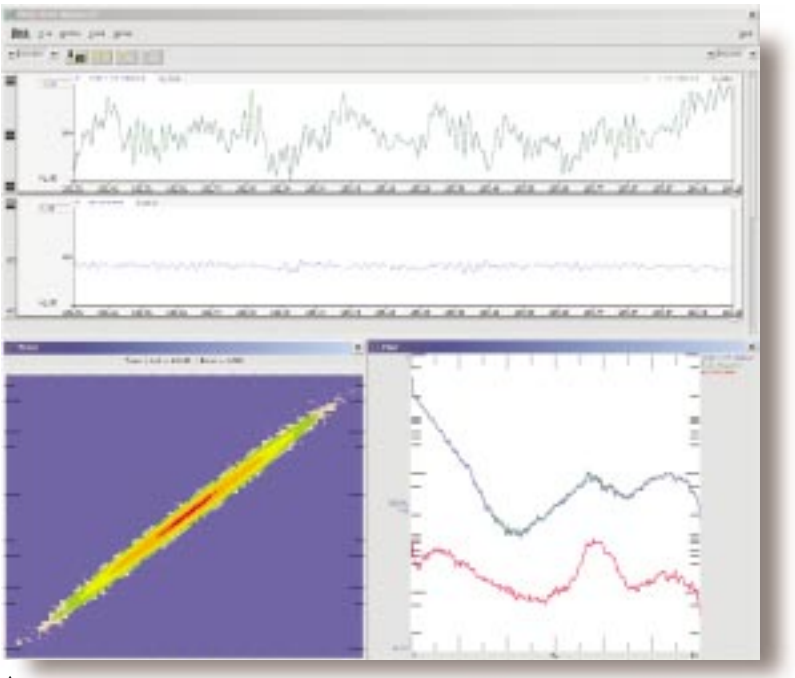
Consistently inspecting the identified FRF models before starting drive file development saves important iteration time. Problems with FRF models, which are typically detected when troubleshooting the iteration, are spotted much earlier in the process. RS TWR offers unique and easy-to-use tools for evaluating the quality of the frequency domain models.

- Multiple and partial coherence functions provide an indicator of model quality
- Prediction tools check how well the linear FRF model maps on the non-linear test structure

Mapping the FRF Model to the Proving Ground

In case the FRF system model quality tools indicate that the model is not yet of sufficient quality to start iterations, RS TWR regenerates new drive signals and acquires an additional model more adapted to the proving ground section to be simulated. Unique tools based on the obtained coherences of the two models allow selection of the better part of two models.

- Automatic recalculation of system identification drive signals allows identification of models at more realistic loading conditions
- Averaging of models based on coherence weighting allows selection of the better part of two models



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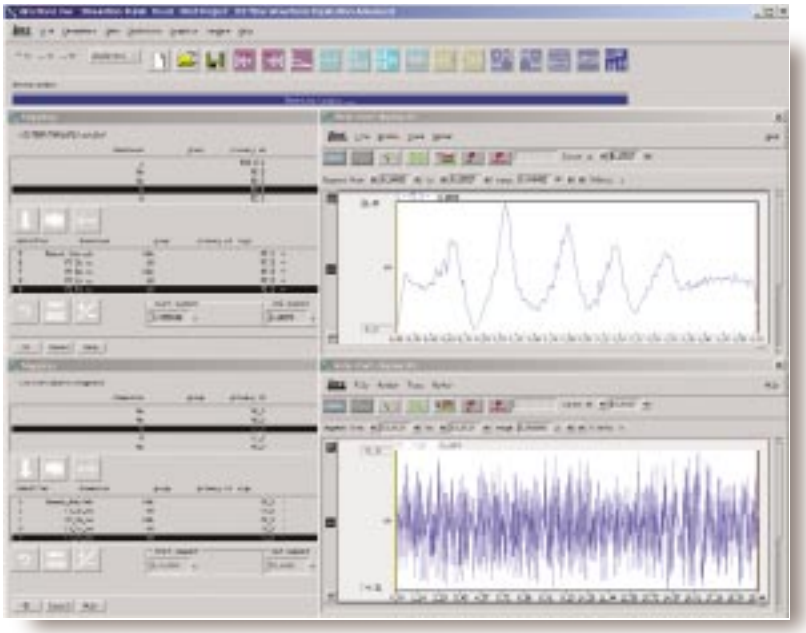
Prediction tools allow evaluation of how well the non-linear behavior of the structure under test can be represented by the linear FRF model.

Target Simulation



▲ **The iteration process is highly configurable. Iteration strategy and the model to be used are linked to each individual proving ground section.**

In the second phase - target simulation - the drive files required to reproduce given road surfaces are determined. The inverse of the FRF matrix identified in the system identification phase is combined with the road surface to be reproduced and a first prediction of the drive file is calculated. The structure is excited based on this drive file and test rig and target road surface results are compared. The resulting differences between test rig and road measurements are evaluated and the initial drive file is corrected. This iterative process can be executed step-by-step interactively or is operated fully automatically.

Iterative Drive File Generation

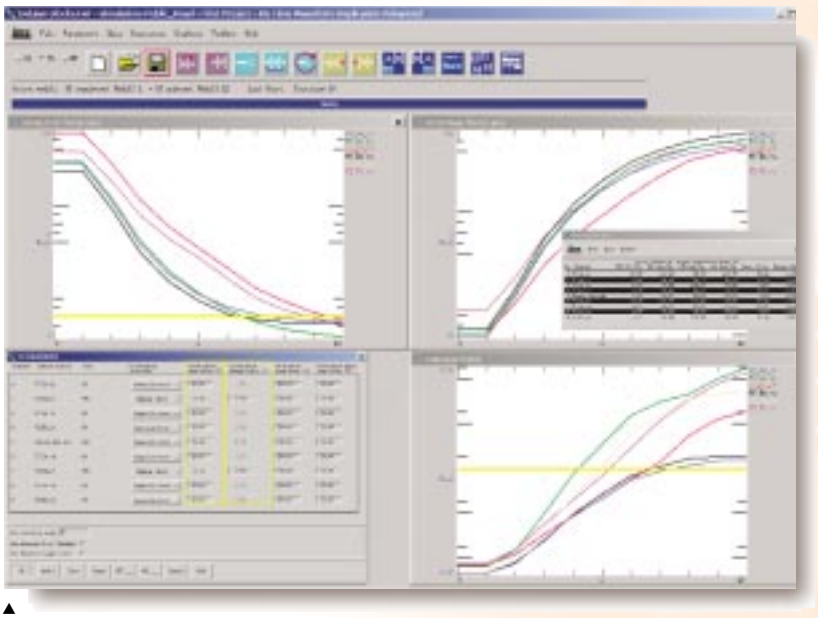
A robust matrix inversion technique using Singular Value Decomposition (SVD) makes this iteration process much easier-to-use and more robust then traditional methods. Automatic scaling allows mixing of different units such as accelerations, displacements and forces. Automatic rank reduction with the SVD technique avoids manual editing of inverse matrices. Switching from a square to a non-square configuration during the iteration process is as easy as selecting, which control channels to add. A new inverse model is calculated automatically.

- Robust matrix inversion technique based on singular value decomposition
- Non-square iteration allows control of more sensors as inputs

Advanced Control Algorithms

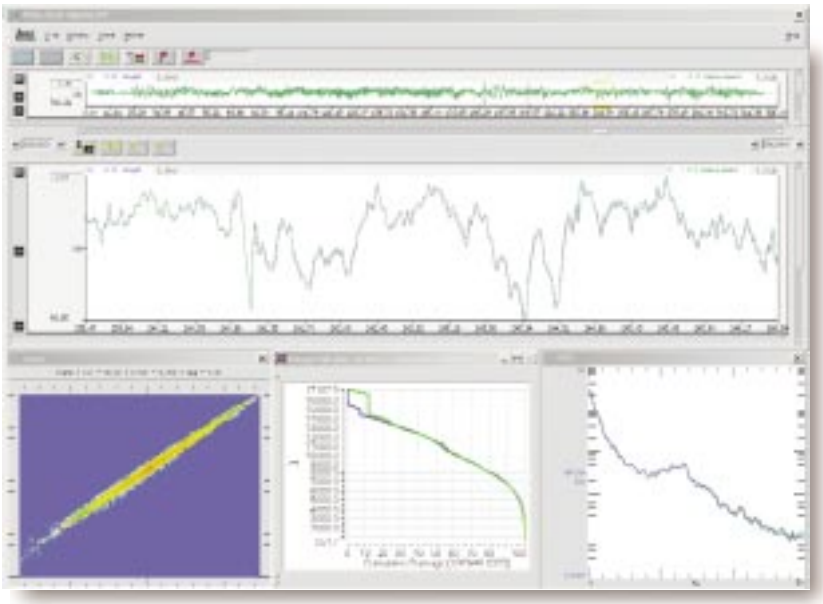
Dedicated control algorithms embedded within RS TWR allow control and testing of any structure under test. Specific tools cope with particularities related to DC-line control, others put you in full control of the iteration process by setting time and frequency dependent gains and shaker specific control bands. Adaptive modelling updates the FRF model during the iteration process.
Non-linear calibration deals with highly non-linear events and intelligently clips the drive files.

- Time and frequency dependent gains
- Adaptive modelling
- Non-linear calibration
- Multiple modes support allows combined simulation of braking and non-braking events by using two system models.



▲ **The iteration is executed interactive or fully automatic, controlled by convergence and divergence criteria, until optimal results are achieved.**

As Automated as You Want, as Flexible as You Need



▲
For every sensor measured, the simulation quality can be evaluated in time-, frequency and damage domain with one single mouse click.

Flexible Automation

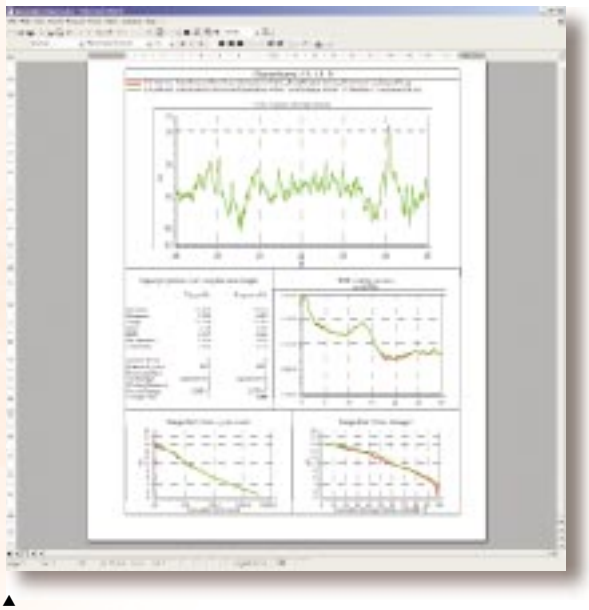
Iterative calculation of the drive files is executed step-by-step interactively, or is completely automated. If you have safety concerns, RS TWR will check the divergence on all channels and safely shutdown the rig before the test specimen is damaged.
Auto-iteration is fully customizable.
The iteration strategy is adapted depending on the road surface to be reproduced.

- Auto-iteration with built-in convergence and divergence checks based on RMS error or damage ratios
- Sequencing allows the test track to be split into different sections and a different iteration strategy applied to each one

Evaluation of Simulation Quality

Considerable time is typically spent interpreting results of a drive file development test. Often, due to physical constraints of your test rig, measured road signals cannot be perfectly reproduced on the test rig.
To evaluate simulation quality, RS TWR has built-in compact display tools for comparison of test rig and measured road data in NVH or Durability-relevant views.

- Advanced comparison functionality during iteration including display of time, frequency domain, and X-Y graph
- Damage ratios and range-pair overlays based on RS Rain allow a fatigue relevant evaluation of simulation quality



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Once simulation quality is acceptable, automated reports can be generated, based on customizable Microsoft® Word templates.

Automated Report Generation

You typically end your drive file development test by documenting results using the automated report generation tools embedded in the software. RS TWR contains a dedicated database browsing tool to select the different data entities to be further post-processed.
It seamlessly integrates with LMS TecWare Reporting/ Batch tools for automated report generation, or can export data into any format for more detailed post-processing.

- Dedicated data browsing tool for data selection
- Pre-configured reports with summary plots of time overlays, PSDs, range-pair and rainflow diagrams
- Export to LMS TecWare, LMS Test.Lab or LMS CADA-X for more detailed post-processing

State-of-the-Art Features

- Automatic handling of all set-up, model and result files with the embedded database concept - increases value-added engineering time by reducing time needed for organizing and finding data.
- Templates for definition and storage of all set-up parameters - capture test rig specific knowledge and standardize your laboratory on processes to follow.
- Process-driven user interface - toolbar guides the user through the different steps of the drive file development process.
- Simultaneous Multiple Input/ Multiple Output (MIMO) system identification in frequency domain. Automatic recalculation of system identification drive signals based on the initial Frequency Response Function (FRF) model. Tuning of FRF model during iteration based on adaptive modeling - models identified at realistic loading conditions result in a faster iteration process.
- FRF model quality evaluation tools - multiple coherence, partial coherence, forward and backward prediction. Customizable displays for easy overlay and comparison of different models. Inspect the quality of your model before starting the iteration process.
- FRF-matrix inversion technique for drive file iteration with automatic engineering units compensation and rank reduction based on Singular Value Decomposition (SVD). Intelligent drive clipping tools for faster convergence. Robust iteration process applicable to a wide range of test rigs.
- Fully automatic drive file iteration capability based on RMS error or damage ratio calculation of target response channels with simultaneous divergence checks. Automated iteration of different road surfaces based on sequencing feature. Run your test rig without requiring operator intervention - while ensuring safe operation.
- Extensive simulation quality evaluation tools including time, frequency, X-Y graph, and range-pair comparison displays. Easy-to-use 'push-button' generation of simulation quality reports, through embedded LMS TecWare reporting tools.
- Multiple modes support (for example braking and non-braking conditions) - adapted to specific needs of chassis suspension testing.

Benefits

Fast
Powerful control algorithms reduce the time required to gain control of your test rig. Work which previously took one week is now finished within one day.

Accurate
The combination of accurate models and a robust iteration process improves simulation accuracy.

Ease-of-Use
Tools provide systematic calculation of realistic system identification drives no guesswork or manual editing of inverse FRFs templates store test rig dependent iteration parameters - reduced operator knowledge is required.

Flexible Automation
Automatic iteration process - run your test rig safely, without operator interaction.

Delivers Engineering Insights
Evaluate simulation quality in Durability or NVH relevant views. Standardize your laboratory on the type of plots you want to evaluate by using the automated report generation tools.

Integrated Data Management Tools
Locate date efficiently, eliminate wasted time and confusion.

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