

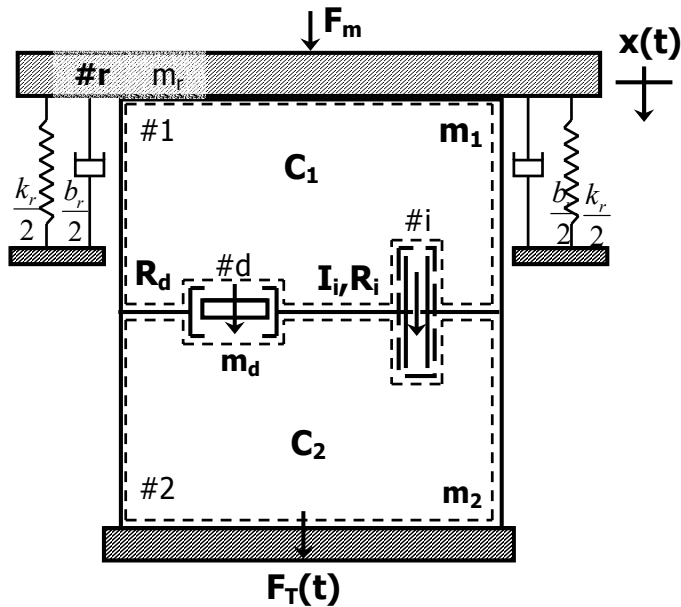
Hydraulic Engine Mount Analysis

HEMA 04.1: *Interactive Design and Simulation Tool*

- Time and Frequency Response Simulations
- Linear and Non-Linear Models (Based on First Principals)
- Estimation of Mount Parameters Given Experimental Data
- Parametric Design Studies
 - Mount as a component
 - Mount within a 1/2 Car Model

Song He and Prof R. Singh

System Model & Parameters



Fluid Model

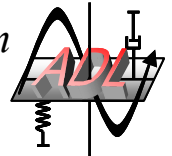
SIMULINK Parameters

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Nss	<input type="text" value="10"/>	[s]	Nfft	<input type="text" value="5"/>	[s]

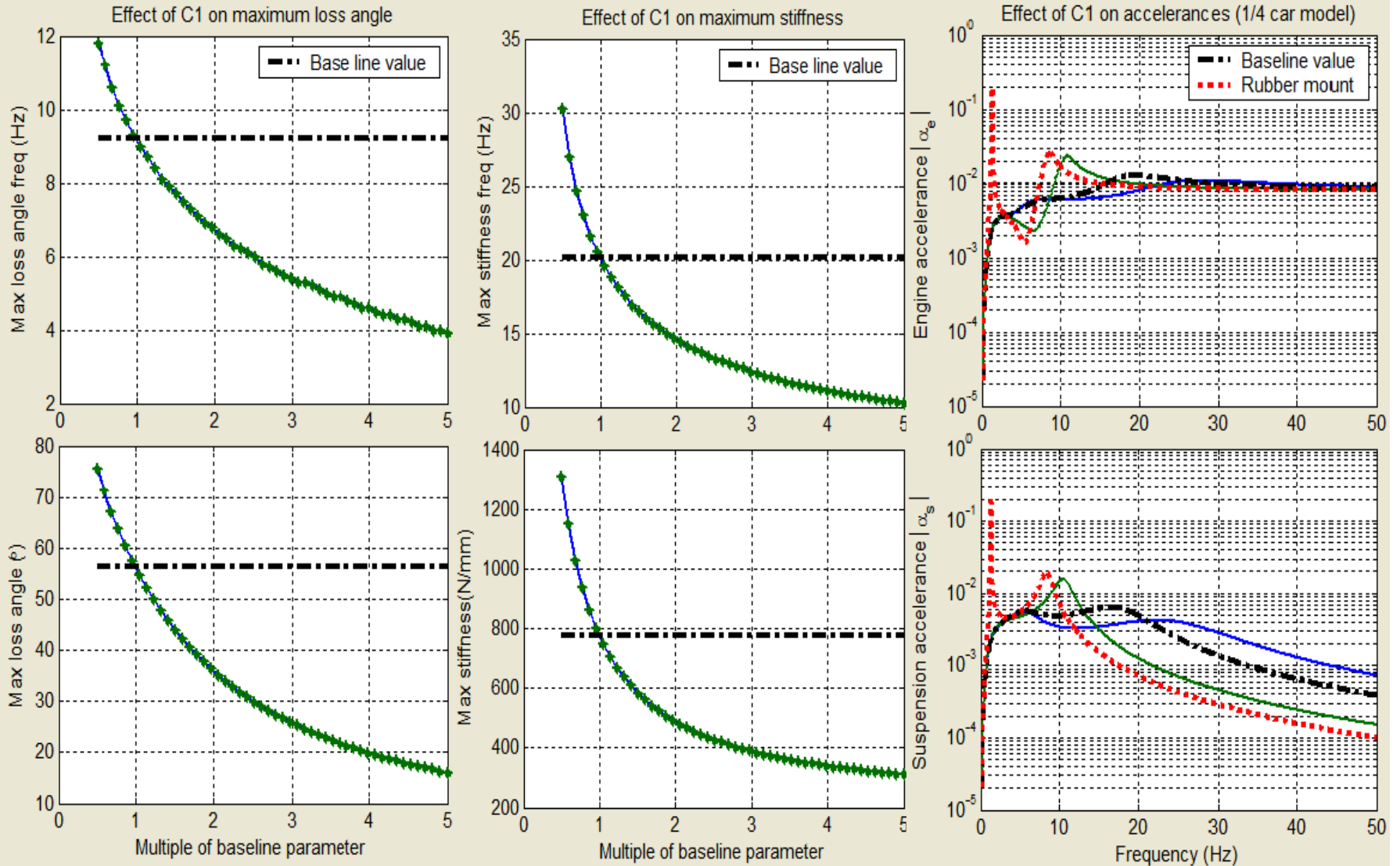
Simulation Parameters

Symbol	Physical meaning	Symbol	Physical meaning
k_r	Rubber dynamic stiffness*	b_r	Rubber viscous damping*
ρ	Fluid density	μ	Fluid viscosity
m_r	Rubber mass	A_r	Piston area
A_i	Inertia track area	A_d	Decoupler area
C_1	Upper chamber compliance	C_2	Lower chamber compliance
R_i	Fluid resistance of inertia track	l_i	Inertia track length
b_{d0}	Equiv. decoupler damping	l_d	Decoupler gap length
m_{d0}	Actual decoupler mass		

* Constant value/experimental result interpolation



Linear Analysis: Effects of Upper Chamber Compliance C1



Nonlinear Analysis I: System Parameters

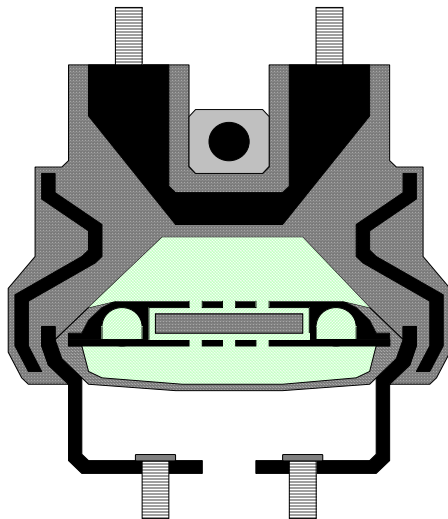


Mount Designs

- Fixed decoupler mount
- Free decoupler mount

Select Response Type

- Steady state response to sinusoidal excitation
- Dynamic stiffness simulation
- Transient responses: Step, Pulse, Saw-tooth, Triangular...
- Realistic profiles response



Nonlinear Hydromount Simulation

Fixed decoupler model
 Free decoupler model

Simulation Type

Steady State - Frequency Domain
Steady State - Time Domain
Steady State - Frequency Domain
Transient Response
Realistic Profile

System Parameters

Use constant kr, br values

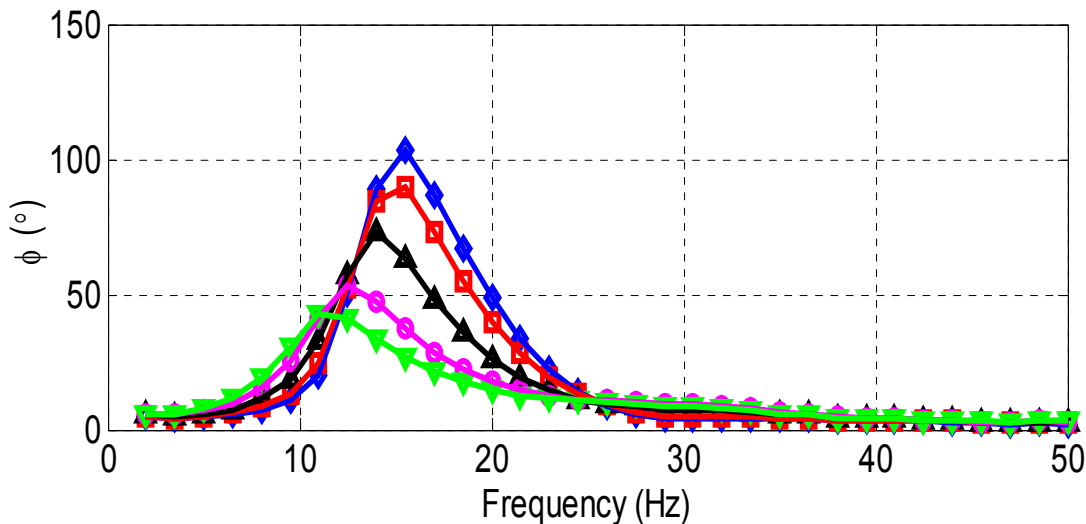
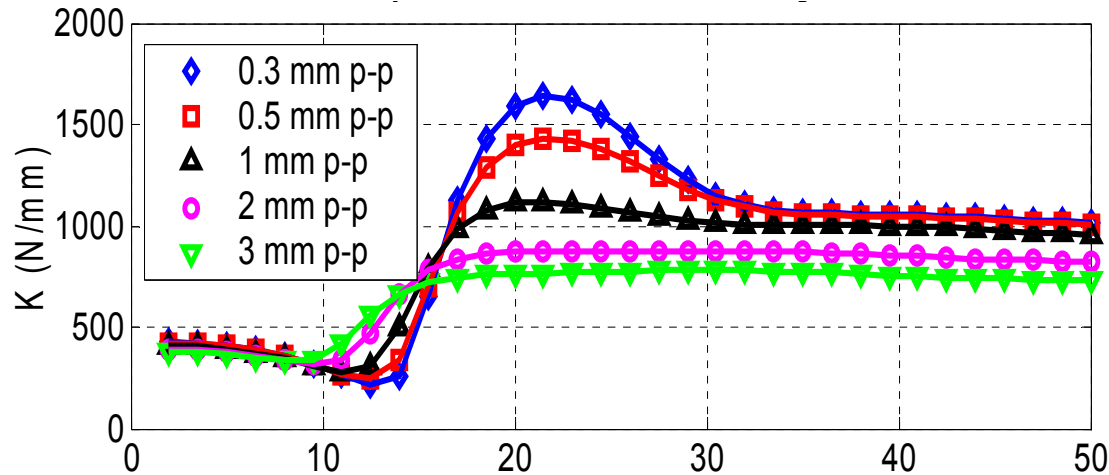
kr	320e3	[N/m]	br	500	[N-s/m]
rou	1000	[kg/m ³]	miu	9e-3	[N-s/m ²]
Ar	3.31e-3	[m ²]	mr	0.3	[kg]
C1	2.5e-11	[m ⁵ /N]	Ai	8.4e-5	[m ²]
C2	2.4e-9	[m ⁵ /N]	li	236e-3	[m]
Ad	1.96e-3	[m ²]	md	6e-3	[kg]
gd	1.1e-3	[m]	bd	100	[Ns/m]

SIMULINK Parameters

tstep	1e-4	[s]	ts	0	[s]
Nss	10	[s]	Nfft	5	[s]

Run Next

Nonlinear Analysis II: Dynamic Stiffness Simulation

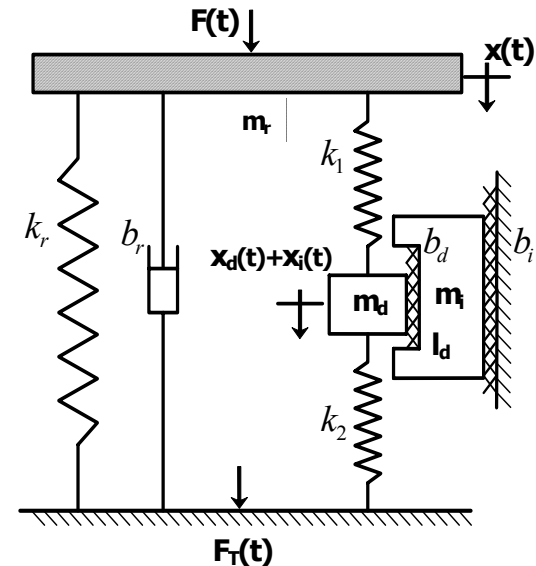


Governing Equations

- Momentum equations
- Continuity equations

Simulation Algorithm

- Solve differential equations in time domain
- Transform results to frequency domain



Analogous Mechanical System



Inclusion of Mount in 1/2 Car Model

Hydromount Stiffness (N/mm)

Minimum Value

Maximum Value

Num. of Pts

Parametric studies block

Undamped Case
 Proportional Damped Case
 Unproportional Damped Case

Modal Damping Ratio

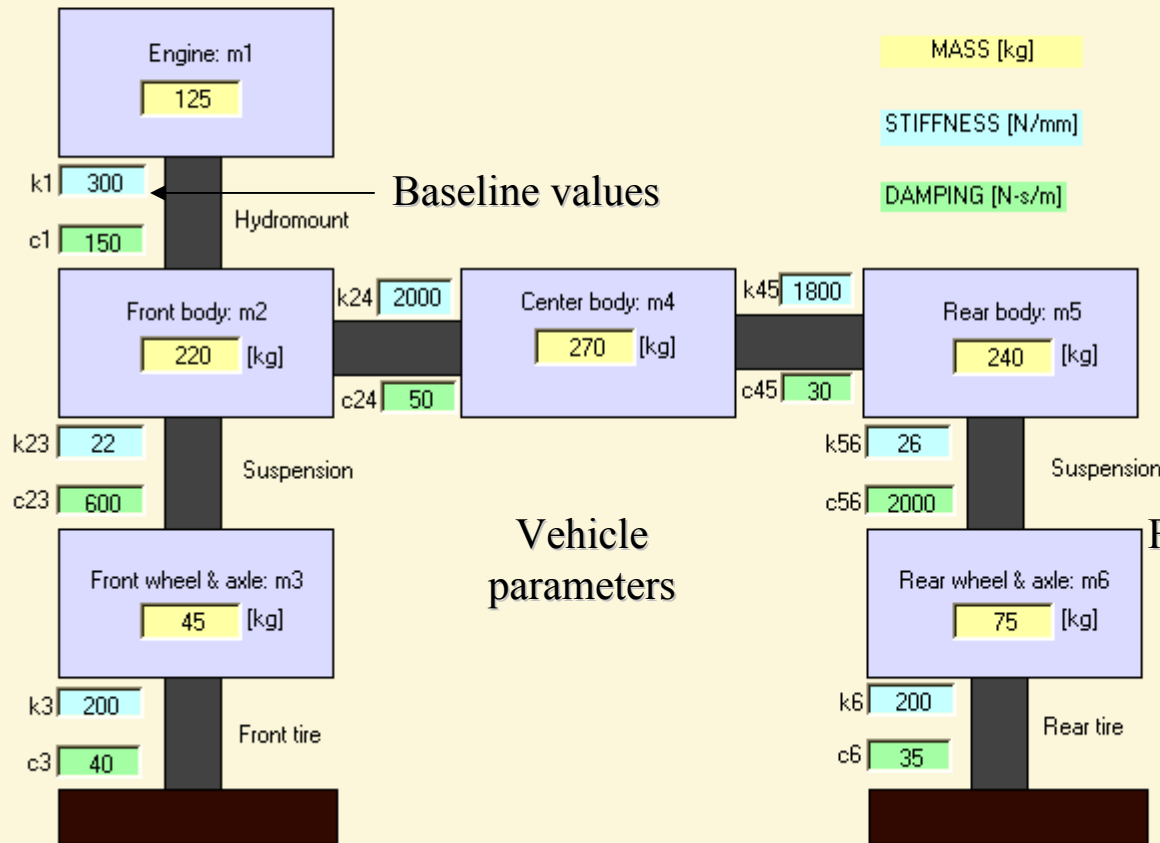
Mode 1 Mode 4

Mode 2 Mode 5

Mode 3 Mode 6

Estimate ratio

Damping study block



Modal analysis block

Complex plane

Mode Amp

Mode Plot

Nat. Freq. Map

Nyquist plots

Excitation

Max Freq [Hz]

Num. of Pts

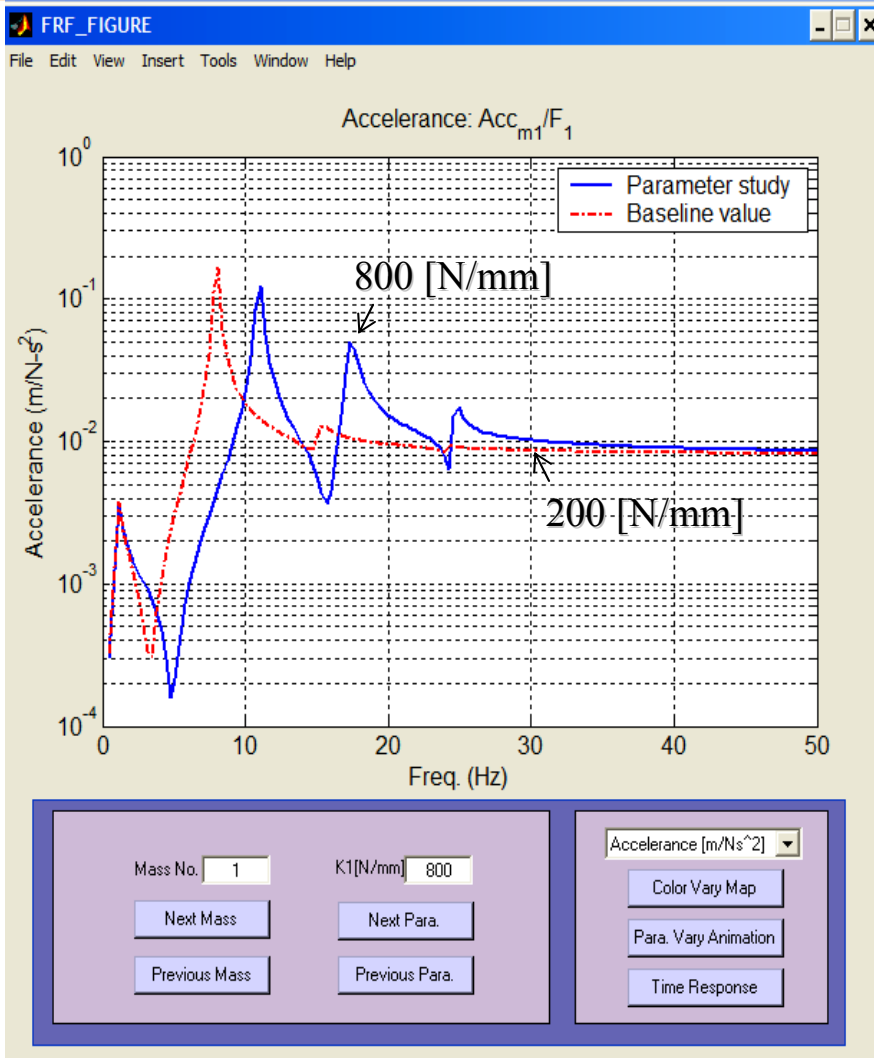
FRF Matrix

Single FRF

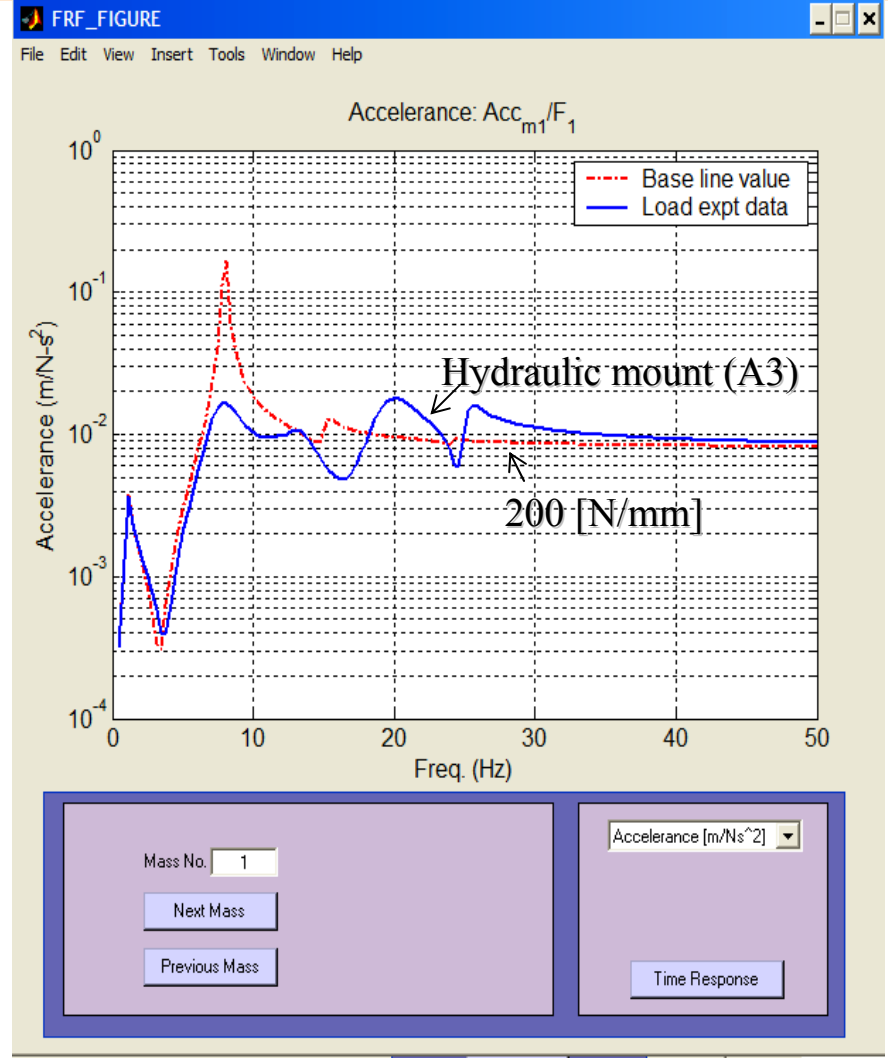
Close

Frequency response block

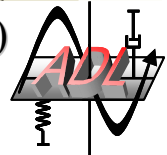
Frequency Response I: Effect of Some Parameters



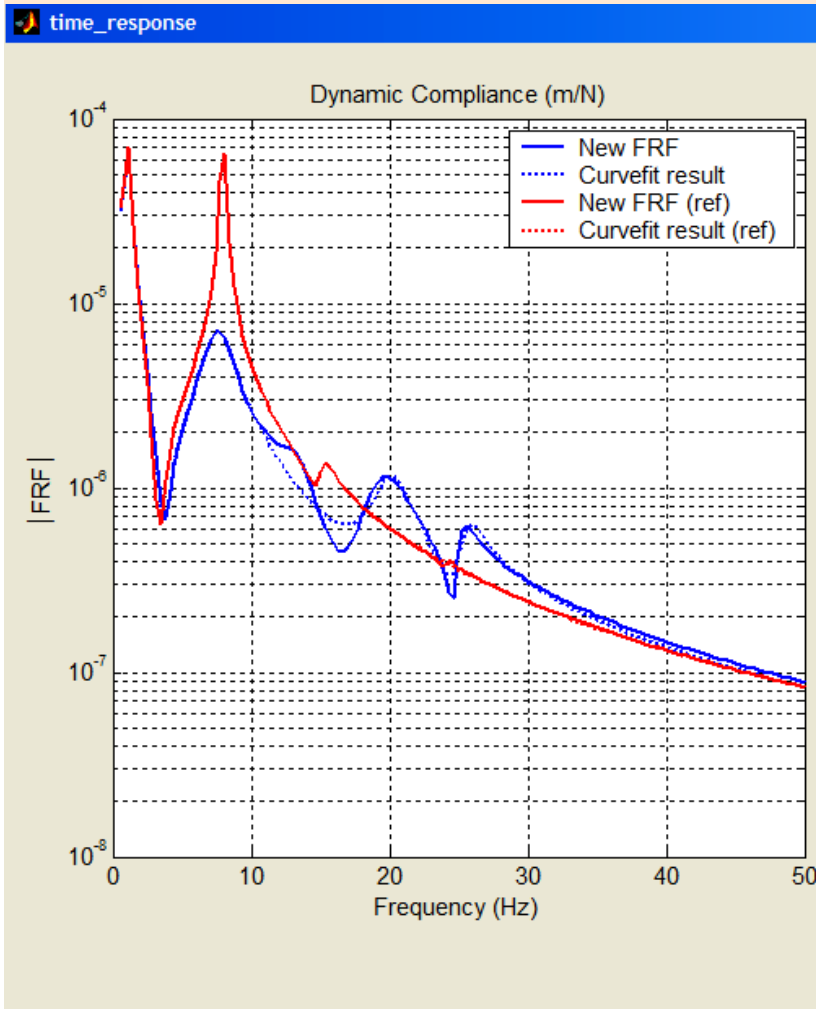
Effect of mount stiffness



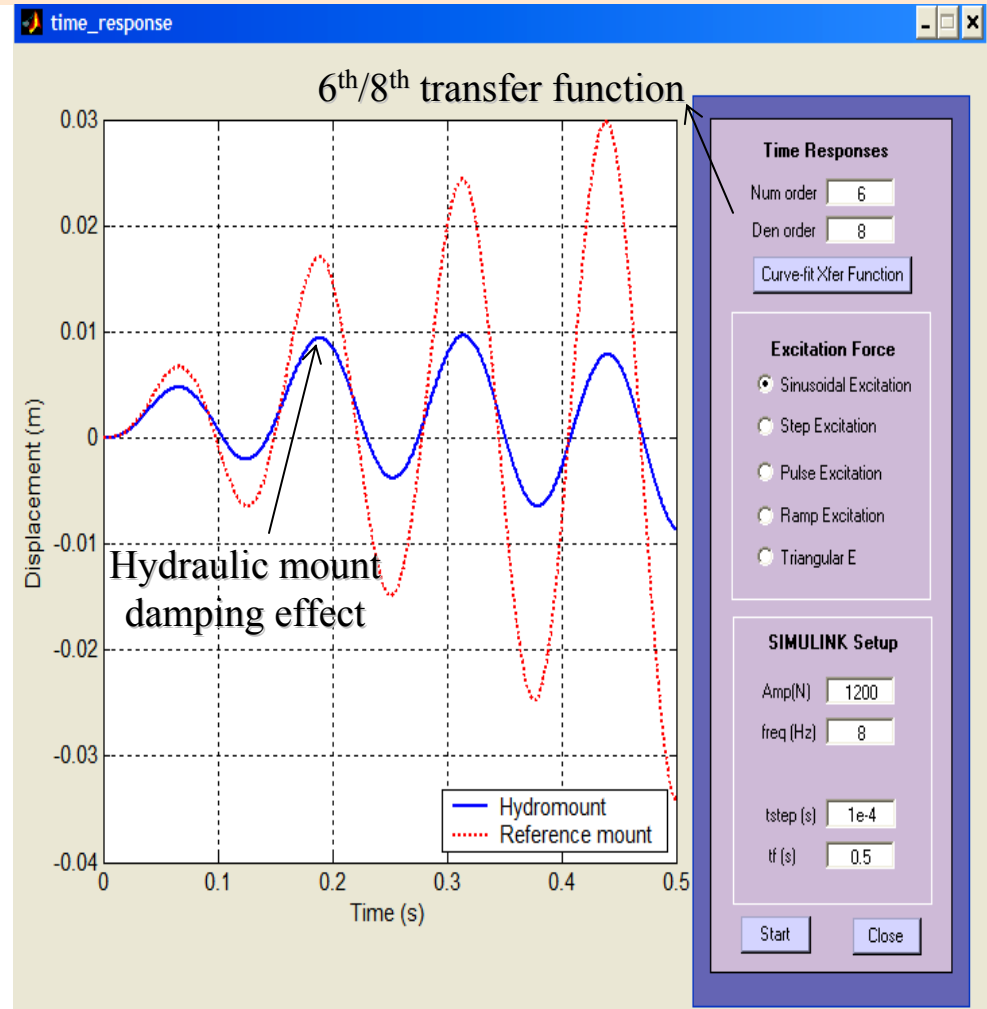
Inclusion of measure stiffness data (A3)



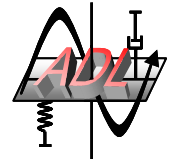
Frequency Response II: Time Domain Responses



Curve-fit transfer function



Displacement response
(given sinusoidal force excitation)



Key References

1. R. SINGH, G. KIM and P. V. PAVINDRA 1992 *Journal of Sound and Vibration* **158**, 219-243. Linear analysis of automotive hydro-mechanical mount with emphasis on decoupler characteristics.
2. G. KIM and R. SINGH 1995 *Journal of Sound and Vibration* **179**, 427-453. Study of passive and adaptive hydraulic engine mount systems with emphasis on nonlinear characteristics.
3. H. ADIGUNA, M. TIWARI and R. SINGH 2003 *Journal of Sound and Vibration* **268**, 217-248. Transient response of a hydraulic engine mount.
4. M. TIWARI, H. ADIGUNA and R. SINGH 2003 *Noise Control Engineering Journal* **51**, 36-49. Experimental characterization of a nonlinear hydraulic engine mount.
5. S. HE 2004 *M.S. thesis, Ohio State University*. Comparative evaluation of linear and nonlinear models of hydraulic engine mounts.
6. A. GEISBERGER, A. KHAJEPOUR and F. GOLNARAGHI 2002 *Journal of Sound and Vibration* **249**, 371-397. Non-linear modeling of hydraulic mounts: theory and experiment.

