

# Evaluation of Interior Noise Based on Loads from a Multi Body Simulation

## An Integrated BETA Suite Solution for Addressing Non-Linear Mounts

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physics on screen



#### Background

- Ride comfort and NVH performance are important criteria for any car development process
- Classical NVH analysis uses linear FE models and linear calculation algorithms. However, important structural parts of a vehicle chassis have non-linear properties.
- MultiBody Dynamics (MBD) analysis is a method to calculate the dynamics of complex systems, like a car in driving conditions, including non-linear effects
- We are offering a process inside the BETA suit that combines MBD in ANSA Kinetics with linear NVH calculations on a Trimmed Body



## **Detailed Process Description**

physics on screen



## Step 1: General Model Preparation

#### Structural Components

- Flexible Components (TB)
- Rigid Bodies for MBD

Acoustic Cavity with ANSA Cavity mesh tool





- 1. Provision of all required components (including acoustic cavity)
- 2. Preparation of TB for linear solver, e.g.
  - Connections

x x

- Trim masses
- Properties/Materials
- Preparation of Subframes, Powertrain, Engine, Radiator for MBD solver:
  - Masses, Inertias
- 4. Preparation of cavity mesh





- Definition of interface
   points
  - Common position in linear model and MBD model
  - Field 10 names for NVH-Console and grid ID scheme for force table definition
- Divide ANSA data base into
  - TB for linear calculation
  - Rigid Body components for MBD

#### Step 2: NVH Model Preparation – Display Model

750K grids

8



- 60K elements ٠
- 60K grids (subset of Full ٠ FE grids)



- Preparation of model from data base I in ANSA **NVH-Console**
- NVH-C model consists of one component (TB with cavity)
- NVH-C Step I: Creation of Display Model in NVH-C as model reduction technique

Display Model in NVH-C is Key Enabler for Manageable File Size of Modal Base





- NVH-C Step II: Creation of reduced rep. of Fluid Structure Interaction (FSI)
- NVH-C Step III: Preparation of SOL103 decks for of calculation of modes:
  - Cut-off 250Hz
  - With Resvec
- NVH-C Step IV: Solving SOL103 decks with Epilysis/AMLS

#### Step 2: Global Modes Analysis





- NVH-Console: Easy set up of dynamic load cases to excite global
  - Lateral modes
  - Torsional modes
  - Vertical modes
- Response curves, calculated from modal base, show the resonance frequencies
- Example Torsional mode: 22.8Hz, 34.4Hz, 41.7Hz

#### Step 2: Global Modes Analysis





- NVH-C: Easy set-up of modal participation calculation for dynamic responses
- NVH-C controls META via session files
- Example: Modal participation for torsional load case
- Result: Main contribution to torsional resonance at 22.8Hz: Mode 19





- Epilysis can calculate MNF file using (NVH)
   Display Model which leads to drastically reduced
   MNF file size (new feature!)
- MNF can be displayed/ checked in META
- Cut-off frequency for MNF calculation taken from global mode analysis
   (50Hz)





Flex Body (Trimmed Body) and Rigid Bodies (Suspension, Powertrain, Radiator)

 Require the definition of bodies, joints, bushings

#### **Tire-Road Interaction**

• Requires tire and road entity definitions





- Non-Linear stiffness curves of bushings via:
  - Tables
  - User expressions
  - Python scripts
- Trimmed Body variants:
  - Rigid
  - Flex Body/Full MNF
  - Flex Body/Display MNF
- MNF (Full/Display) can be created directly in ANSA Kinetics

#### Step 3: Kinetics – Tire-Road Interaction



#### PAC2002

- Tire formulation embedded in ANSA Kinetics
- For road frequencies < 8Hz

#### <u>FTire</u>

- Advanced tire formulation including effects of tire belt
- For road frequencies < 250Hz





#### Variants:

- Two different tire formulations:
  - PAC2002 (Pacejka)
  - FTire
- Two different road surfaces modelled:
  - Sine Road (26Hz)
  - Belgian Block Road
- Road Builder supports the parametric construction of different road surfaces

# Step 3: Kinetics – Simulation of Driving Car on Road Display of Animation in META MDB results in META with Flex Body Animation



- Several MBD load cases have been simulated in time domain depending on
  - Type of TB: Rigid Body/Flex Body
  - Tire formulation
  - Road surface
- Overall simulation time: T = 1s
- Vehicle speed:
   v = 54Km/h

#### Step 3: Kinetics – Preparation of Loads





- Python scripting in ANSA and META converts the calculated loads from MBS to Nastran loads
- NumPy package in BETA installation included
- Example: Frt Top Mnt forces for Sine Road
- Higher harmonics due to non-linearities?

#### Step 4: NVH Post Processing – Modal Response Tool

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- BUT, transient acoustic response has not been implemented in Modal Response tool yet. It will be implemented in the near future!!
- Transient analysis for acoustic response shown here has been done with Nastran SOL112



- Modal Response, Powerful NVH tool in META
  - 2D/3D transient and frequency response
  - Participation factors
  - Acoustic grid point participation
- Input:
  - 1. Modal result file
  - 2. FS-Interaction file
  - 3. Load case file
  - 4. Freq/time steps
  - 5. Response Dof
  - 6. Response type







- Sine Road (26Hz)
- Transient and frequency results
  - Pressure at microphone at driver's ear position (acoustic)
  - z-Displacement at seat attachment (tactile)
- Observation:
  - Rigid Body leads to increase responses





- Sine Road (26Hz) and **Belgian Block Road**
- Transient and frequency results
  - Pressure at microphone at driver's ear position (acoustic)
- Observation:
  - Rigid Body leads to increase responses

#### Step 4: Modal Response – 3D Animations



Transient Structural Response

Frequency Acoustic Response



Frequency Structural Response



Frequency Grid Point Participation



 3D Animations in Modal Response Tool

#### Step 4: Modal Response – Structural Modal Participation





- Example:
  - Belgian Block Road, MBD Rigid Body
  - Structural modal participation
  - Main contribution to 22.5Hz peak in SPL: Global Torsion

#### Step 4: Modal Response – Fluid Modal Participation





- Example:
  - Sine Road (26Hz), MBD
     Flex Body
  - Fluid modal participation
  - Main Contribution to 50Hz peak in SPL: Fluid rigid body mode

Easy Root Cause Analysis with Modal Participation

#### Step 4: FRF Assembly Tool - Transfer Path Analysis (TPA)

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- Advanced NVH analysis in META:
  - TPA in FRF Assembly Tool for any frequency response
  - Reveals which interface Dof and which force component causes mainly the response of the system





- Example:
  - Sine road (26Hz), MBD
     Flex Body
  - 50Hz peak in SPL
- TPA Tool displays for N top contributing paths:
  - Path participation
    - Absolute (1)
    - Complex (2)
    - Fraction (3)
  - Forces (4)
  - Point Mobility (5)
  - Transfer functions (6)

# Conclusions/Summary

physics on screen



#### Summary/Results

- A seamless process, completely inside the BETA Suite, was presented using forces from a Non-Linear MBD analysis to calculate NVH related responses on a Trimmed Body
- Using forces calculated with **Flex Bodies** instead of Rigid Bodies in the MBD simulation has a significant effect on the NVH results
- Utilizing a Display Model during the NVH analysis AND for the MNF file calculation leads to feasible file sizes and especially facilitates the application of Flex Bodies in the MBD simulation
- META NVH tools enable efficient root cause analysis methods

Identified Areas for Tool Improvements

#### **ANSA Kinetics**

 Automatic creation of transient and frequency load case (including all necessary options for FT) to avoid scripting solution

#### META

- Calculation of transient acoustic response
- Modal participation for transient response

Implementation Depends on Customer's Request/Interests in this Process!



## **Outlook - Advanced Processes/Applications**

## **Advanced Models**

- MBD model with more than one Flex Body, e.g. Subframes also as Flex Bodies
- Linear NVH model with more than one component, e.g. TB and IP separated
  - Coupling of components with FRF assembly or CMS in Epilysis
  - Easy set-up in NVH-Console

#### **Automated Process**

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Scripting capabilities in ANSA/META enable automatization and set-up of optimization loops



# **Backup Material**

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	1. Mode [Hz] (no)	2. Mode [Hz] (no)	3. Mode [Hz] (no)
torsion	22.8 (19)	34.9 (39)	41.7 (54)
lateral	19.6 (15)	24.9 (23)	34.9 (39)
vertical	26.1 (26/27)	28.2 (28)	72.2 (135)



- Global modes are identified by torsional, lateral and vertical dynamic loads
- Main peaks reveal the global modes frequencies
- Modal participation analysis reveals the global mode numbers







- FT on transient response is similar but not identical as frequency response due to FT of forces!
- Possible root cause: Different damping mechanism in frequency and time domain