Virtual NVH Process with ADAMS/Vibration

Mechanical Dynamics

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Agenda

- **Two approaches for system-level vibration analysis**
- Integrating vibration investigation in the development process
- Accessing continuous product development

Tacoma Narrows Bridge

New Tacoma Narrows Bridge

The Virtual NVH Process

Inputs to Mechanical Model

- Time Domain Inputs
- Frequency Domain Inputs

ADAMS solution

Time Domain; Physical Space; Fully nonlinear

Slower; higher fidelity

Frequency Domain; Modal Space; Linear

Faster; approximate

Post-processing

Plots, animations, & tables and some frequency data within ADAMS

NVH data processing within I-DEAS Test

DESIGNER
DYNAMIC
ADAMS

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The Time Domain Approach

Inputs to Mechanical Model

ADAMS solution

Post-processing

Time Domain Inputs

Time Domain; Physical Space; Fully nonlinear

Slower; higher fidelity

Plots, animations, & tables and some frequency data within ADAMS

NVH data processing within I-DEAS Test

DYNAMIC DESIGNER ADAMS

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The Time Domain Approach

- Standard ADAMS product line as virtual prototyping vibration tool
  - Independent from physical testing
  - System-level approach (opposed to FE-like component approach)
  - ADAMS/Solver enables to take into account non linearity effects
  - CPU time increases proportionally with the required frequency resolution

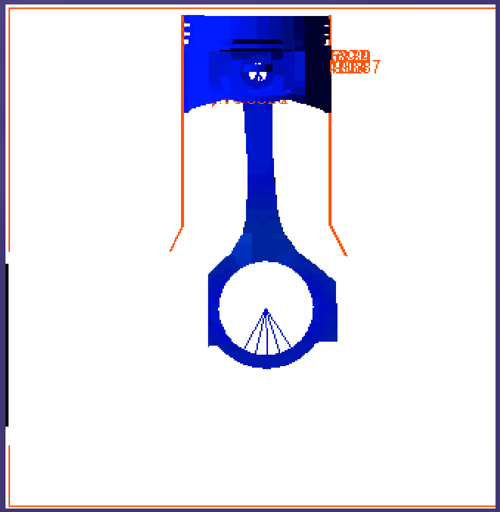
Case Study: Ford Motor Company

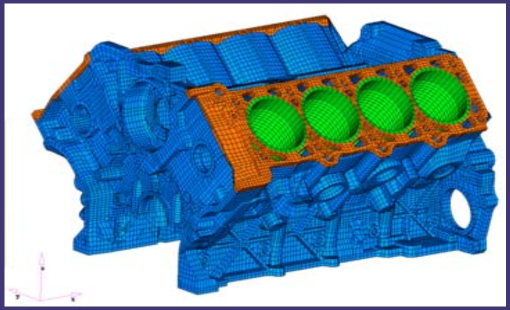
Business: Major automotive manufacturer

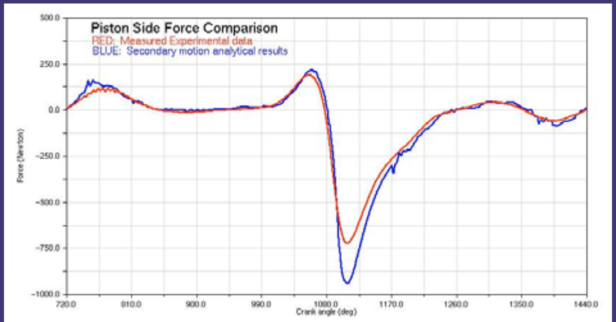
Challenge: Estimate radiated block noise (strong customer dissatisfier) caused by side thrust forces

Solution: FFT of piston side forces from an ADAMS detailed model are used as input for the NVH analysis in the FE tool to predict sound power level and correlate it with measurements

Value: Piston slap noise in different engine configurations can be virtually predicted earlier in the design process







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Ford Motor Company

The Virtual NVH Process

Inputs to Mechanical Model	ADAMS solution	Post-processing
Time Domain Inputs	Time Domain; Physical Space; Fully nonlinear *Slower; higher fidelity*	Plots, animations, & tables and some frequency data within ADAMS
Frequency Domain Inputs	Frequency Domain; Modal Space; Linear *Faster; approximate*	NVH data processing within I-DEAS Test

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The Frequency Domain Approach

Inputs to Mechanical Model

ADAMS solution

Post-processing

Frequency Domain Inputs

Frequency Domain; Modal Space; Linear

Faster; approximate

Plots, animations, & tables and some frequency data within ADAMS

NVH data processing within I-DEAS Test

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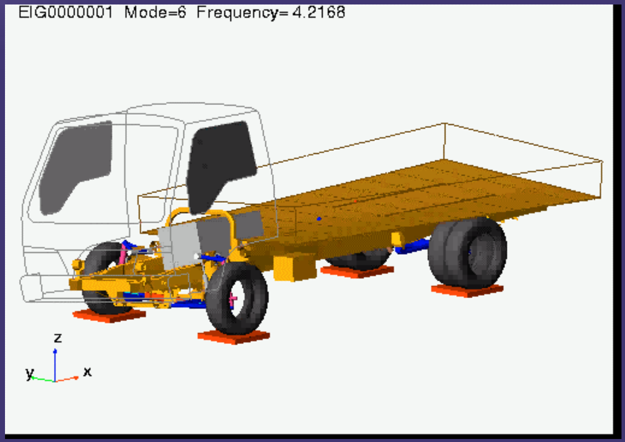
The Frequency Domain Approach

- ADAMS/Vibration add-on product as virtual prototyping vibration tool
  - Allows to take your system to different operating points to analyze the vibratory behavior (without having to create new models!)
  - Allows various evaluations in modal space, including forced response in the frequency domain, FRF and mode shape analysis, modal participation factors
  - Validity within the limits imposed by linearization approach

Case Study: Isuzu

Business: Major truck manufacturer

Challenge: Create vehicle natural frequency map to investigate vibration problems bypassing the expensive, time consuming typical experimental approach



Solution: Development of customized ADAMS environment able to allow to review frequency data with the help of a web tool

Value: Accurate evaluation of vehicle vibrations over 50Hz helps to shorten development time and to cut cost

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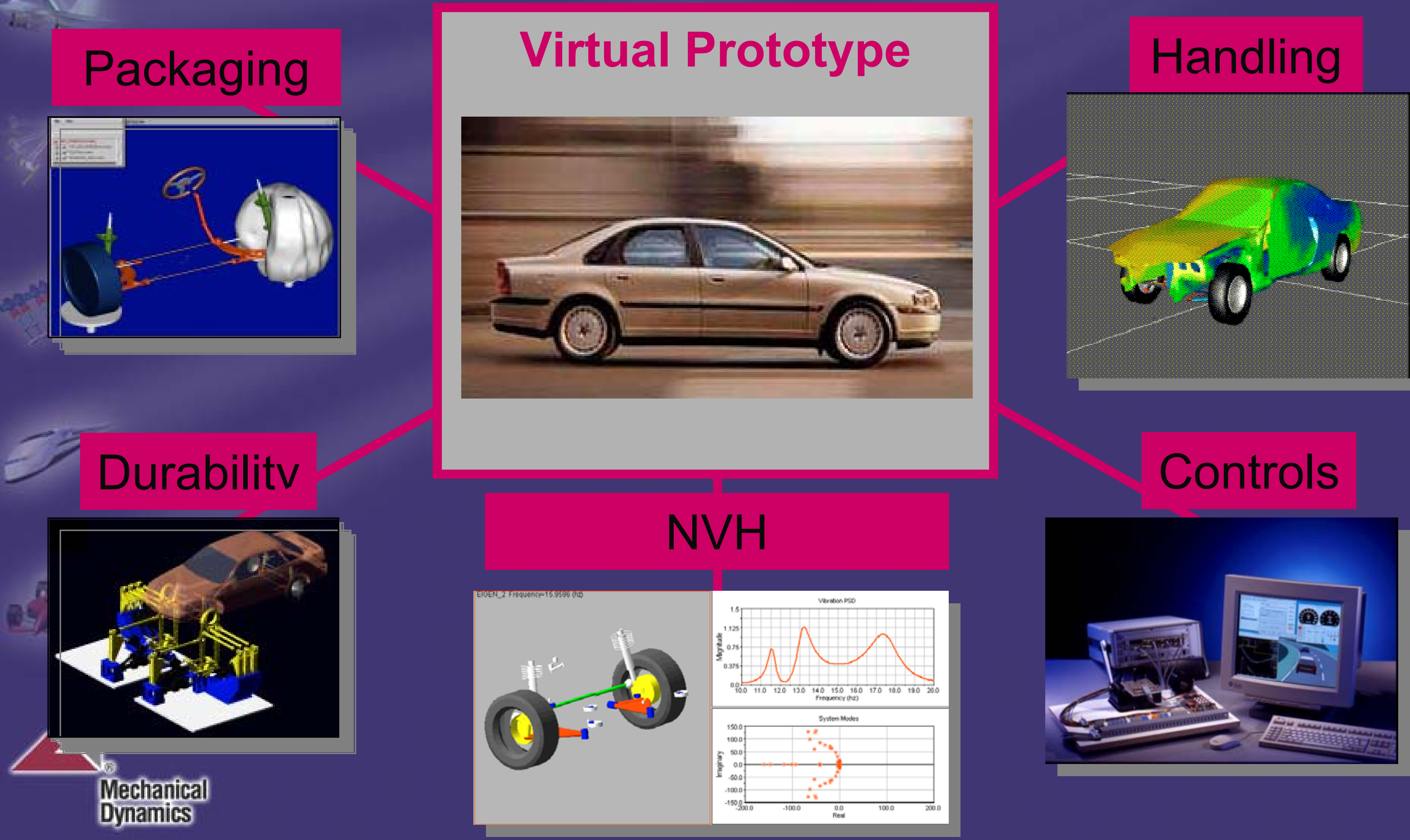
ISUZU

Agenda

- Two approaches for system-level vibration analysis
- **Integrating vibration investigation in the development process**
- Accessing continuous product development

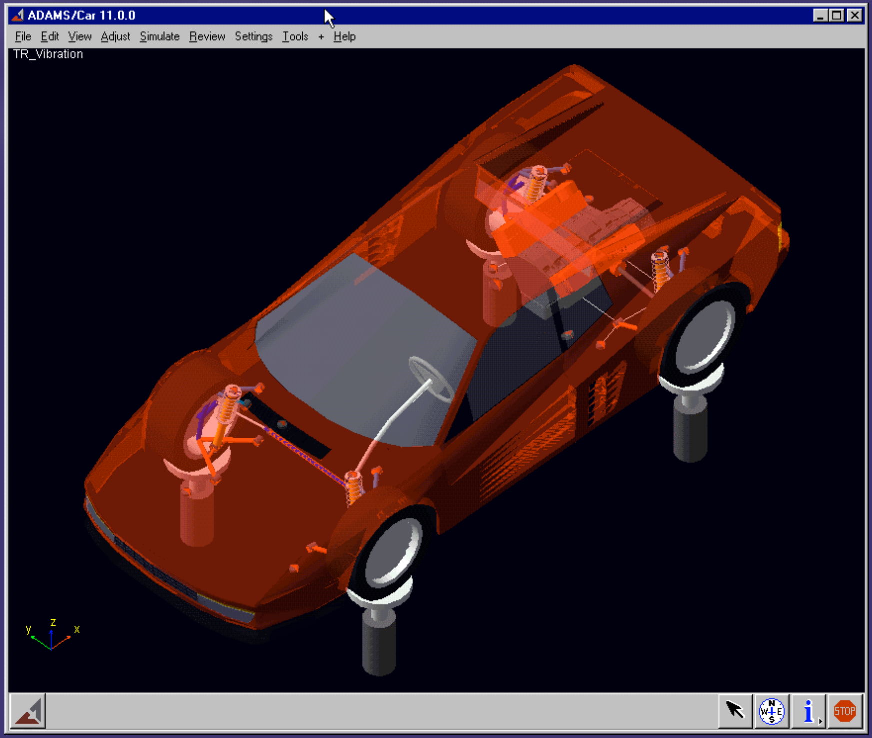
Integrated NVH in the Functional digital Prototype



Typical Automotive System-Level Scenario

Engine-Mount Manufacturer's Sensitivity Test

- Input (to front wheels):
  - In-phase sine sweep
  - 0.8 – 40.0 Hz
  - 2mm peak-to-peak displacement
- Measure: acceleration at 3DOF on both sides of all engine mounts. Also at selected points on body.
- Graph: response vs frequency, with phase.



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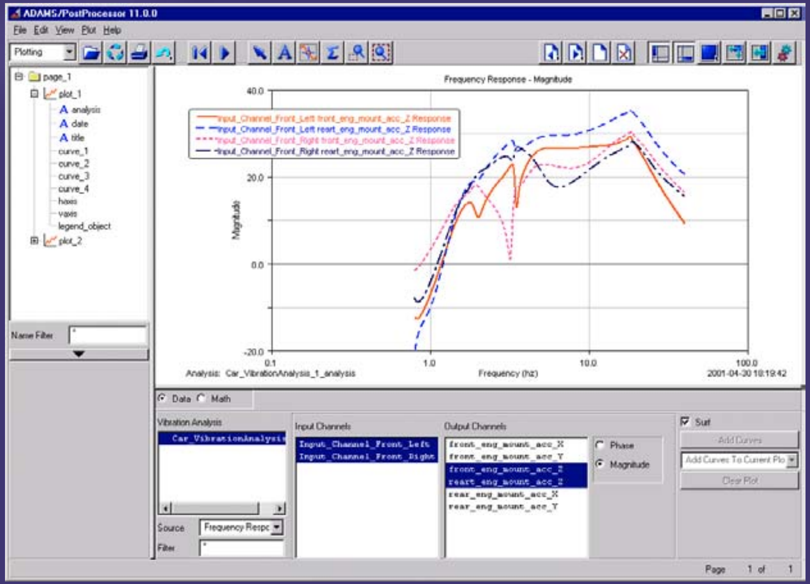
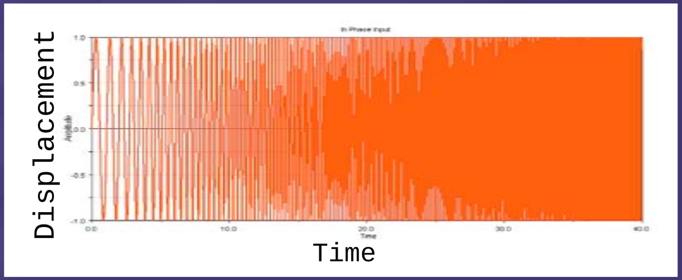
Typical Automotive System-Level Scenario

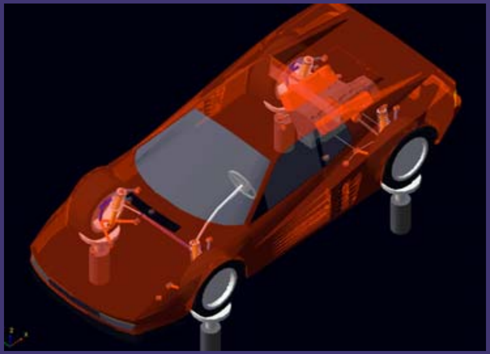
- In modal space with ADAMS/Vibration:
  - Instantaneous calculation of FRFs between any input and any output to quickly understand vehicle dynamics
  - Forced vibration animation
  - Modal contribution map for selected input channel and frequency

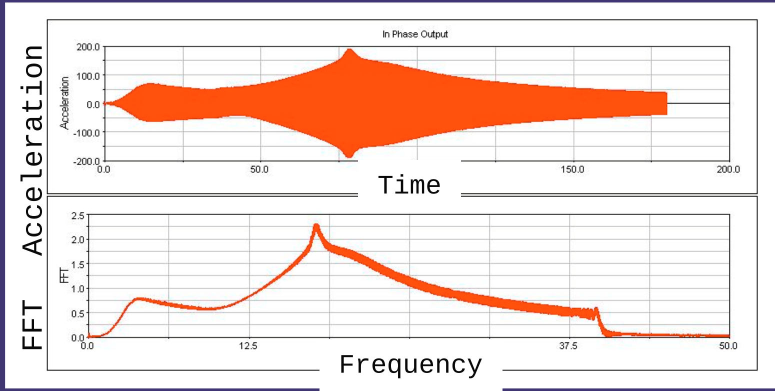


Typical Automotive System-Level Scenario

- In physical space with ADAMS/Solver:
  - Input specified in time domain (frequency sweep)
  - Solution in time domain, using $\Delta t = 0.002$, $t_f = 180$ sec
  - Output in time domain (acceleration requests in the engine mounts)







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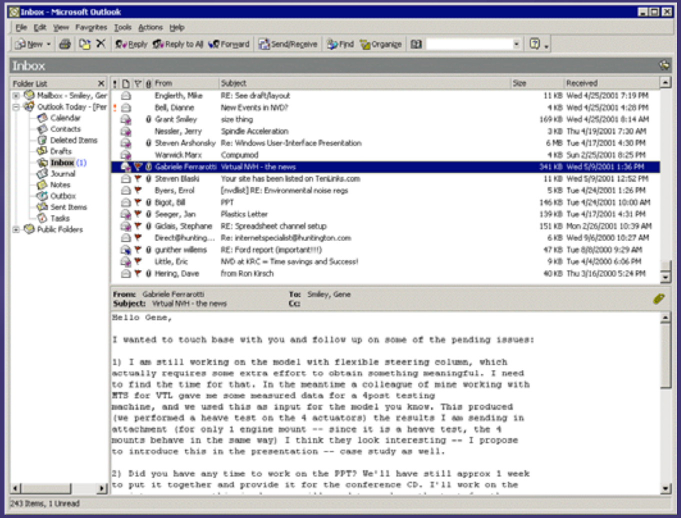
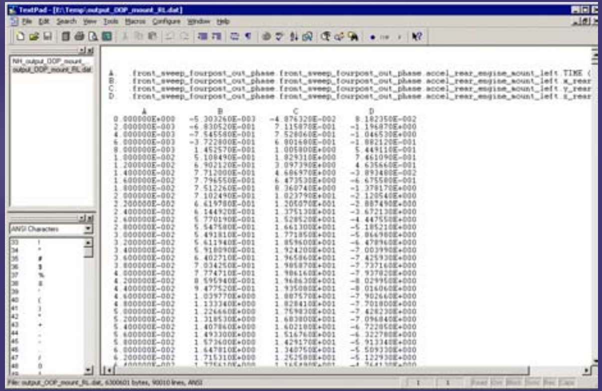
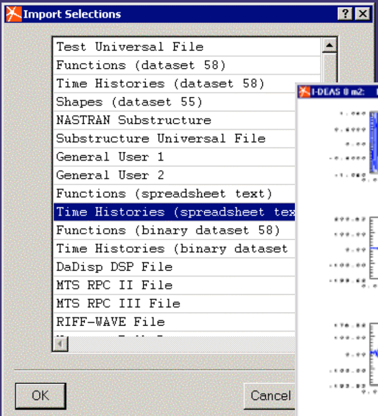
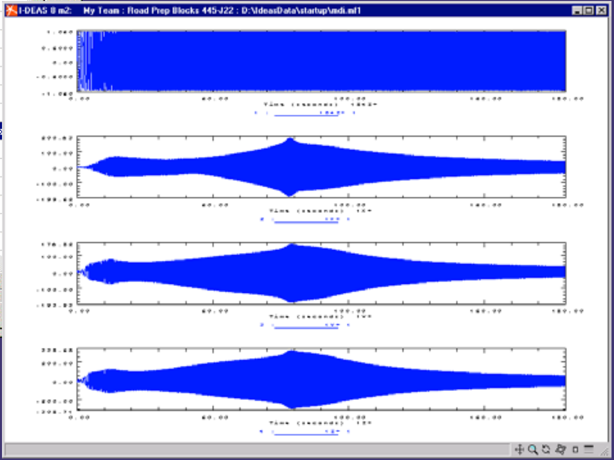
Typical Automotive System-Level Scenario

- ADAMS time domain results provided to NVH analyst in TXT - RPC format
- Can be imported into I-DEAS Test from MTS









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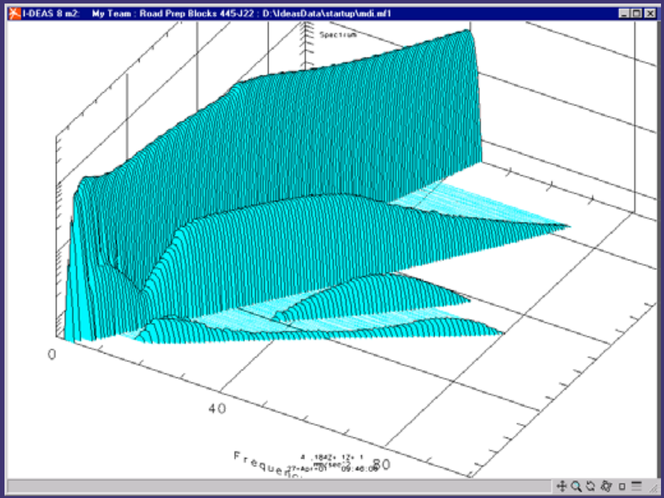
Typical Automotive System-Level Scenario

- Observations:
  - Harmonics are due to non-linear components in the model (bushings, mounts, suspension dampers)
- Conclusions:
  - “Modal space analysis” with linearized model provides fast qualitative NVH information
  - “Physical space analysis” with complete non-linear model provides higher fidelity NVH information



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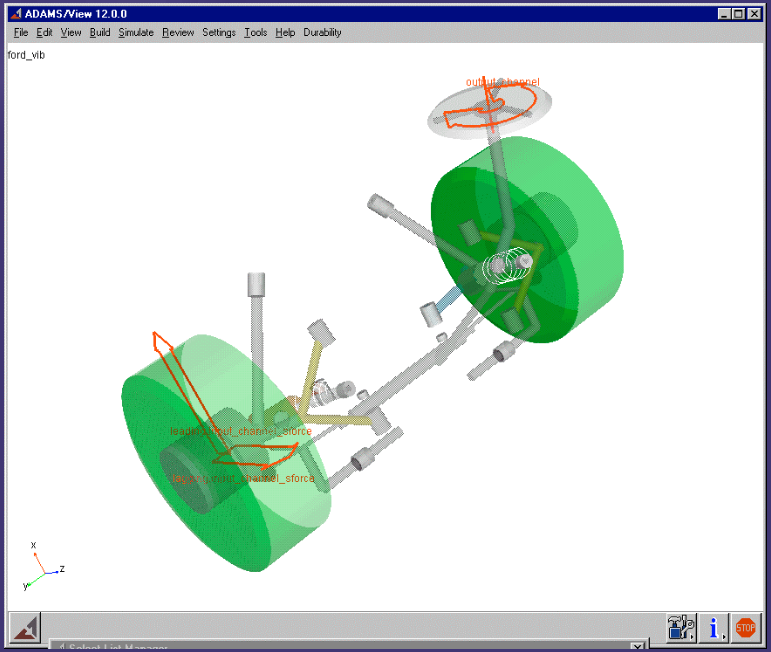
Typical Automotive System-Level Scenario

Wheel Out Of Balance (OOB) Analysis

- Input:
  - Unbalanced masses (leading and lagging) on right wheel (5 g, 2 cm)
- Measure:
  - local rotational velocity at steering wheel
- Graph:
  - Frequency responses
  - Sensitivity study to spring stiffness values



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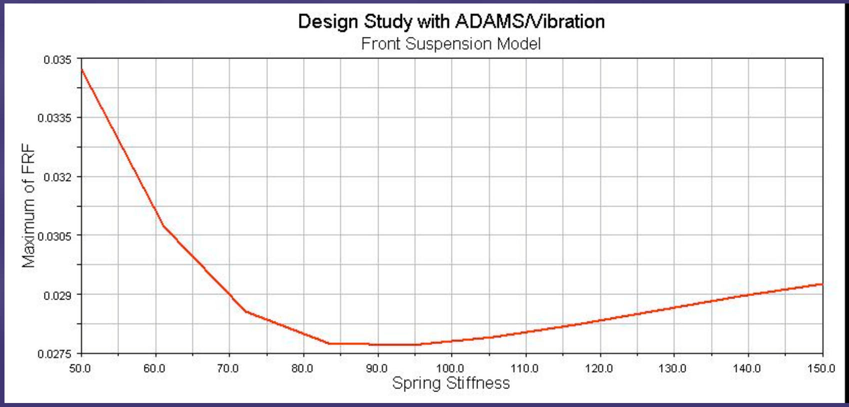
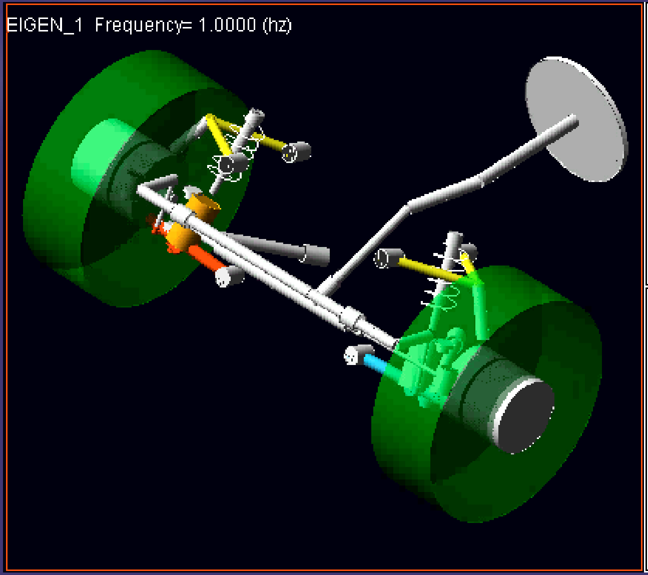
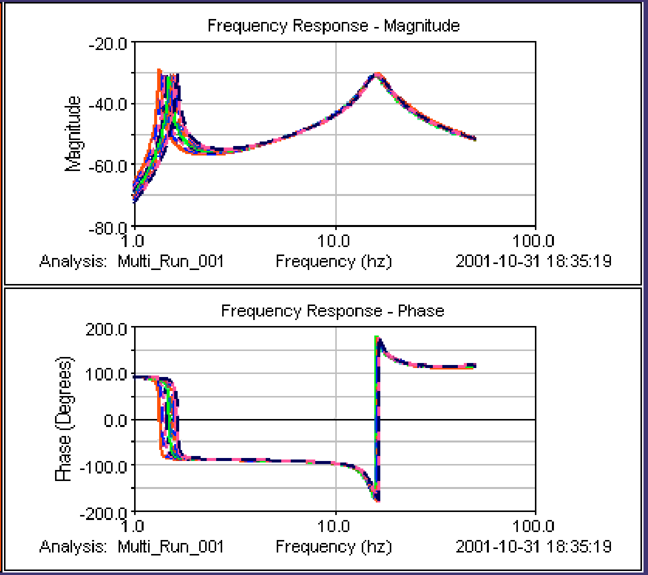
Typical Automotive System-Level Scenario

- Investigate the steering wheel resonance shift due to change in spring stiffnesses







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Additional Automotive System-Level Scenarios

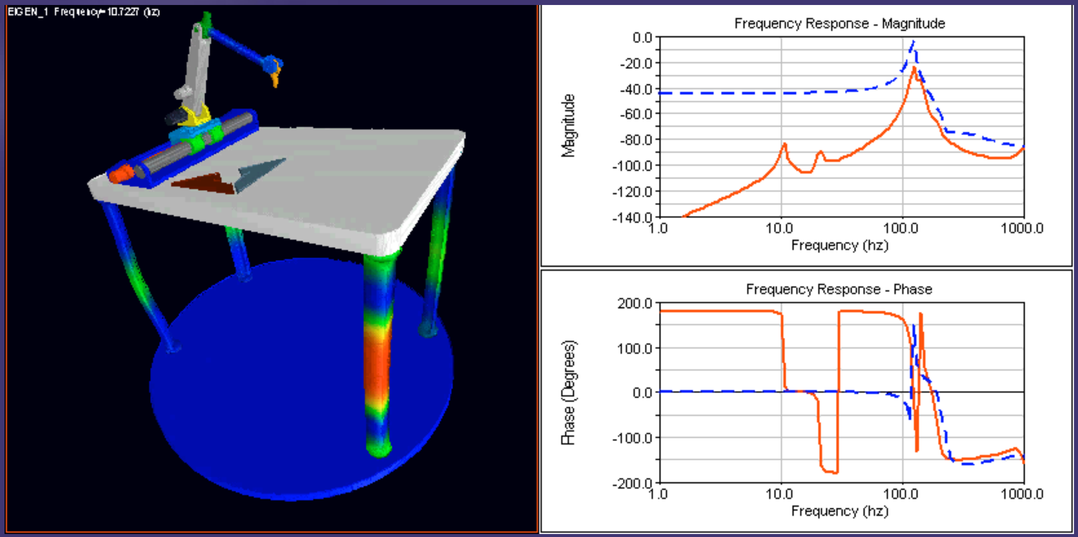
- Random Road Profile Analysis
  - Observe the PSD response of vehicle components to PSD inputs at the contact patch
- Powertrain Out Of Balance (OOB) Analysis
  - Observe the frequency response of vehicle components to out of balance inputs acting on powertrain components (i.e. driveline vibration analysis)

Agenda

- Two approaches for system-level vibration analysis
- Integrating vibration investigation in the development process
- **Accessing continuous product development**

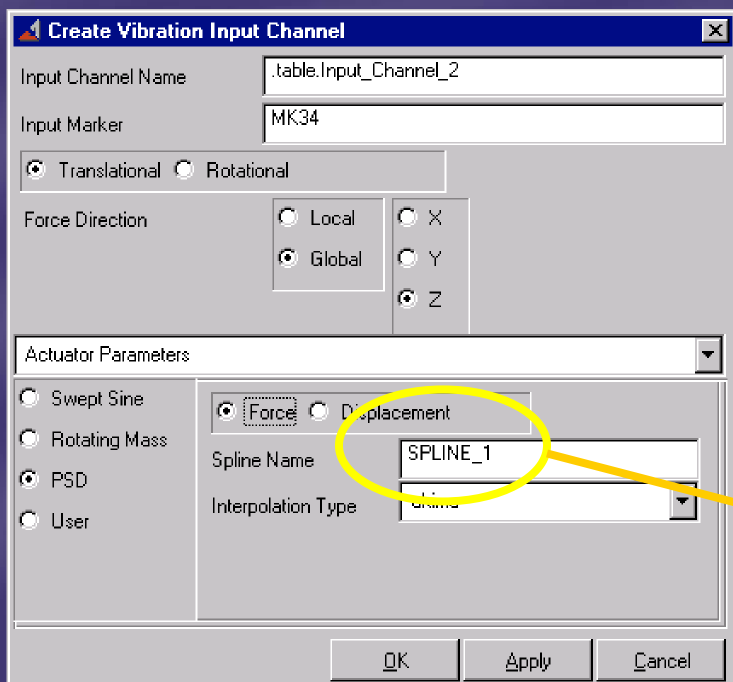
The ADAMS/Vibration Solution

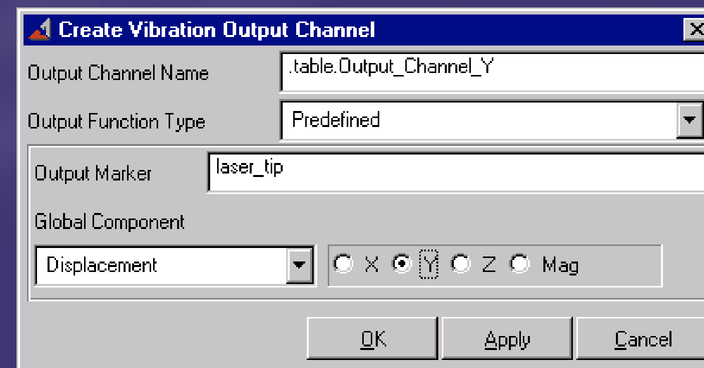
- ADAMS/Vibration 11.0 offers:
  - Frequency domain input forcing functions
  - Frequency response function calculations
  - Modal participation tables
  - Forced vibration animation

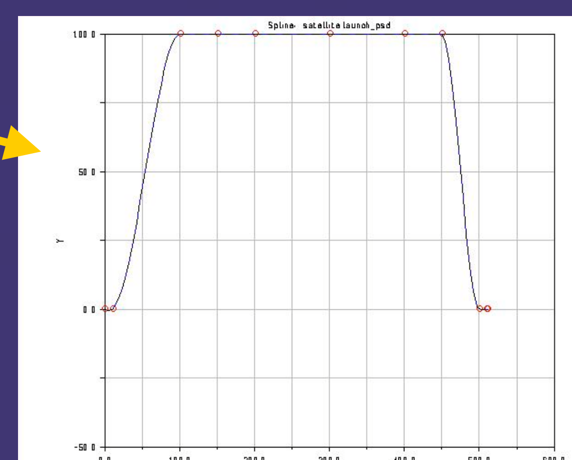


The ADAMS/Vibration Solution

- Step 1: Create input channels, output channels, and actuators



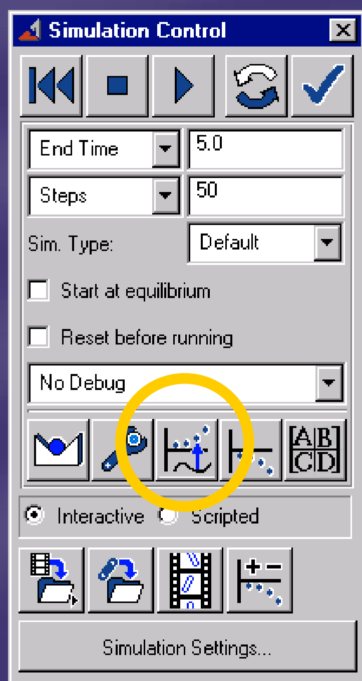


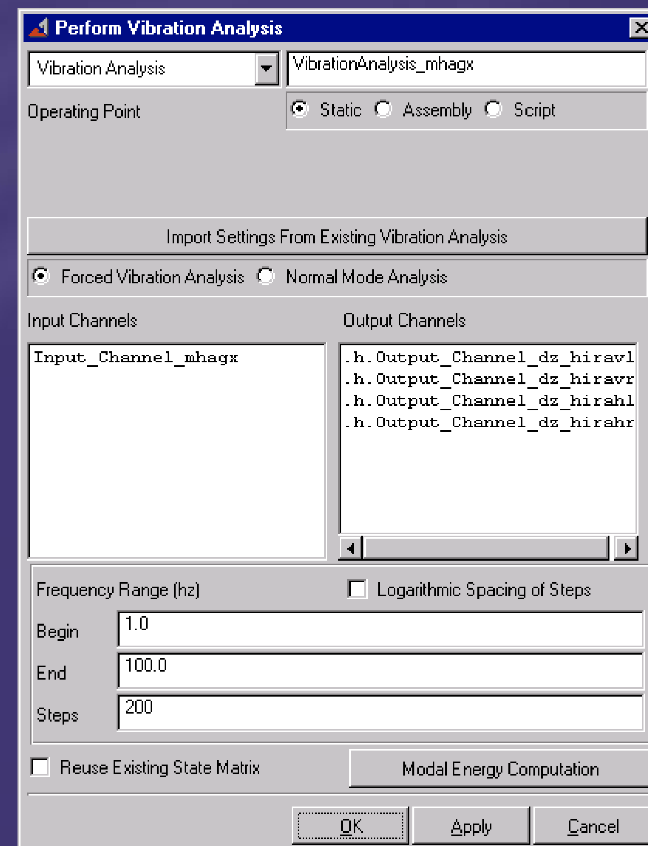


Spline defines PSD

The ADAMS/Vibration Solution

- Step 2: Run Analysis

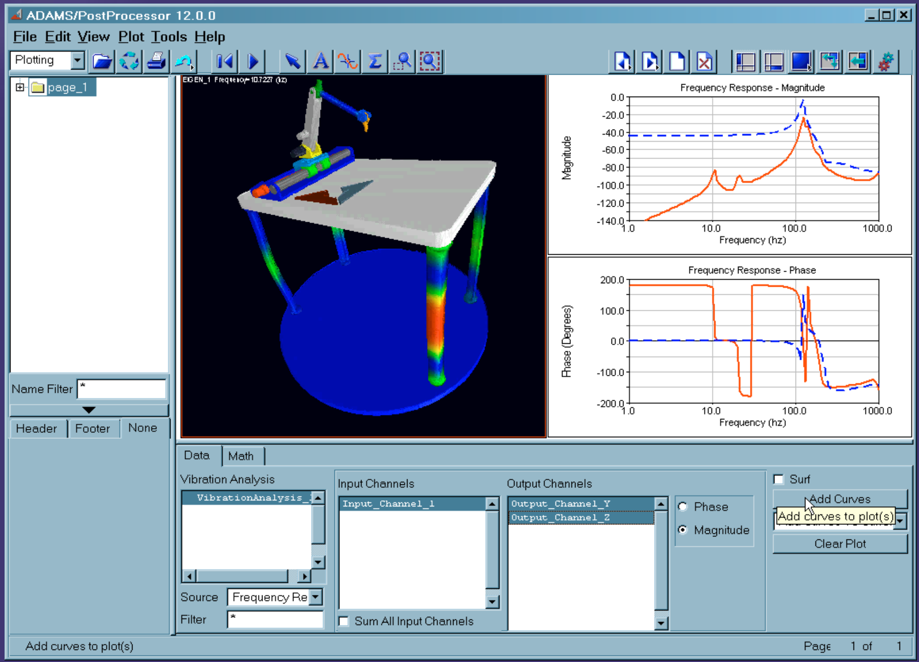




Define inputs/outputs to be used, operating point, frequency range, and steps

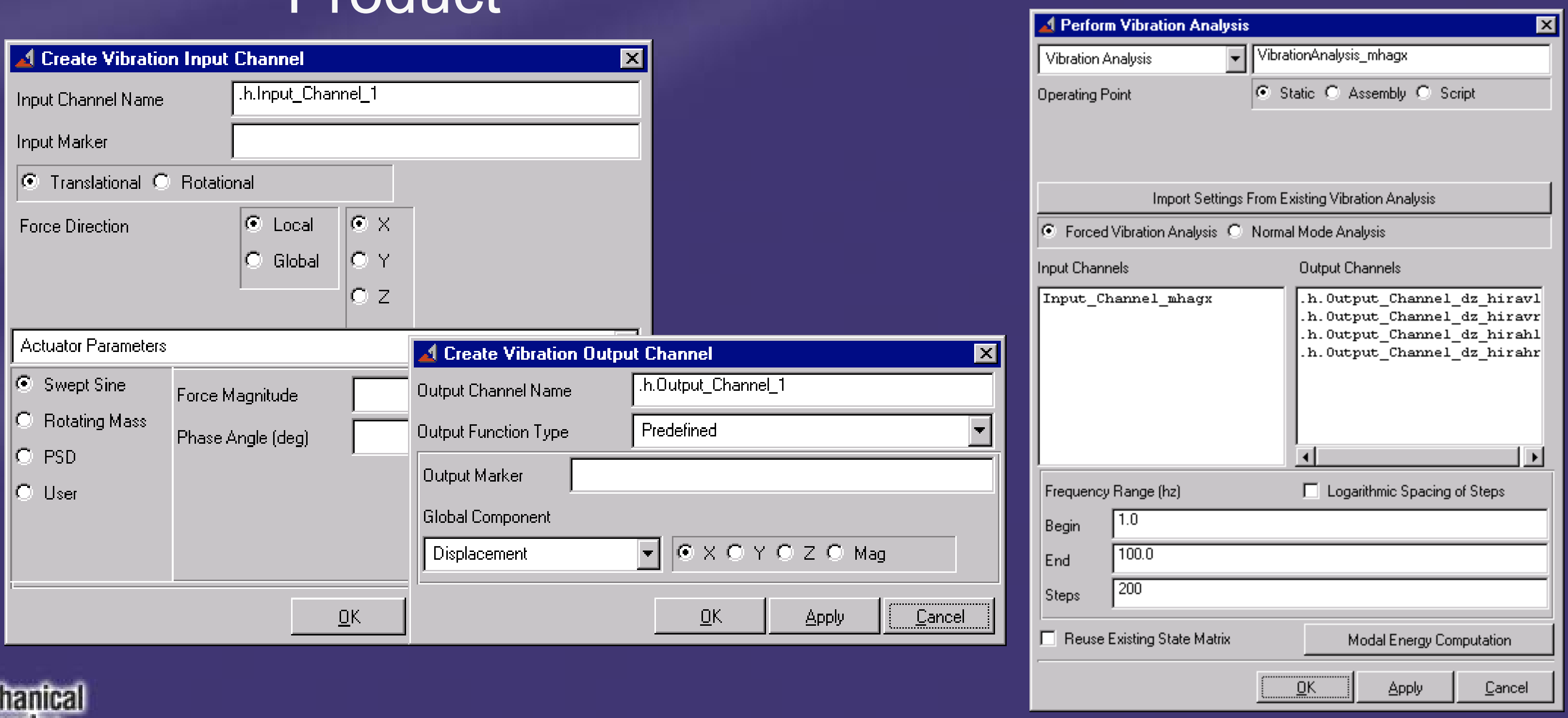
The ADAMS/Vibration Solution

- Step 3: Postprocessing
  - System Modes
  - Frequency Response Functions
  - Power Spectral Density
  - Modal Participation Tables
  - Normal Mode Animation
  - Forced Vibration Animation



The ADAMS/Vibration Solution

- ADAMS/Vibration 12.0 offers:
  - Integration with vertical products
    - Same look and functionalities for ADAMS/Standalone and ADAMS/Vertical Product



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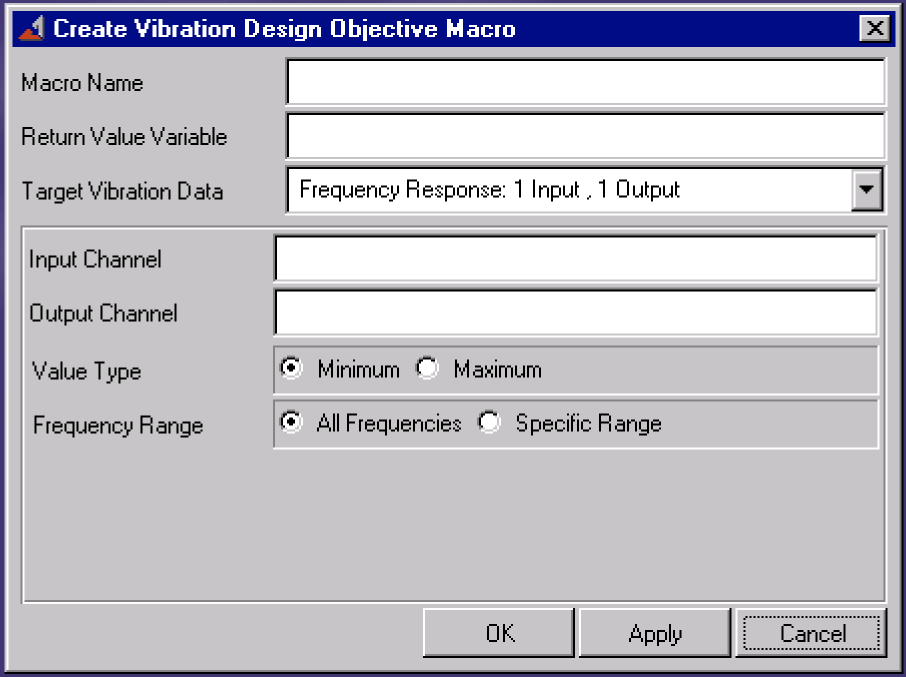
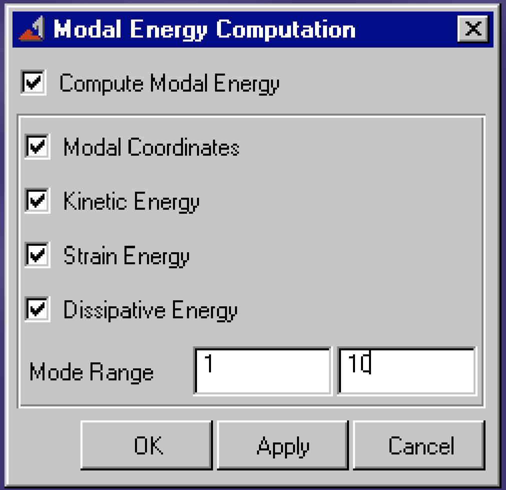
The ADAMS/Vibration Solution

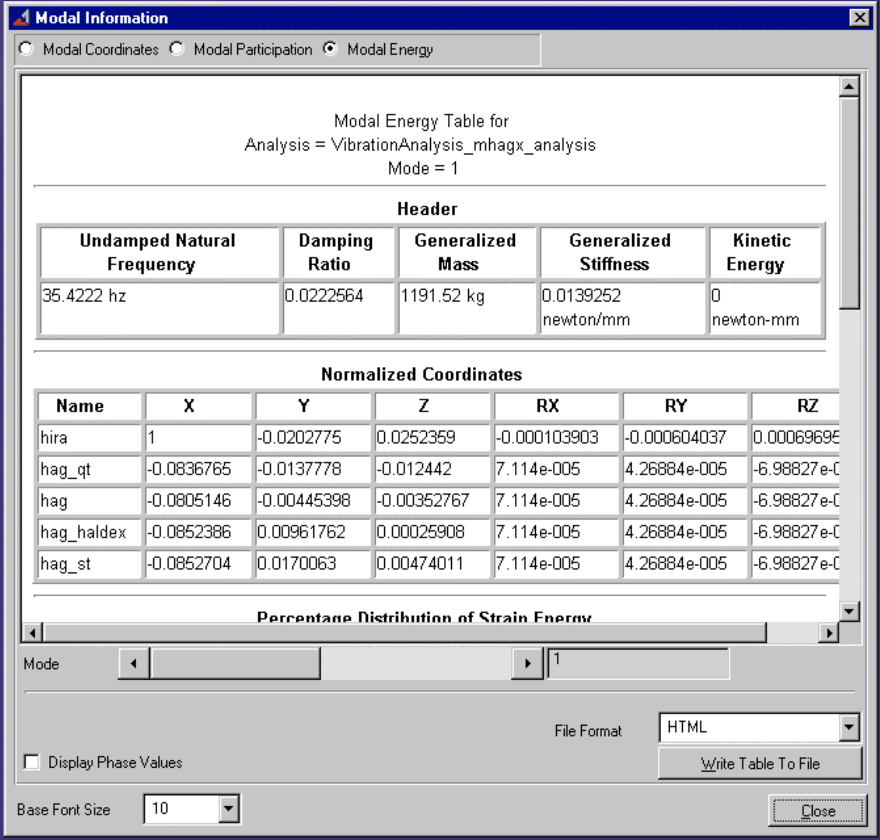
- ADAMS/Vibration 12.0 offers:
  - Integration with ADAMS/Insight
    - Dedicated dialog box to create objective macros for DOE - A/Insight



The ADAMS/Vibration Solution

- ADAMS/Vibration 12.0 offers:
  - Modal energy computation
    - Energy contribution of each model element in HTML format





Modal Energy Table for
Analysis = VibrationAnalysis_mhagx_analysis
Mode = 1

Header

Undamped Natural Frequency	Damping Ratio	Generalized Mass	Generalized Stiffness	Kinetic Energy
35.4222 hz	0.0222564	1191.52 kg	0.0139252 newton/mm	0 newton-mm

Normalized Coordinates

Name	X	Y	Z	RX	RY	RZ
hira	1	-0.0202775	0.0252359	-0.000103903	-0.000604037	0.00069695
hag_qt	-0.0836765	-0.0137778	-0.012442	7.114e-005	4.26884e-005	-6.98827e-0
hag	-0.0805146	-0.00445398	-0.00352767	7.114e-005	4.26884e-005	-6.98827e-0
hag_haldex	-0.0852386	0.00961762	0.00025908	7.114e-005	4.26884e-005	-6.98827e-0
hag_st	-0.0852704	0.0170063	0.00474011	7.114e-005	4.26884e-005	-6.98827e-0

Percentage Distribution of Strain Energy

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Conclusions

- ADAMS provides two approaches for system-level vibration analysis allow complete NVH insight early in the design process
- ADAMS allows to balance competing requirements for optimum NVH by integrating the vibration investigation in the development process
- ADAMS continuous product development guarantees a steadily improving solution for your NVH process