Analysis of Powertrain Mounting System

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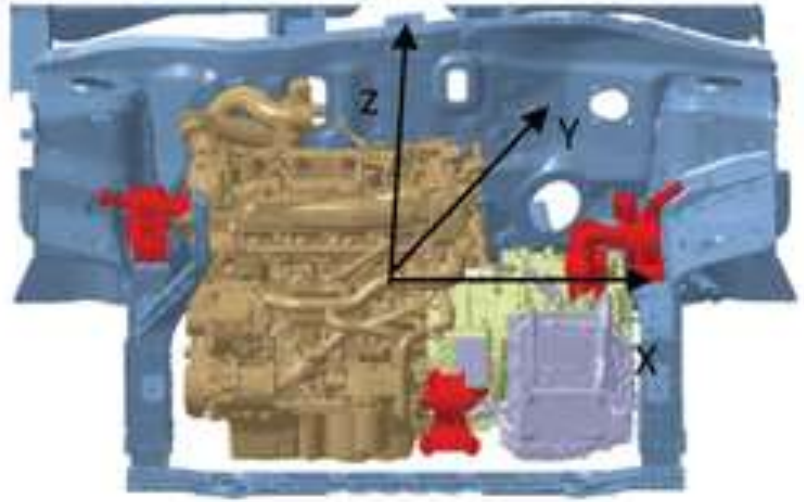
Simulation Objective

- Determines the optimum engine mount configuration from the minimum set of data available at the early vehicle concept stage
- Helps to design mounts close to their optimum position and to make more realistic full vehicle models for conceptual designs
- Used to calculate the eigenfrequencies, rotations and displacements of engine mounts

Powertrain Mount

- Powertrain is having considerable mass and inertia.
- Primary Excitation is through the Engine excitation and Road excitation.
- Major role in Vehicle NVH and passenger Ride & Comfort
- Modal frequency and kinetic Energy of decoupled system



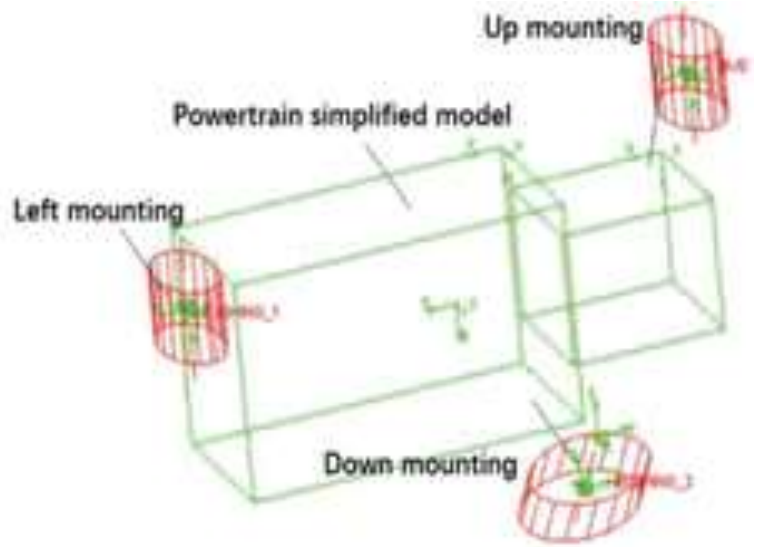


Fig. Reference: Xiangyang Xu *et*al, **Optimization design of powertrain mounting system considering vibration analysis of multi-excitation**

6-DOF Model of Powertrain on Mounts

Equation of Motion $[M][\ddot{x}] + [C][\dot{x}] + [K][x] = 0$

Eigen Value → $f_i = \frac{\sqrt{D_i}}{2\pi}$

Natural Frequency

Equation of Motion without Damping $[M][\ddot{x}] + [K][x] = 0$ ⟹ $[K] - \omega_i^2[M] = 0$

Eigen Vector → $[E_i] = [[V_i]^T[M][V_i]][n]^{-1}$

Energy

$$[M] = \begin{bmatrix} m & 0 & 0 & 0 & 0 & 0 \\ 0 & m & 0 & 0 & 0 & 0 \\ 0 & 0 & m & 0 & 0 & 0 \\ 0 & 0 & 0 & I_{xx} & -I_{xy} & -I_{xz} \\ 0 & 0 & 0 & -I_{yx} & I_{yy} & -I_{yz} \\ 0 & 0 & 0 & -I_{zx} & -I_{zy} & I_{zz} \end{bmatrix}$$

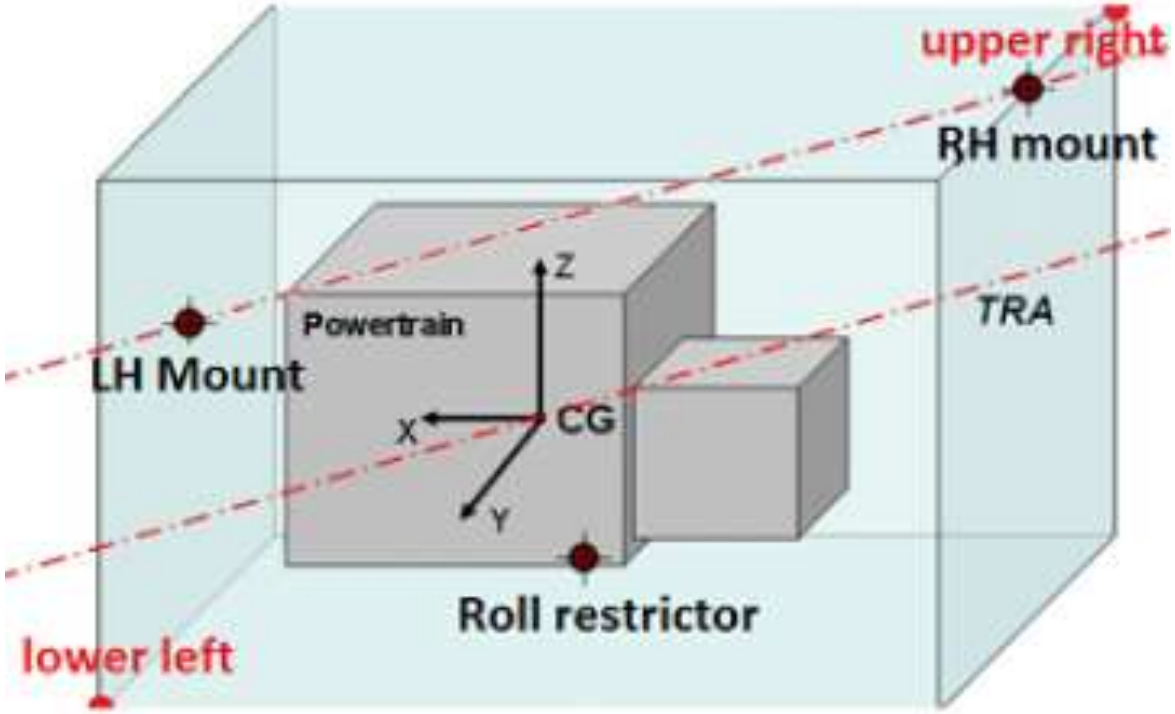
$$[K] = \sum_{i=1}^{n} [B_i]^T[T_i]^T[k_i][T_i][B_i]$$

$$[B_i] = \begin{bmatrix} 1 & 0 & 0 & 0 & z_i & -y_i \\ 0 & 1 & 0 & -z_i & 0 & x_i \\ 0 & 0 & 1 & y_i & -x_i & 0 \end{bmatrix}$$

$$[T_i] = \begin{bmatrix} \cos(X'X) & \cos(Y'X) & \cos(Z'X) \\ \cos(X'Y) & \cos(Y'Y) & \cos(Z'Y) \\ \cos(X'Z) & \cos(Y'Z) & \cos(Z'Z) \end{bmatrix}$$

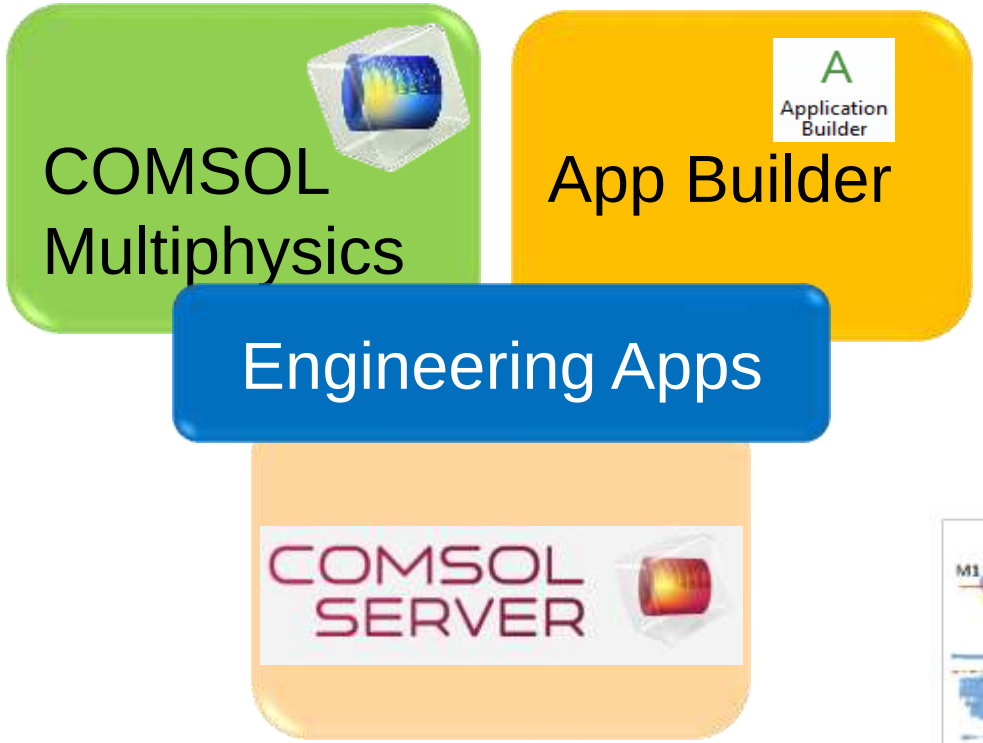
Analysis

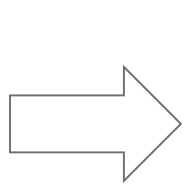
- Eigen Frequency Study
  - Eigen Frequency
  - Modal Shapes
- Stationary Study
  - Packaging
  - Mount Loads

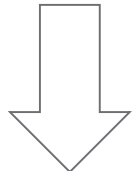


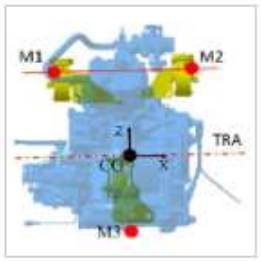
Web Based Mathapps GUI

- Deployment of the application on our web based portal across our organization “Mathapps”









Engine Mounts Kinetic Energy Distribution

Latest Version: **1.0**
Business Unit: **PTD**
Application Group: **Engines**
Application Type: **COMSOL**

This application can be used for engine mount KE distribution study

Launch

Help

COMSOL Application

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INPUT

Reset To | Stationary | Eigenfrequency | Generate | Email

Please choose the desired Load case and close the Dialogue Box: 1

1	Static Design Position (Under PT Self Weight)	12	Max reverse engine torque & rearward acceleration RWD(-0.5g)
2	Max forward Engine Torque	13	Max reverse engine torque & rearward acceleration AWD(-0.6g)
3	Max reverse engine torque	14	8 KPH front bumper (-11g)
4	Max Forward Engine Torque and forward accelerat	15	8 KPH rear bumper (+11g)
5	Max Forward Engine Torque and forward accelerat	16	Vertical up loading (+5g)
6	Max Forward Engine Torque and forward accelerat	17	Vertical down loading(-5g)
7	Max forward engine torque & +1g left cornering	18	Lateral left loading
8	Max forward engine torque & -1g right cornering	19	Lateral right loading
9	Max forward engine torque & -2g bump	20	Vertical +5g up & -3g lateral left loading
10	Max forward engine torque & +2g rebound	21	Vertical +5g up & +3g lateral right loading
11	Max reverse engine torque & rearward acceleratio	22	Vertical -5g down & -3g lateral left loading

Load Case
Maximum engine torqu
First gear ratio:
Reverse gear ratio:
Multiplication factor:
Stall torque ratio:
Acceleration due to gra
Final drive ratio:
Fx

RESULT

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Results

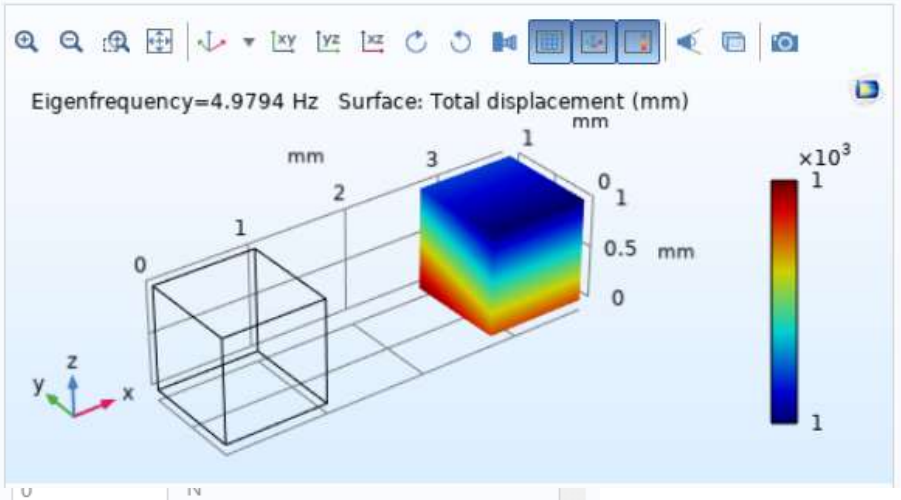
Eigenfrequency Study | Stationary Study

Kinetic Energy Distribution (%)

Eigenfrequency (Hz)	X	Y	Z	X-Rot	Y-Rot	Z-Rot
4.979	99.999	0	0	0	0.001	0
8.009	0.205	0.054	0	99.723	0	0.017
11	0	0	100	0	0	0
16.18	0.378	0.027	0	0.166	99.151	0.278
17.808	0	99.987	0	0	0	0.012
20.937	0.007	5.31	0	1.195	0.095	93.392

Mode Shapes

Eigenfrequency (Hz): 4.9794 Scale factor: 0.002731



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Correlation: Eigen Frequency

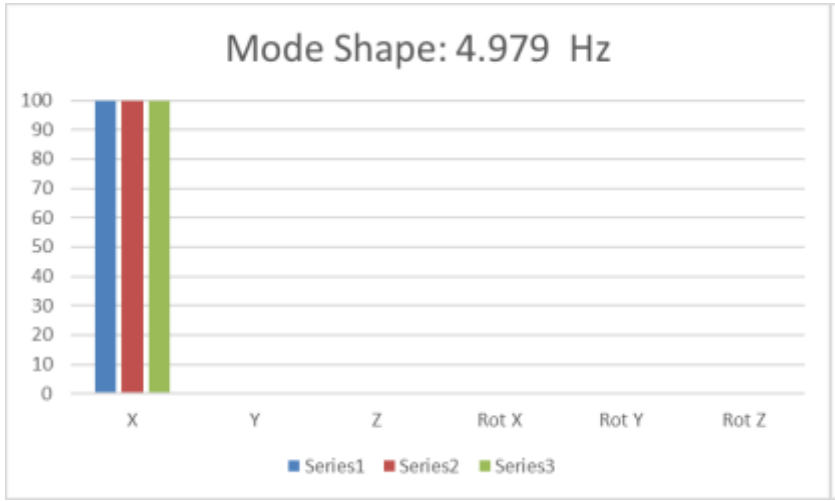
Eigen Frequency Correlation

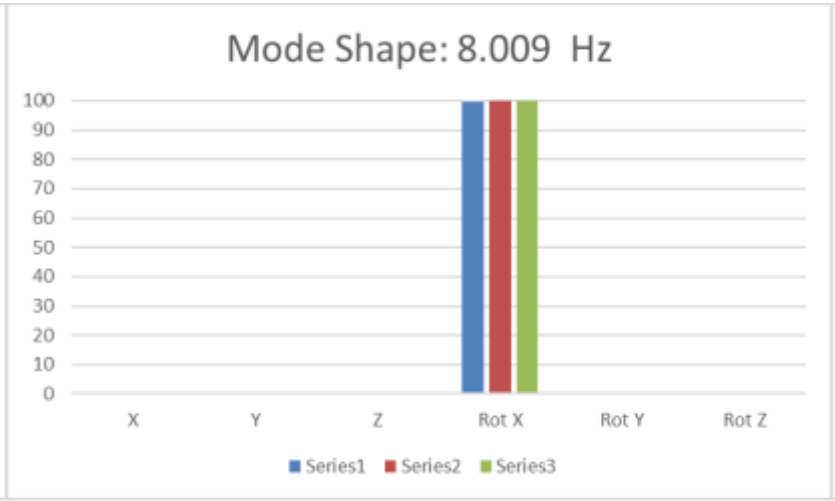
Result from Internal Tool	4.979	8.009	11	16.18	17.808	20.937
Result From a Global Commercial Tool	4.9679	8.0124	10.9958	16.3297	17.808	20.9531
Result From COMSOL	4.979	8.009	11	16.18	17.808	20.937

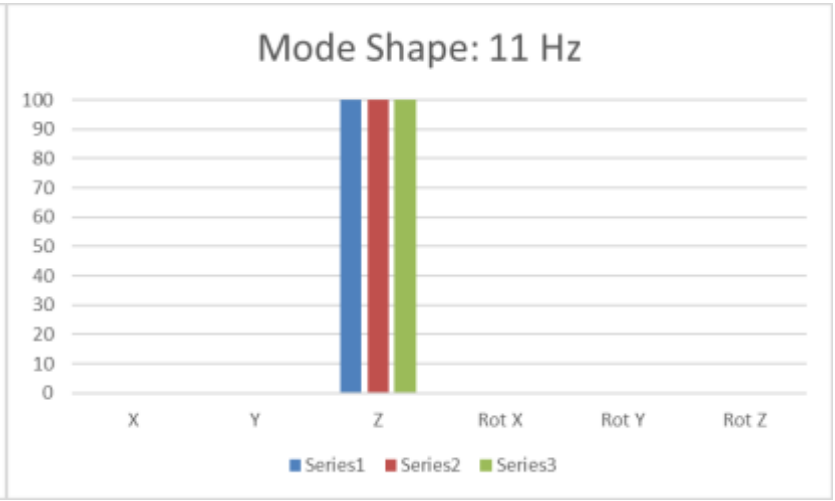
Result From COMSOL

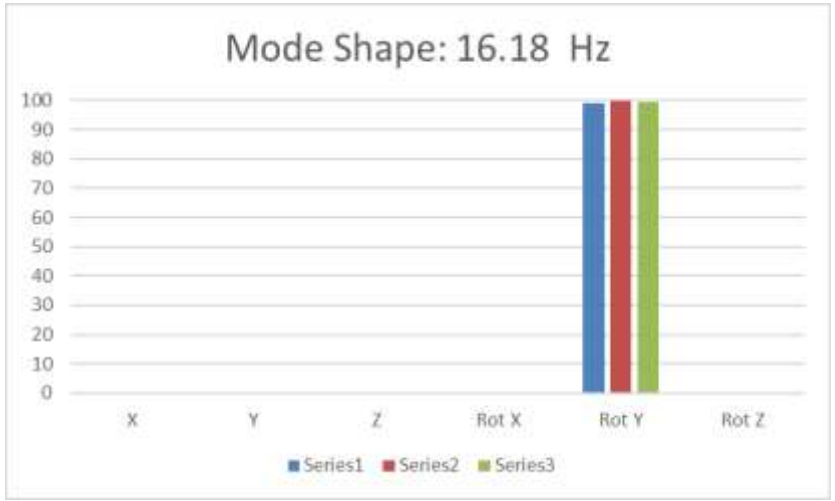
Modes (Hz)	4.979	8.009	11	16.18	17.808	20.937
X	99.999	0.205	0	0.378	0	0.007
Y	0	0.054	0	0.0027	99.987	5.31
Z	0	0	100	0	0	0
Rotation about X	0	99.723	0	0.166	0	1.195
Rotation about Y	0.001		0	99.151	0	0.095
Rotation about Z	0	0.017	0	0.278	0.012	93.392

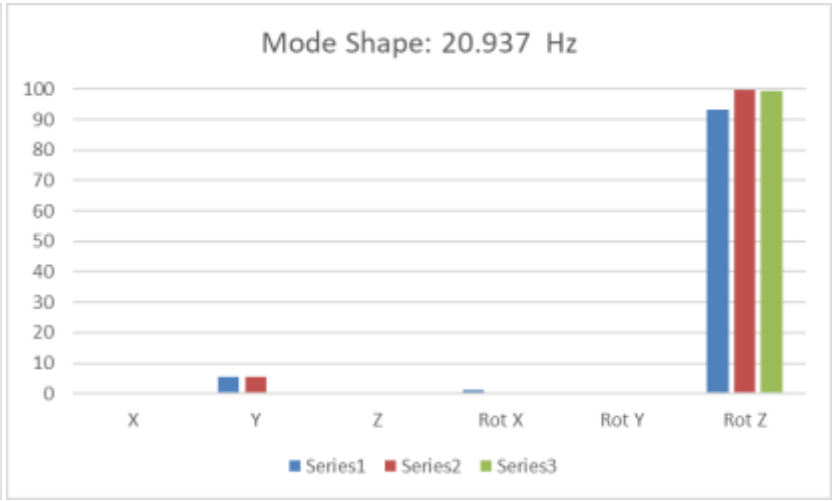
Correlation: Mode Shapes











Series1: Result from Internal Tool

Series 2: Result From a Global Commercial Tool

Series3: Result From COMSOL

Summary

- The application calculates the modal frequencies and Kinetic energy distribution of a decoupled system accurately
- Helpful for designer in the early phase of development
- COMSOL App builder was be used to prepare the customize applications (GUI) based on user requirement
- The web based portal deployment via COMSOL server gives access to any of the user across different locations in the organisation

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Thank You

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