Acoustic Analysis with Simpack and wave6

North American Multibody Simulation User Meeting

Brad Heers, Phil Shorter
Why SIMULIA for noise and vibration simulation?

**SOURCES**

- **Simpack**
  - multibody dynamics
  - accurate modeling of high frequency content of powertrain sources
- **CST**
  - electromagnetics
  - accurate modeling of emag sources in electric machines/vehicles
- **xflow**
  - unsteady CFD
  - accurate and fast modeling of aerodynamic sources in flow noise

**PATHS**

- **Abaqus**
  - Explicit and Implicit Finite Elements
  - Best-in-class solvers and materials
- **Wave6**
  - Vibro-acoustics and flow noise
  - Full spectrum analysis methods

**SIMULIA has best in class tools for modeling both the sources and the transmission of noise and vibration**
Vibration ("Noise") at the Vehicle Level

- "1D" System Approach
- "FE Approach"
- "Multi-Body Approach"
Critical Assumptions in (Noise and) Vibration

- “In-situ” conditions
- Sources (internal, external, etc.)
- Joints, bushings, etc
- Damping
- Accurately capturing system stiffness and mass
  - “Substructures”, “FE-bodies”, “flex bodies”, etc.
- Scalability to large systems and frequency ranges
Traditional 1D Approach

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Traditional FE approach

► “In-situ” conditions
► Sources (internal, external, etc.)
► Joints, bushings, etc
► Damping
► Accurately capturing system stiffness and mass
  ▶ “Substructures”, “FE-bodies”, “flex bodies”, etc.
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Traditional Multi-Body Approach

- “In-situ” conditions  
- Sources (internal, external, etc.)  
- Joints, bushings, etc  
- Damping  
- Accurately capturing system stiffness and mass  
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- Scalability to large systems and frequency ranges
Simpack’s Advantages over “Traditional” MBD…

➤ Less numerical damping
  ➤ “Better damping”
  ➤ More accurate source paths through joints, etc.

➤ Powerful linearization and frequency response capabilities
  ➤ Allows “in-situ” with frequency-based responses
    ➤ Considerable investment in this approach over last two development cycles

➤ Large degree-of-freedom flexible bodies and integration into FE codes
  ➤ Including Abaqus
Simpack Approach (with integrated technologies)

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Flexbody: a variety of options (Abaqus-Simpack)

**Small deformation**
- Increased efficiency for NVH and acoustics
- Substructuring for fluid structure coupling in Simpack
- Flex. body preparation on 3DX platform

**Large deformation – reduced**
- Research project has been finished
- Project work to study accuracy/efficiency
- Discover synergies with surrogate modeling and machine learning to increase robustness
- Release date: TBD

**Large deformation – detailed**
- Co-simulation Simpack & Abaqus/XPL
  - speed-up by factor 3
- Co-simulation Simpack & Abaqus/STD
- Generic Interface to couple any flex. body physics with Simpack through a flex. body user routine
Combining SIMULIA Products & Technologies

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multibody dynamics
accurate modeling of high frequency content of powertrain sources

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**wave6**
vibro-acoustics and flow noise
full spectrum analysis methods
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wave6
vibro-acoustics and flow noise full spectrum analysis methods
Combining SIMULIA Products & Technologies

**Simpack**
- multibody dynamics
- Powertrain Sources
- Chassis sources and paths

**Abaqus**
- Substructures used to generate flexible bodies
- Recovery matrices directly within Simpack

**wave6**
- vibro-acoustics and flow noise full spectrum analysis methods
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What is wave6?

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**wave6**

- Vibro-acoustics and flow noise
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we have released a new standalone product called “wave6” for accurate simulation of noise and vibration (including flow induced noise and vibration) across a broad frequency range

wave6 accurately models wave propagation in structures, fluids, foams and fibers … across the audible frequency range (120 dB = 1e6)
wave6: vibro-acoustic analysis methods

<table>
<thead>
<tr>
<th>Low frequency (deterministic)</th>
<th>Mid frequency (mixed)</th>
<th>High frequency (statistical)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finite Element (FE) structure</td>
<td>Finite Element (FE) acoustics</td>
<td>Boundary Element (BEM) and APML infinite acoustic fluids</td>
</tr>
<tr>
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<td>Porous (Foam) Finite Elements (PEM)</td>
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<td>Statistical Energy Analysis (SEA) structure</td>
<td>Statistical Energy Analysis (SEA) cavities</td>
</tr>
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<td>Poroelastic (Foam) infinite acoustic fluids</td>
<td>Poroelastic (Foam) noise control treatments</td>
<td></td>
</tr>
</tbody>
</table>

wave6 contains all of the main vibro-acoustic methods in a single environment with a single license feature (a “power session” license is also available for solving on unlimited hardware)

Methods can be combined together in the same model for more accurate predictions
Example applications

Aero-vibro-acoustics (FE+BEM+SEA+CFD)
- Side mirror interior “wind noise”

Vibro-Acoustics (FE + BEM)
- HVAC and muffler “shell noise”

Vibro-Acoustics (SEA)
- Sound package design

Aero-Acoustics (FE + BEM + CFD)
- Hydro-acoustics (“installation effects”)

Vibro-Acoustics (BEM)
- Exterior diffraction (“pass-by noise”)

Vibro-Acoustics (SEA)
- Aircraft/launch vehicle interior noise
Aerodynamic side mirror interior “windnoise” : Daimler

Large fully coupled FE/BEM models: NASA and Lockheed Martin

I. Dandaroy “Analytical Tool for Numerically Simulating a Direct Field Acoustic Test” Proc. SCLV 2017

Orion test article

DFA test speaker stacks

wave6 FE/BEM model

Each speaker box modeled w/ simple acoustic source (monopole)

Floor effects modeled

Orion Test Article

BEM

Image credit: NASA

Image credit: NASA
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Simple example to demonstrate the combined use of Simpack and wave6
Example: noise from a rotating shaft

**Analysis process**

- **Simpack**  
  flexible bodies with modes
  - Mode shapes
  - Modal amplitudes

- **wave6**  
  acoustic radiation using FE/BEM model
  - Automated workflow

SPL(rpm, freq, xyz)
Modal contributions to SPL (and SPL vs rpm/freq)

- Modes
- Mode 4: SPL@2kHz
- Frequency

![Frequency vs RPM graph with SPL sound pressure level (dB re: 2.00000e-5 Pa)]
Summary

• SIMULIA can help you model both the sources and transmission of N&V
• wave6 = next generation software for “full spectrum” vibro-acoustics
• includes automated “templated/pipelined” workflows
• Makes it easy to predict radiated sound from a SIMPACK model
• (you don’t have to be an acoustics expert to predict/diagnose SPL)
• Simple shaft example created to demonstrate the process
• Combines SIMPACK + ABAQUS + wave6
• Contact us for more information