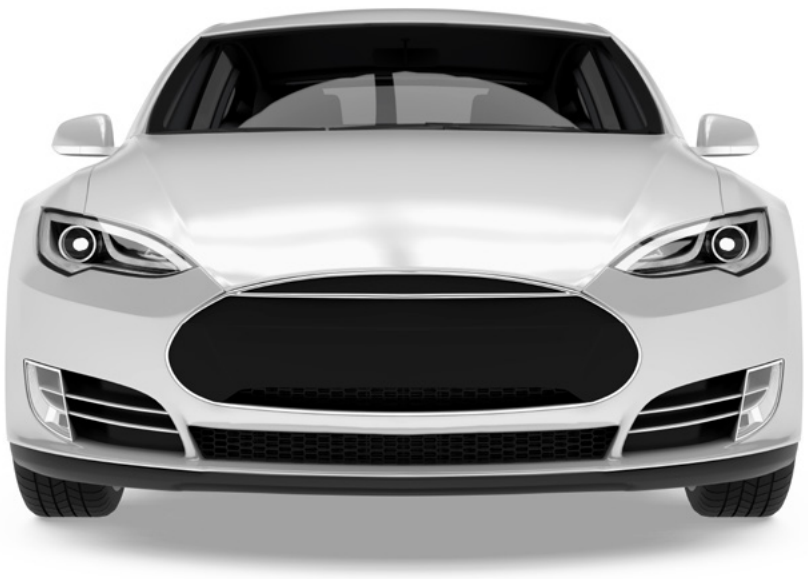
SINGLE MODEL MULTI-ATTRIBUTE ANALYSIS AND OPTIMIZATION

The analysis of a design, especially for a more complex product, system, or component, often requires building multiple simulation models. One model will be built for fatigue calculations, another for nonlinear analysis of strength, and yet another model for stiffness/noise, vibration and harshness (NVH) evaluation. Even though each model isn't always built from scratch, typically the use of different solvers for each attribute requires that models need to be converted from one solver format to another. This practice is not only time consuming but frequently error prone resulting in an inefficient use of engineering time.



Overview

Studying a design using structural optimization brings further complexity, potentially adding another software for parameterization of the problem, and possibly another product for running the optimization itself. The traditional multi-attribute analysis and optimization process is not just a burden to the engineering team but is also a significant challenge for IT as it requires management of multiple vendors and ensuring sufficient license availability throughout the development lifecycle.

A single model multi-attribute analysis and optimization workflow offers many advantages. It requires a solver capable of simulating linear, nonlinear, and fatigue problems as three different subcases of one model with the ability to optimize. An automotive subframe model is an ideal example to demonstrate this method using Altair OptiStruct™.

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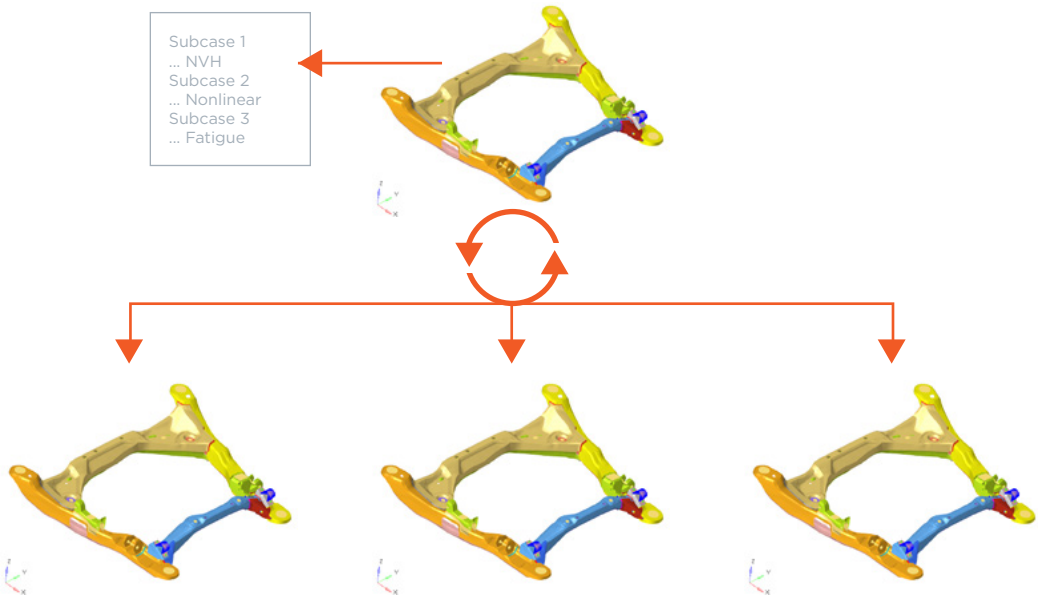
Single Model Multi-attribute Design Workflow



Linear/NVH, OptiStruct

Strength Analysis,
Nonlinear Implicit, OptiStruct

Fatigue, OptiStruct

Why Implement a Single Model Multi-attribute Method?

1 **Save Engineering Time**
Eliminate either the wasteful work of creating multiple models or the tedium of model conversion. Building separate models for stiffness, strength, and fatigue analysis is both time consuming and redundant. Using a single model, multi-attribute approach frees up engineering time for more valuable product development tasks.

2 **Reduce Modeling Errors**
Remove modeling inconsistencies between attribute models by following a single model build process. Modeling inconsistencies due to multiple model build and analysis processes such as non-uniform material definitions and different ID management schemes can be avoided by using same base model for all analysis types.

3 **Enable Process Automation**
The use of a common modeling practice can drive yet greater efficiency by making automation more straightforward. Compounding the gains of using a single model and ensuring modeling practice standardization, automation supports faster analysis loops allowing simulation to provide more timely input to the design process.

4 **Explore Iterations Faster**
A single model method offers a better way to perform design studies and assess iterations because the models are ready for optimization. It provides the freedom to explore designs without the administrative complexity of integrating and managing the multiple solvers traditionally required for multi-domain optimization.

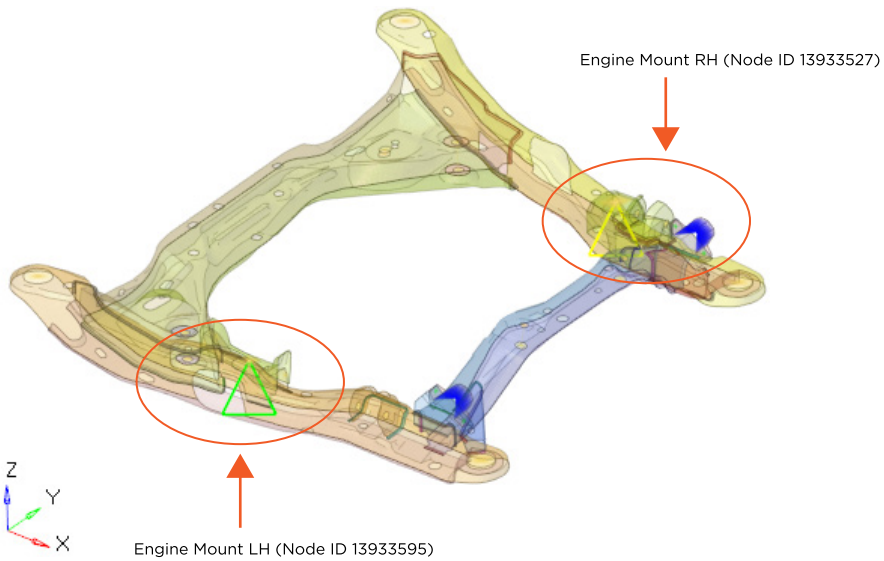
5 **Ensure Model Synchronization**
When attribute models are created independently vehicle programs struggle to synchronize design content. This can result in each attribute engineer testing different solutions to improve their specific requirements. Geometry or gauge changes, material substitutions, and integration level are difficult to manage across multiple models.

6 **Decrease Development Costs**
In addition to saving manhours and improving simulation efficiency, a single model, multi-attribute process reduces procurement costs. A pool of licenses from one vendor providing a comprehensive solver scale more efficiently than three pools from separate vendors for stiffness, strength and fatigue analysis.

Stiffness

In this example the frequency response function (FRF) at two engine mount locations was simulated using OptiStruct to understand compliance in the design. This transfer function measurement uses a unit load to excite the mount location and calculate the displacement per unit force as a measure of the stiffness of the subframe and its ability to enable low transmissibility of powertrain disturbances to the vehicle.

FRF Setup



Unit load excitation at the two engine mount locations

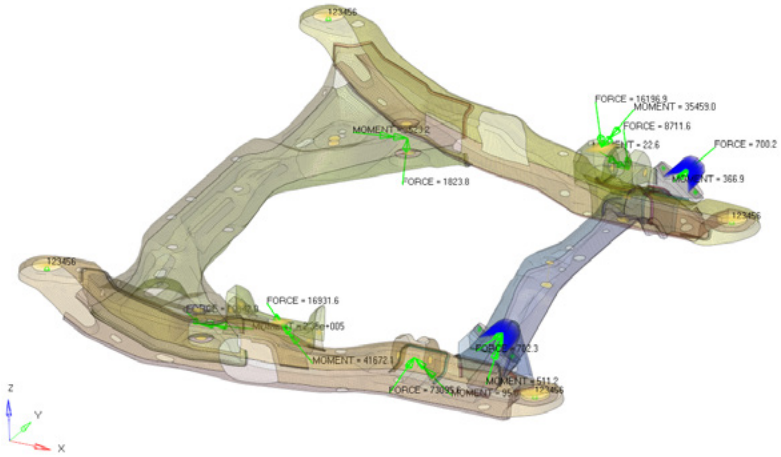
In addition to standard dynamic stiffness analysis OptiStruct includes specialty NVH and acoustics solvers. The unique capabilities and integrated specialty solvers (AMSES and FASTFR) enable efficient diagnostic analyses, from component to full vehicle.

Strength

OptiStruct provides a rapidly expanding and efficient set of nonlinear analysis features including modern, efficient contact algorithms, bolt and gasket modeling, hyperelastic material, and thermal analyses.

In this subframe model geometric and material nonlinearity are considered to enable the simulation of permanent set as a result of a pothole event. Permanent set is the amount by which a material fails to return to its original size or shape when the load is removed after being stressed beyond its elastic limit.

Strength Analysis Set-up (Permanent Set)



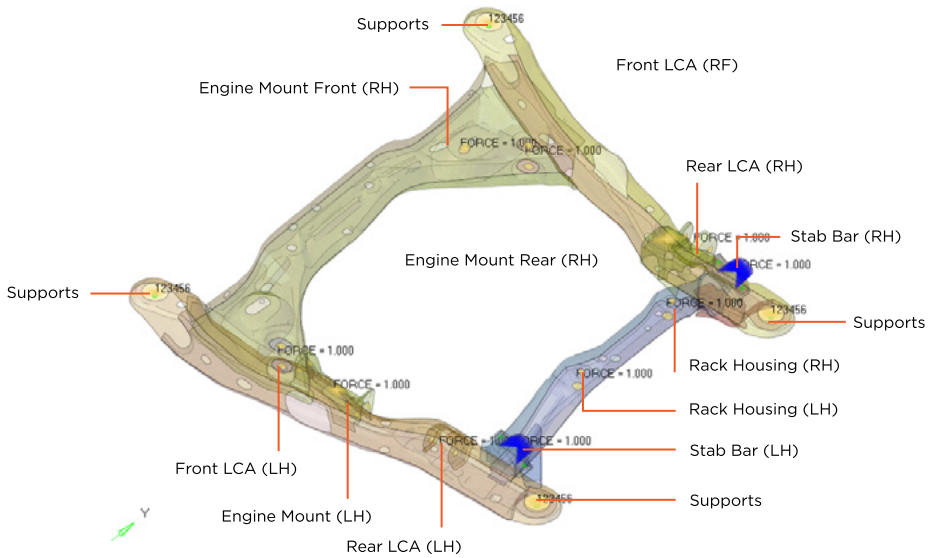
Applying loads for a pot hole event

Durability

OptiStruct provides the functionality to both perform parent material fatigue and seam or spot weld fatigue with linear superposition of multiple static load cases. It supports the stress life (S-N), strain life (E-N), and Dang Van Criterion fatigue definitions for the parent and weld material. Physical test or multi-body dynamic road load-time histories can be used for the fatigue event sequence for each subcase with native support of standard file formats.

In the subframe example, ten unit loads locations were defined in the x, y, and z directions for a total of 30 load cases. The fatigue load static subcases are associated to a load-time history, with fatigue events identifying one or more fatigue loads. The fatigue loading sequence defines combinations, scalers, and repetitions of these fatigue events. The subframe required seam weld fatigue analysis using the "Volvo" method is to calculate the hot spot stress from the nodal force at the weld line.

Fatigue Set-up (Loading Locations)



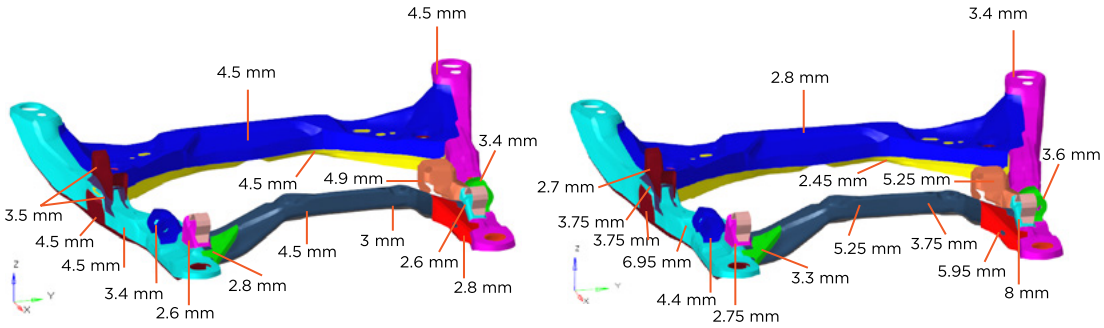
Unit loads at 10 locations in X, Y, and Z

The fatigue workflows inside Altair HyperWorks™, Altair HyperLife™, accelerate the traditionally laborious manual processes of fatigue strength assessments. Its functionality identifies and classifies weld lines across an entire structure then checks for fatigue issues throughout a structure and across multiple joint types, providing a consistent and efficient method to run a full weld line verification process.

Multi-attribute Optimization

A single model multi-attribute analysis is convenient, but when multi-domain optimization is performed the advantages of this approach are even greater. In this example, optimization uses parent material gauge as the design variables, minimizing mass as the objective, and constraints on dynamic stiffness, Neuber strain, and weld damage. The linear, nonlinear, and fatigue problems have been created as three subcases of one model and therefore don't require any of the typical pre- and post-processing complexity to link variables across multiple solvers for a multi-domain optimization.

Optimization Result



LEFT: Mass Baseline Design 46.88 Kgs. RIGHT: Mass Optimized Design 43.8 Kgs.

In this simple example the material thickness optimization achieved all performance targets while offering a weight saving. There are significant opportunities to efficiently employ other optimization features in OptiStruct to achieve a greater mass reduction including:

- Topology on the parent metal to strategically positioning lightening holes
- Topology on seam welds to reduce weld length while maintaining weld life
- Topography to add beads to the parent metal to improve stiffness
- Freeshape to place doublers for improved multi-attribute performance

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Working with Altair

Building on more than 25-years of innovation, OptiStruct is a proven, modern structural solver with comprehensive solutions for linear and nonlinear analyses across statics and dynamics, vibrations, acoustics, fatigue, and multiphysics analyses. It is used globally at industry-leading companies to drive design with optimization and validate structural performance.

Commercially introduced in 1994, OptiStruct is a first-to-market simulation technology that seamlessly integrates structural optimization and analysis. OptiStruct solves both linear and nonlinear problems using an enhanced proprietary version of NASTRAN and a modern proprietary nonlinear formulation developed and maintained by Altair.

Optistruct solutions are accurate, fast, and highly scalable on central processing units (CPUs) and graphics processing units (GPUs), ensuring the maximum return from your high-performance computing (HPC) investments including Altair's state-of-the art private cloud appliance available in both physical and virtual formats, offering unlimited use of all Altair software. Altair HyperWorks Unlimited™ addresses the unique needs of enterprises by simplifying access to an HPC infrastructure, allowing engineers and scientists to focus on their work rather than how and where their jobs are executed. Powered by Altair PBS Professional®, Altair's appliances provide users with a secure cloud-based platform (either on-premises or off-premises) to run, monitor, and manage simulations while meeting their computing needs. In addition, Microsoft and Altair offer Altair PBS Works™ on Azure for manufacturing users who need fast, easy access to HPC resources.

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