A SUCCESS STORY

CDH/AMLS and CDH/FastFRS help Mercedes-Benz perform gear whine simulation in a system approach using NX NASTRAN.

OVERVIEW

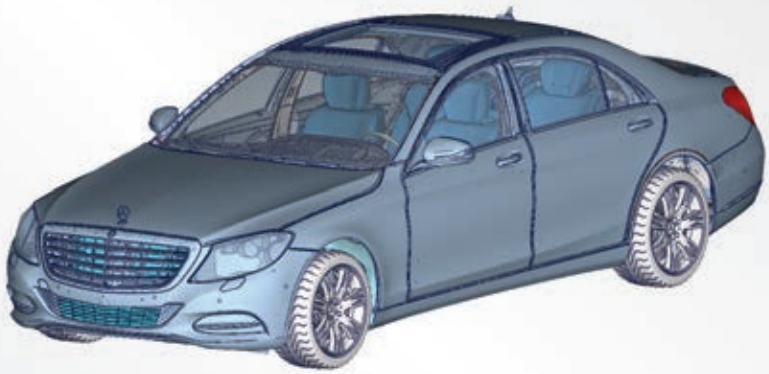
Using a combination of CDH/AMLS and CDH/FastFRS the engineers at Mercedes-Benz passenger car development group are able to carry out particularly challenging analyses of differential gear whine using a systems approach. Simulation provides more detailed insight into the problems of design than is possible through testing.

BACKGROUND

The extensive use of lightweight materials, new hybrid and electric drive systems combined with increasing customer awareness are driving the requirements for improved vibration comfort in the development of modern passenger vehicles.

Mercedes-Benz is committed to offer maximum comfort to customers. This goal is achieved at the design stage using computer-based full vehicle comfort simulation.

With the assistance of CDH/AMLS and CDH/FastFRS software solutions, Mercedes-Benz has dramatically reduced the time required to perform complex NVH full vehicle simulations, including the analysis of gear whine noise.



KEY HIGHLIGHTS

Industry
Automotive

CDH Solution
AMLS/FastFRS

Challenge
Reduction of gear whine noise to improve passenger comfort

Benefits
- Efficient higher frequency gear whine noise analysis in full vehicle environment feasible
- Drastic reduction of analysis time and disc space requirements
- Improve passenger comfort
- Speed up development time

THE CHALLENGE

Importance of reducing gear whine noise for passenger comfort

The meshing of gear teeth induces vibration excitation and emitted noise. In modern cars, for which the overall noise levels have been significantly reduced in recent years, noise sources such as gear whine have become more important. Furthermore, gear noise, with its relatively pure sinusoidal sound, is particularly annoying to the human ear.

For Mercedes-Benz, such noise emission is unacceptable. For these reasons, a great deal of engineering effort must be invested to achieve the desired noise quality. This effort must be repeated for each engine and driveline configuration and for both two-wheel and four-wheel drives.

Testing in connection with gear whine phenomena is difficult. This is related to the fact that rotating parts are involved and the accessibility of the shafts is often limited. It is thus extremely useful to perform computer-based simulation to identify configurations with high risk of unwanted noise levels and to propose potential solutions before the first hardware tests can be performed.

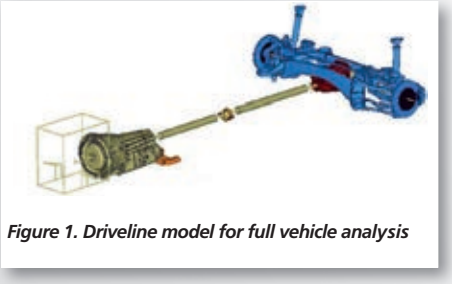


Figure 1. Driveline model for full vehicle analysis

SOLUTION

Perform gear whine noise analysis using a systems approach utilizing CDH/AMLS and CDH/FastFRS

A systems approach requires a very detailed finite element model and the analytical tools necessary to perform analysis to the frequency required.
The typical model size of the full vehicle model used at Mercedes is in the tens of million degrees of freedom range. The frequency range of the noise phenomenon is from 400 to 900 Hz.

Attempting to solve a problem of this size directly would not be successful. The solution of a single frequency step requires, on current hardware, between 2 and 4 hours. To address the full frequency range of interest for a 5 Hz interval would require several weeks of computation.
At first glance, a modal reduction approach does not look much more promising. Using classical methods for eigenvalue solutions together with modal reduction would be prohibitively expensive for a problem of this scale with tens of thousands of modes.

However, using CDH/AMLS for the eigenvalue calculation makes it possible to complete the calculation in less than two hours. The structural part of the coupled problem typically contains 30 000 modes and the fluid part some 3000 modes. The interesting question, then, is how to solve the resulting modal frequency response problem, as this means solving a fully populated coupled system with 33000 modal degrees of freedom?

The classical Gaussian elimination would require around 15 minutes per frequency step. This would give a turnaround time for the 5 Hz frequency increment of 25 hours. This would be feasible, but very inconvenient. Using CDH/FastFRS the turnaround time for 300 frequency steps is around 15 minutes. Further, the required analysis time is largely insensitive to the number of frequency steps.

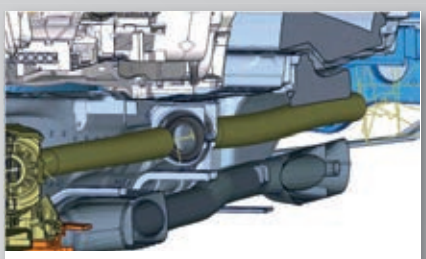


Figure 2. Higher frequency analysis requires detailed modeling

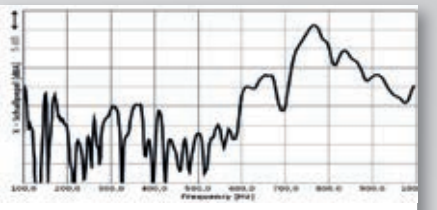


Figure 3: Typical frequency range for gear whine (400-900 Hz)

BENEFITS

CDH/AMLS and CDH/FastFRS enable users to perform most complex NVH analyses efficiently

The combination of CDH/AMLS and CDH/FastFRS allows the engineer at the Mercedes-Benz passenger car development group to solve the challenging load case of differential gear whine using an analytical systems approach. This allows for a more detailed insight into the engineering problem as the limits of measurement are removed. Furthermore, the tedious data transfer requirement when applying measured or externally calculated forces to a standalone FE trimmed body model is completely avoided.

This novel integrated system approach allows for a thorough assessment of rear differential gear whine long before the first hardware is available. Simulation provides a clear understanding of the complex coupling of torsional and bending effects along the driveline and allows trade off studies between candidate design solutions. The total analysis turnaround time of less than 5 hours means that even numerical optimization procedures become feasible. CDH/AMLS and CDH/FastFRS provide the engineer with the powerful tools to tackle the problem of rear differential gear whine with an integrated approach.

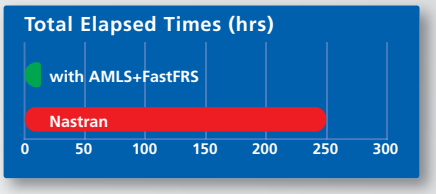


Figure 4. Total elapsed computational time in hours

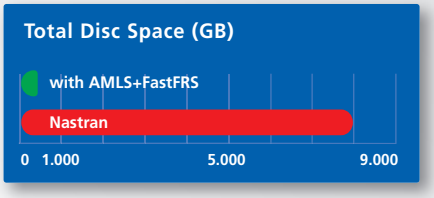


Figure 5. Total disc space requirements (GB)

For more information on CDH/AMLS and CDH/FastFRS, please visit www.cdh-ag.com:

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