

# Solving vibro-acoustic challenges with the MLMM modal parameter estimator

## Solution brief

Siemens Digital Industries Software

In the ever-changing world of engineering and product development, advanced testing tools and processes have never been more essential. With digital twins on the horizon, more and more computer-aided engineering (CAE)-based simulation methods are counting on critical and accurate test data to solve long-standing engineering enigmas. Known for decades as the go-to solution for advanced testing methods, Siemens PLM Software's Simcenter™ solution continues to push the limits when it comes to testing and engineering innovation.

Interestingly enough, when looking at the challenges of modal analysis today, the main issue is not on the simulation or computing side, but rather how to organize and optimize the masses of data and the choices to be made during a modal analysis test campaign. Engineers are struggling with how to handle the high number of inputs required to properly excite a highly damped system, like a trimmed-body vehicle or the acoustic cavity of a cabin.

Until recently, most advanced modal analysis challenges still required a high degree of user interaction. Users were confronted with many choices and manual iteration loops to find an acceptable set of modal parameters to ensure a good fit with the experimental data. With all the computing power at hand, why not look into developing a more automated process?

### Challenges

- Acquire critical test data for digital twins
- Pinpoint issues and design flaws early
- Manage increasingly complex test setups and data sets

### Solutions

- Optimally adjusts all modal parameters
- Reduces differences between modally calculated and measured FRFs
- Accurately handles heavily damped structures and complex systems

### Results

- Increase accuracy by up to 15 percent
- Establish a streamlined process
- Identify optimal frequencies, damping and mode shapes

## Solution focus

The real impetus for developing a more automated process was the customer. Automotive customers who were working on acoustic modal analysis were raising concerns about obtaining real mode shapes and accurate damping estimates from huge cavity noise databases in the most optimized way. At that time, the Simcenter Testlab™ software, part of the Simcenter portfolio, could offer a solution – just not the best one. Solving this issue for the customer eventually led to the creation of the Simcenter Testlab MLMM modal parameter estimator, a new solver that iteratively identifies the parameters of a modal model. Today, it is available as an add-on that works with either Simcenter Testlab Modal Analysis or, ideally, Simcenter Testlab Polymax. It is also available on a token basis.

Working with in-house experts, a new process emerged based on a dependable and trusted tool: Simcenter Testlab Polymax. From these initial results, the Simcenter Testlab MLMM modal parameter estimator takes over to further optimize the modal parameters.

For the user, this is good news because the maximum likelihood estimation of the modal model (MLMM) process in Simcenter Testlab is not complicated at all: push a button and the solver will identify the optimal frequencies, damping ratios and mode shapes that minimize frequency response function (FRF) synthesis errors.

### The nuts and bolts of the Simcenter Testlab MLMM

As in every optimization process, a good initial solution will increase the chances of finding the optimal solution faster. For this reason, Simcenter Testlab Polymax can be used, as is standard practice today. Then, instead of manually iterating between parameter estimation and modal synthesis, the MLMM takes over. It automatically adjusts the estimated modal parameters to reduce the difference between the modally calculated and measured FRFs for all identified modes.

For heavily damped structures and complex systems such as acoustic cavities or trimmed-body analysis, MLMM can provide significantly higher quality results. While the MLMM solver searches the optimal solution, the user can keep an eye on the optimization process online, examining the cost function evolution and monitoring the convergence rate.

Because the MLMM solver starts from an existing modal model and iteratively optimizes modal parameters to maximize the fit between the measured FRFs and the synthesized ones, all the user has to do is to check the synthesis and level of modal model improvements.

The resulting synthesized FRF set can be used further to derive dynamic stiffness parameters, validate numerical models or perform assembly calculations.

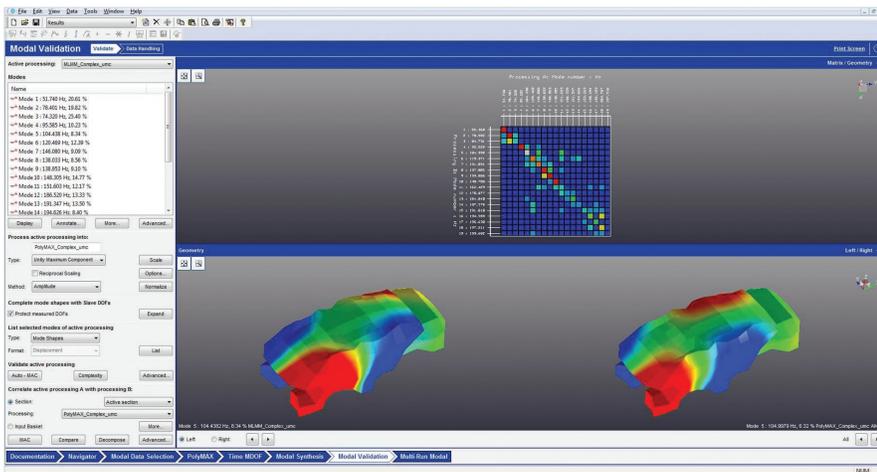
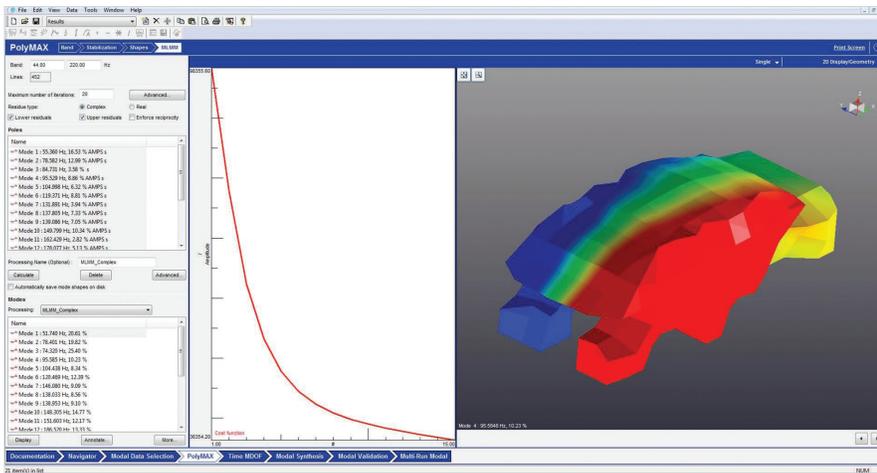
### Examples of MLMM innovation

The Simcenter Testlab MLMM modal parameter estimator is being used to perform acoustic modal analysis of interior car cavities. It can also be used to solve fully trimmed vehicle issues, such as creating reciprocal models for highly damped, complex structures.

### Acoustic modal analysis

The Simcenter Testlab MLMM modal parameter estimator is an excellent tool for advanced acoustic modal analysis. For example, interior acoustics in a car is a critical brand value for many vehicle manufacturers, and they want to know the acoustic behavior early in the design phase. Today, with reliable simulation models and advanced computer processing, predicting interior acoustic performance is much easier than it was five or 10 years ago.

Acquiring accurate and reliable testing data for this type of work is based on multiyear programs to improve modeling know-how. The only way to gain the data required to improve the simulation model is by testing existing vehicles.

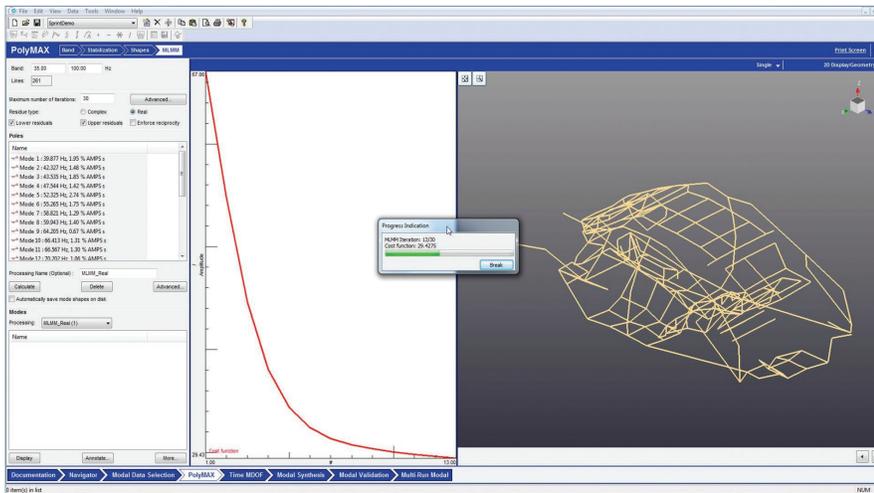
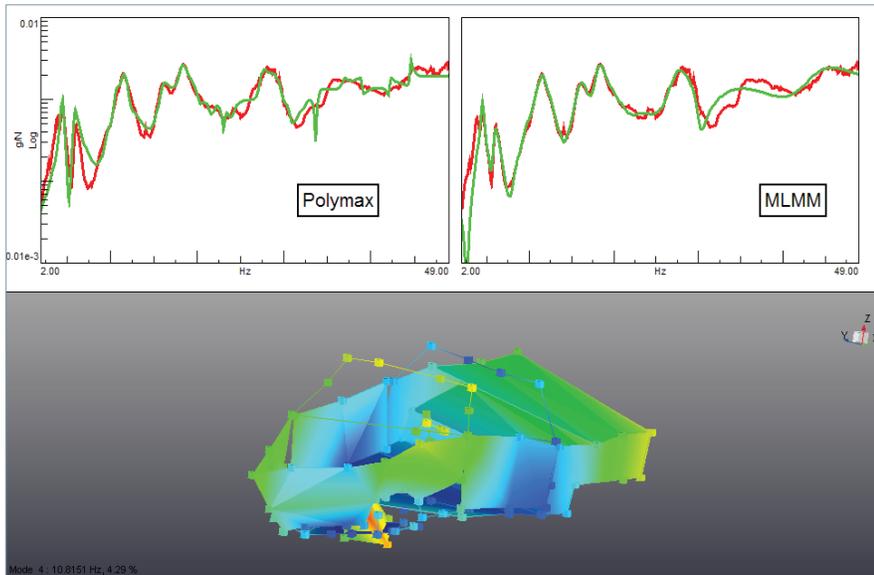


The testing data is acquired, analyzed and used to improve the simulation for future design development. A classic modal setup might include a shaker and accelerometers connected to Simcenter SCADAS™ hardware. For acoustic modal analysis, however, this classic setup might be replaced by loudspeakers or Simcenter Qsources™ hardware and microphones hooked up to Simcenter SCADAS to measure the FRFs and perform the modal analysis. With advanced hardware systems, a single test setup can result in thousands of FRFs. The Simcenter Testlab Polymax and Simcenter Testlab MLMM modal parameter estimator can be used to process and optimize this data with easily a 15 percent accuracy increase per model.

### Trimmed body modal analysis

Another challenging case in structural dynamics is the characterization of the response of a fully trimmed vehicle. Deriving an experimental dynamic model for evaluating the complete vehicle vibro-acoustic performance and predicting the effect of local modifications on the response is extremely appealing. However, the presence of damping layers, windows, seats, and full dashboard makes it challenging to reliably excite the structure and measure high-quality frequency response functions. In typical scenarios, such experiments required exciting the structure at more than 20 locations, while measuring the response with more than 100 sensors. Because of the huge amount of references required, the high modal density and the relatively high structural damping, modal analysis with standard estimators became troublesome and the modal model could not be reliably used for further calculations.

Thanks to the introduction of the Simcenter Testlab MLMM method, customers can impose more physical constraints to their modal model, such that the modes are bound to be real and reciprocal. MLMM then iterates to find the optimal modal fitting of the measured data while satisfying the constraints. The resulting modal model is more reliable when assessing the impact of local structural modification on the vehicle behavior or the deformations due to operational loads in hybrid simulation.



### Vibro-acoustic modal models

Certain acoustic modal users also include accelerometers to monitor the body structural response, resulting in vibro-acoustic modal models with both acoustic and structural data. Measuring acceleration and obtaining typical FRFs as well as the FRFs between the force and the sound pressure are examples of results. Similarly, excitation with an acoustic source generates body responses in terms of vibration. Also here, the new MLMM solver is the right tools to optimally exploit the precious test data.

### Increasing accuracy by an estimated 15 percent

Including the Simcenter Testlab MLMM modal parameter estimator, accuracy of the obtained modal model accuracy can improve by 15 percent compared to standard modal parameter estimation. In the world of digitalization, these types of mode shapes are valuable to simulation-driven digital design and development processes.

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