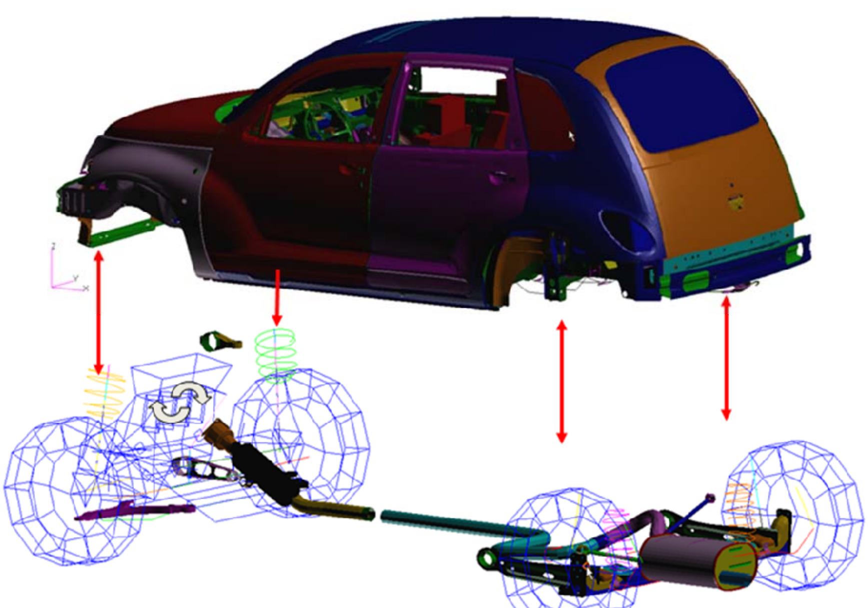
SIMULATE MORE ACCURATELY

Improving the Ability to Simulate NVH in a Vehicle

Multidiscipline Simulation playing a key role in reducing factors contributing to noise & vibration



MSC Software

Business challenges faced by automakers related to NVH MD Solutions

Background

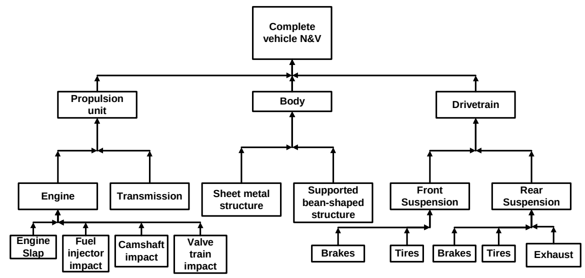
Perception of a vehicle's quality is generally tied to the vibratory and acoustic response of the vehicle. In modern luxury cars, the overall noise levels are around 60 dB (A) at/or around 100 km/h speed. Hence N&V has been a focus of the automotive industry for the past several years. Some of the challenges faced by automotive manufacturers include:

a. Maintain a brand related acoustic signature: A customer purchasing a family van may be looking for a smoother, quieter ride, while a customer looking to buy a sports car may seek a unique 'roar' while accelerating, but a softer sound during cruise.
b. Filter unwanted sounds: Road noise, wind noise and brake squeal sounds that could be uncomfortable and interfere with conversations need to be minimized. Pervasiveness of electronics like cellular phones and voice activated systems also makes it important that the conversations and voice commands do not get interfered by undesired transmitted noises in the passenger cabin.
c. Reduce vibrations: Increased vibrations are not only uncomfortable, but they can also tire a driver. They may also affect the durability of a structural component.

The field of NVH (Noise, Vibration and Harshness), also called N&V (Noise and Vibration), has gained increased importance in the past several years as engineers try to address customer requirements and sometimes contradicting design criteria. 'Noise' can be defined as the acoustic signature experienced by the occupants, while 'Vibration' studies deal tactile perception of the structural vibration by the occupants. Both perceptions play a role in a customer's impression of the ride and vehicle quality.

Business Challenges

Factors that contribute to overall N&V in a vehicle:



The primary objective of the acoustics engineer is to minimize both *structural-borne* as well as *airborne noise*. The quest to minimize unwanted sound has expanded the tools that are being used to design and improve the testing of vehicles. In general, when NVH engineers consider noise, they normally would start with a component that produces minimum noise or the one that has the most appealing sound signature. The designer is trying to strike a balance between quiet and sound signature. A component may make very little noise but it is the integrated vehicle noise that creates the perception of quality in customer's mind.
Sound engineering is a blend of science and human psychology to determine which sounds should be eliminated to create the higher quality perception. A single subsystem such as power train may perform very well in one vehicle but may not perform very well in another vehicle because the overall structure has changed.
Since optimized sub-systems do not necessarily lead to optimal performance of the full vehicle, it becomes important to test NVH performance of a completely assembled production vehicle. However, this approach has several disadvantages:

a. Cost: Running an analysis on a full vehicle can be very expensive

b. Time: Since the results would be available too late in the design and development process, it will be difficult to make modifications. If critical issues are identified, it could lead to significant changes to design and thus time to market.
c. Sub-optimal design: During the late stages of the development process, the design space shrinks and thus engineers would have to work with fewer, often sub-optimal solutions.

A vehicle's success relies significantly on its NVH performance and time-to-market is important in today's competitive markets. Hence it is crucial to use predictive modeling using CAE tools early in the design phase. MSC.Software has been a leader in providing tools to meet the NVH challenges for several years. The solutions provided by MSC are being used by the leading Automotive and Aerospace companies to solve the noise and vibration problems.

MD Solutions for NVH

MSC.Software has been providing leading technologies in the recent years to enhance the robustness and performance of NVH solutions. Some of the major developments introduced by MSC.Software in the recent past include:

a. ACMS – Automated Component Mode Synthesis for faster, parallelized modal analysis of large models. ACMS features automatic domain decomposition and modal reduction, and performs the analysis in small pieces rather than all at once. This leads to reduced memory, disk and I/O bandwidth requirements.
b. External superelements for use in assembly process – Superelements enable logical partitioning of a full-vehicle and reuse of component information helping reduce solution time.
c. Coupled Fluid-Structure Interaction for interior acoustics – Simulation of acoustics pressure inside a bounded domain. This is used to solve for sound pressure levels experienced by the occupants.
d. Coupling with exterior acoustics – This capability is used to analyze the sound field radiated by a vibrating structure in a single coupled vibro-acoustic analysis. With the use of infinite elements, the need for large meshes of the field around acoustic sources is eliminated. Efficient sparse solver is also available to solve the unsymmetric matrices encountered in exterior acoustics frequency response analysis.
e. Time NVH analysis – Used to analyze a transient event that could trigger a potentially nonlinear dynamic response. Fast Fourier Transformation is used to extract modes and frequencies that characterize the dynamic solution.
f. Brake squeal analysis – Involves prediction of dynamically unstable friction-induced modes that create noise. The objective is to optimize structural design to avoid these undesired modes and eliminate brake squeal noise.

One of the challenges in NVH analysis is identifying the path of energy flow from source to a point of interest. Also, it is very beneficial to understand the source of undesired vibration or noise well in advance of vehicle assembly. In order to address these issues and provide additional flexibility to the users, MSC.Software has introduced a new Frequency Response Function (FRF) based methodology in MD Nastran R2. This new functionality will not only help with engineer's productivity, it will also elevate the use of simulation in NVH and push its usage further into the early stages of design cycle.

FRF based NVH analysis

FRF based NVH analysis is a powerful new capability for frequency response analysis that can reveal how excitations on one component affect responses at other components in the assembly.

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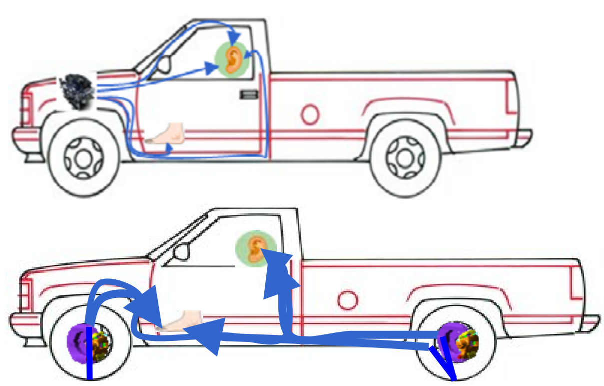
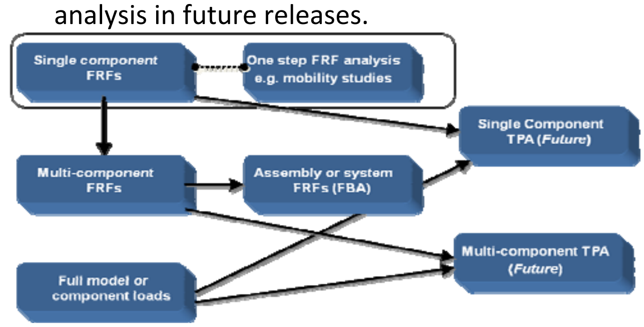
FRF represents frequency response of components due to unit loads at a given frequency. The FRFs of components can then be combined to yield the FRFs of assemblies of these components. An advantage of this approach is that it lends itself to transfer path analysis (TPA). Through transfer path analysis, users can trace the energy flow from source to receiver. This allows identification of critical paths and noise sources. For instance, on the picture in the left, it shows that the source of noise is engine and on the right the noise source is the coming due to tire loads.   Thus, to perform NVH, it is necessary that the design engineer does a full body analysis and *MD Nastran provides the desired scalability with its superior solvers*.



FRF based approach used to analyze engine and tire loads

A complete vehicle system generally consists of several sub-systems or components. However, only a few parameters of specific components are changed during the design cycle. So, doing a complete dynamic analysis on the entire system multiple times may not be the best way to use the computer resources. MD Nastran allows reuse of frequency response information obtained from a component analysis. In fact, it offers multiple ways to conduct frequency response studies based on user needs.

1. Single component analysis – needed when it is being studies or optimized to meet target response
2. The FRFs can be computed for multiple components simultaneously.
3. The FRFs computed can then be assembled to obtain a system FRF (FRF based assembly) by specifying appropriate connectors between the different components
4. The FRFs of the entire system can also be computed in a single step without going through prior component FRF calculation
5. Computation of the frequency response for each of the component and/or system will also enable calculation of transfer path analysis in future releases.

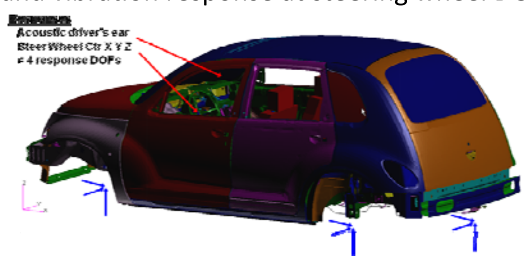


The FRF approach provides several advantages. Other than being an alternative to current technologies generally used in FEA codes, it is an efficient method for dynamic response studies. Since the component information (both the modal results and frequency response) can be reused, it will provide significant resource savings, especially for large models and assemblies. The technique also lends itself to transfer path analysis and enables users to do a complete NVH analysis in virtual environment, which will be the focus of further enhancements in MD Nastran.

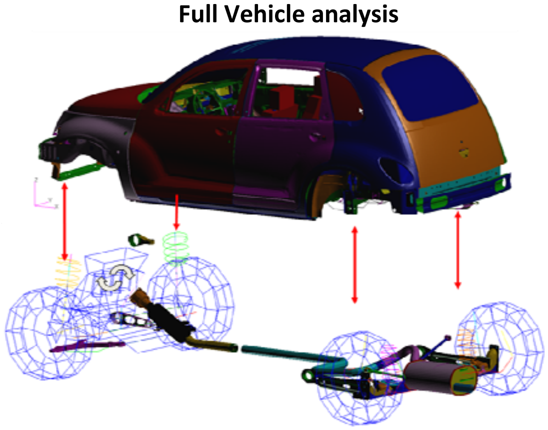
This capability has been further enhanced in MD Nastran R3 to improve its usefulness. By making components names (along with IDs) identification markers of components, it makes it easier for users to identify the appropriate components. In MD R2, the user loads specified were limited to unit loads. Hence the responses obtained were always limited to that of unit loads. In the current version, this limitation has been removed. The user may wish to apply nonunit loads and get the response as desired. This will save time by eliminating the need to scale the responses based on user loads.

The connections between the various components play a crucial role in determining system response. These connectors have been enhanced to provide more flexibility in the choice of connectors. In addition to rigid connections available in R2, R3 supports flexible connections and grounded connections. Also, the connectors can be released at specific DOFs. This enables analysts to run various design studies much more easily.

Here is an example of a full vehicle analysis that takes into account ***N&V effects*** from ***propulsion unit, body and drivetrai*n**. The responses being studied are the acoustic response at driver's ear and vibration response at steering wheel DOFs.

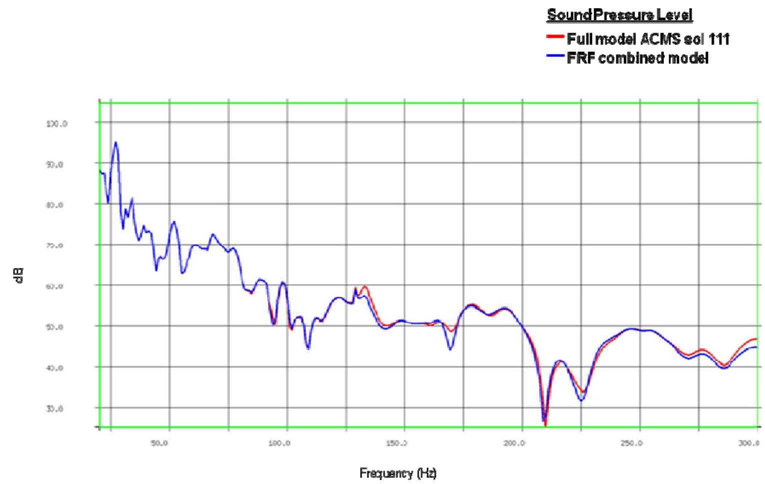


Full Vehicle analysis



Connectors are specified between the trim body and the suspension at 4 locations

The plot shows the sound pressure level (SPL) at driver ear at various frequencies. The results are compared with well established ACMS method. The results show high correlation between MD Nastran results and ACMS method.



The following figure shows the acoustic response analysis of radiated sound (exterior acoustics). The study allows auto manufacturers calculate the sound pressure generated by passing vehicle. This reduces the expenses of using a semi-anechoic chamber to obtain the required data. With the use of infinite elements, MD Nastran also reduces the computational expense and improves the results by modeling the field around the noise source more accurately. Unlike in a test environment, there is no limit to the response points where the output can be obtained.

Conclusion:

The NVH analysis capabilities of MD Nastran continue MSC's tradition of providing leading technologies in simulation and enabling cost-saving, productivity increasing enhancements. With the new developments in MD Nastran, engineers can more confidently address NVH related questions, before the physical testing of a full-vehicle prototype. *Optimization of the designs becomes easier and the engineers can search a broader design envelope for better solutions*. With the ability to integrate test data with FEA, MD Nastran takes advantage of existing information and improves the accuracy of the results.