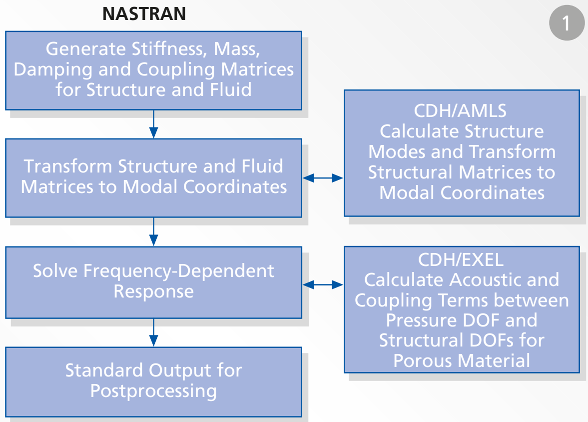
EXEL

Analysis of Porous Absorption Materials

1. CDH/EXEL-The Analysis Tool for Vehicle Acoustic Response

Efficient sound insulation is a key factor in the design of modern high-quality vehicles. However, owing to their complexity, acoustic treatments are usually ignored in the standard computer-based noise and vibration virtual design processes for vehicle body structures.
The desire to model the important effects of the acoustic trim is motivated by the requirement to design an efficient lightweight acoustic package in the early stages of a virtual design process.
CDH/EXEL is a new analysis tool for NASTRAN vehicle finite element models containing sound absorbing trim materials such as carpets, and foam-filled ceiling headliners. CDH/EXEL has been designed to facilitate low- and mid- frequency acoustic response analysis of NASTRAN models. With CDH/EXEL the results of vehicle acoustic analysis are more accurate, leading to more effective simulation-based design decisions.



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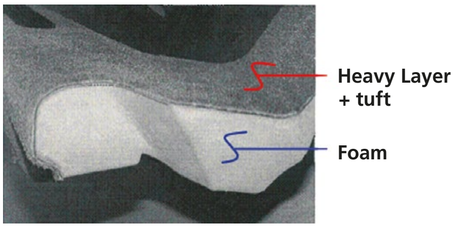
2. Acoustic Trim and Porous Materials

As shown in Figure 2, almost all acoustic treatments comprise several layers of poro-elastic foam, felt or a "heavy layer" of visco-elastic material.
The basic mathematical modeling of poro-elastic trim materials involves complex interactions between mechanical and fluid components. Trim materials also exhibit frequency-dependent characteristics that are important, even at relatively low frequencies.
CDH has recently completed an intensive development project to create new finite elements for the analysis of porous materials. This development, carried out in cooperation with Professor Peter Göransson, an internationally recognized expert in the development of finite elements for porous material modeling, has resulted in a new NASTRAN-based procedure known as CDH/EXEL.



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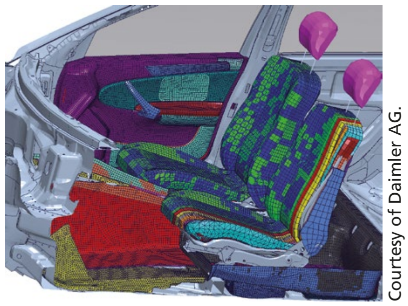
3. Overview of CDH/EXEL Analysis

The data flow for the CDH/EXEL procedure is shown in Figure 1. Standard NASTRAN elements and meshing procedures are used to model the structure, the acoustic cavity and the acoustic trim.
During the NASTRAN run, CDH/EXEL external programs are automatically invoked to augment the standard NASTRAN solid element matrices used for the trim with additional poro-elastic coupling terms that model the mechanical behavior of the trim porous materials.
The correct assembly of the matrices for structure, air and porous materials, as well as efficient frequency dependent analysis is automatically carried out by the CDH/EXEL software.



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4. Familiar NASTRAN User Interface

The CDH/EXEL approach is very intuitive to the NASTRAN user, since all trim materials are modeled by standard NASTRAN elements. In addition to any frequency-dependent material properties for the structural trim elements, the user must provide the special poro-elastic material properties. This data is required by CDH/EXEL to generate the correct coupling terms. The definition of finite element models with porous trim for calculations in the mid-frequency range requires the following steps:

- Identify the porous material elements (must be solid elements: CHEXA, CPENTA, CTETRA) and specify the porous material properties (MAT9).
- Specify any frequency-dependent structural material properties for the porous material (MATTi; TABLEMi).
- Couple the porous material mesh to the structure and fluid meshes.

For example, the MAT9 entry contains the porous material properties:

MAT9	MID	IUNIT	OUNIT	RHo	Por	Sigma	Tort	Lm
	Lmp	Omemax	Cpbase	Rgas	Mp	TempMu	Gamma	
	Pr	Pform	Porty					

MID: Material identification number • **IUNIT:** Units used for input (<0 for MK, 0 for MMT, >0 for MMKF)
OUNIT: Units used for output (<0 for MK, 0 for MMT, >0 for MMKF)
RHo: Ambient density of fluid ([kg/m3]; for [T/mm3] (1e-12)) • **Por:** Porosity of material
Sigma: Air flow resistivity ([N s/m4]; for [N s/mm4] (1e-12)) • **Tort:** Tortuosity • **Lm:** Viscous characteristic length ([m]; for [mm] (1e3))
Lmp: Thermal characteristic length ([m]; for [mm] (1e3)) • **Omemax:** Highest excitation frequency ([Hz])
Cpbase: Speed of sound in porous material (def=50, [m/s]; for [mm/s] (1e3))
Rgas: Specific gas constant (def=286.7, [N m/(kg K)]; for [N mm /(T K)] (1e6)) • **Mp:** Thermal form factor (def= 0.25)
Temp: Ambient temperature (def= 20 [deg C]) • **Mu:** Dynamic viscosity (def=1.8e-5, [N s/m2]; for [N s/mm2] (1e-6))
Gamma: Ratio of specific heats (def= 1.4) • **Pr:** Prandtl's number (def= 0.71)

Typical trim material cross-sections and configurations are shown in **Figures 4 & 5.** The vehicle body structure is modeled as usual with standard NASTRAN shell elements.
The foam or felt is modeled using solid elements and the "heavy layer" can be modeled either with shell or solid elements, depending on the actual thickness and physical behavior. Typical response quantities of interest such as the pressure in the acoustic cavity, radiated power, surface velocities etc. can be obtained via standard NASTRAN output.

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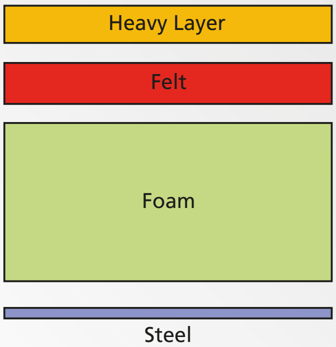

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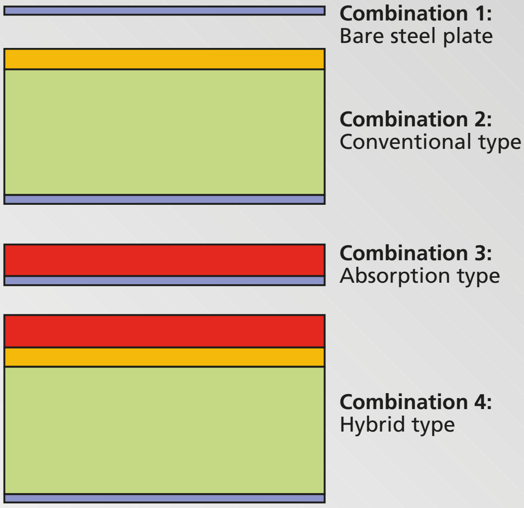
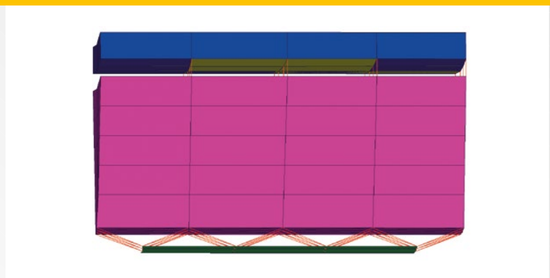


5. CDH/CONNECT Utility Program

The CDH/CONNECT is a utility program supplied with the CDH/EXEL software. This utility supports the user by automatically connecting the porous material mesh to the structure and fluid meshes.
Given the structural model data and a definition file of trim GRID data, a set of multi-point constraints in the form of RBE3 data is created to represent the required connec-tions as shown in Figure 6. The user can also allocate spe-cific degrees of freedom for the dependent and independent GRIDs of the RBE3 constraint.



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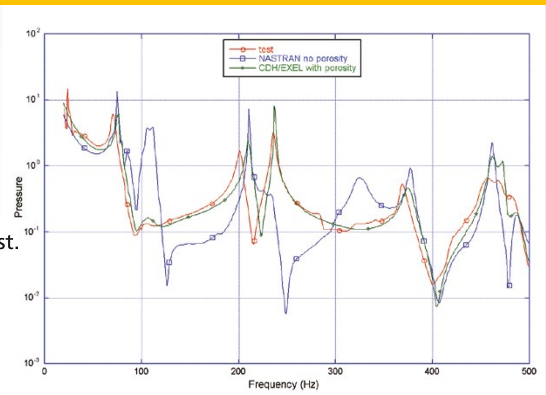
6. CDH/EXEL Verified Accuracy

Numerous tests have verified the importance of including the effects of trim in calculations for acoustic responses.
Figure 7 shows acoustic response FRF results for a representative structure calculated with and without the effects of porous trim. The results of actual tests are also shown in the figure.
The results demonstrate that even at relatively low frequencies, the effects of trim can have an important effect on the accuracy of results and improve correlation with test.



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7. Summary of CDH/EXEL Advantages

- CDH/EXEL is an extension to NASTRAN to perform modeling and analysis of acoustic trim and porous materials.
- CDH/EXEL supports existing FEM Trimmed Body or Full Vehicle models for standard NASTRAN analysis.
- CDH/EXEL utilizes standard solid or shell elements for acoustic trim and porous material representation in the NASTRAN FEM model.
- CDH/EXEL allows prediction of acoustic trim effects and extends vehicle body analysis using NASTRAN into the mid-frequency range.
- CDH/EXEL seamlessly integrates into clients NASTRAN analysis process.
- CDH/EXEL enables advanced NVH analysis with existing FEM models in a familiar NASTRAN environment.

8. System Requirements

Software:
- MSC.Nastran 2008 or later
- NX NASTRAN Version 6 or newer

Hardware:
- IBM (AIX)
- Red Hat or Suse Linux64 (x86_64)

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