Mercedes-Benz Research and Development India

Robustness Analysis in Vehicle Ride Comfort

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Agenda

- What is robustness ?
- Analysis objective and the approach.
- Robustness process for CAE.
- Input parameters.
- Prognosis results.
- Conclusions.

What is Robustness ?

A system or design is said to be "**robust**" if it is capable of coping well with variations (sometimes unpredictable variations) in its operating environment with minimal damage, alteration or loss of functionality.

Why consider variations?

- The real world is not perfect. In reality, all the components will have values that show scatter with respect to the ideal values.

Examples:

- Variations due to the engineering tolerances in test data like stiffness characteristics, damper characteristics …. etc.

The Objective and Approach

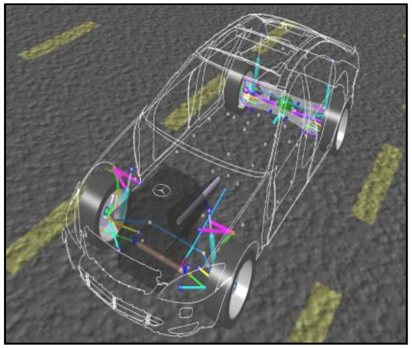
Objective :

- To investigate the effect of engineering tolerances on vehicle ride comfort.

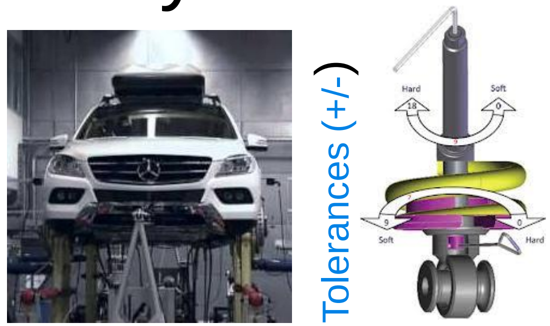
Approach :

- A set of design parameters which could have significant influence on ride comfort are selected and varied within the engineering tolerances.
- Various configurations are generated with a random combination of these variations.
- The configurations are driven on a virtual rough road at 60 kmph and their responses are analyzed to comprehend the robustness of the CAE model and their influence on vehicle ride.

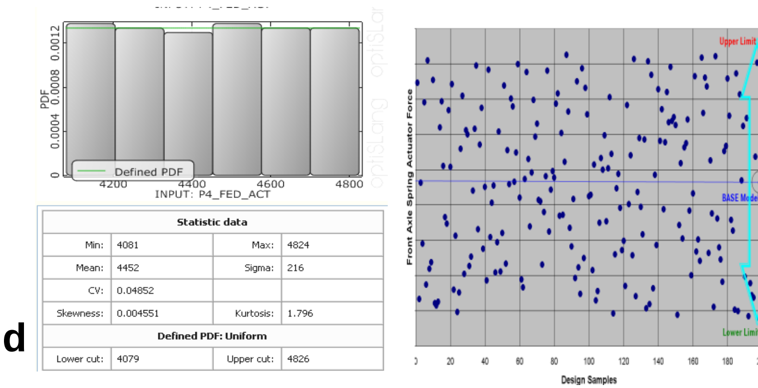
Robustness Analysis Flowchart



1 Digital Ride Model



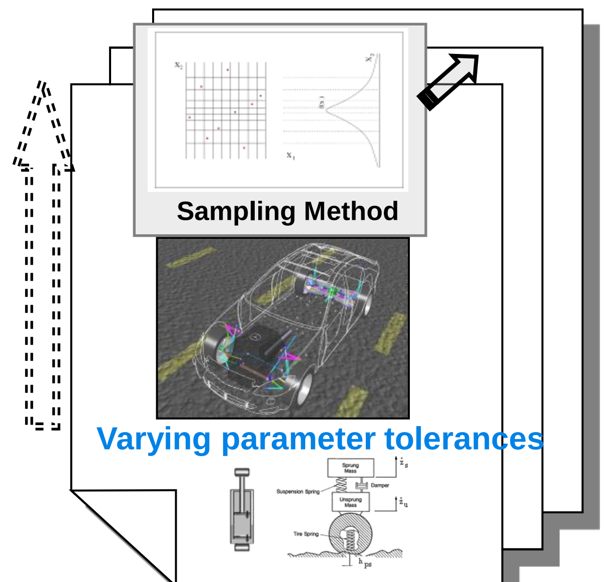
2 Identification of parameters and their real time tolerances



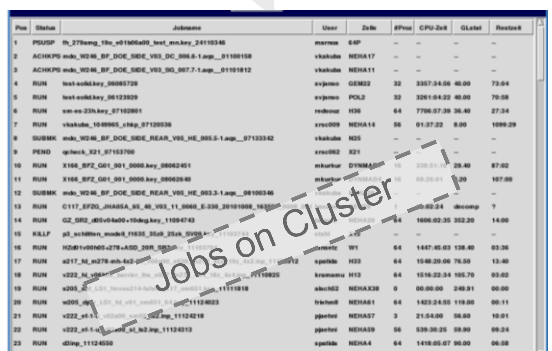
3 Defining the variations in the Parameters

Robustness

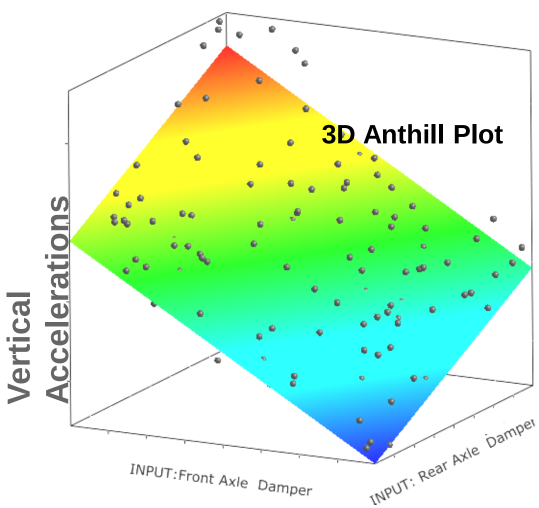
Process



4 Generation of Samples

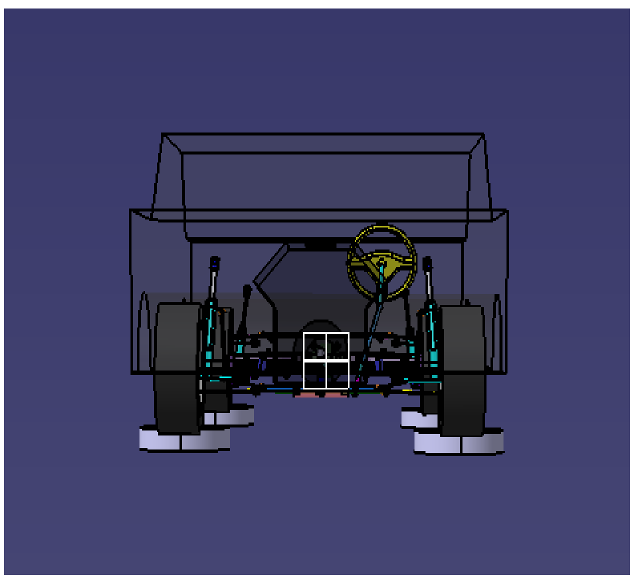


5 Computation of Samples

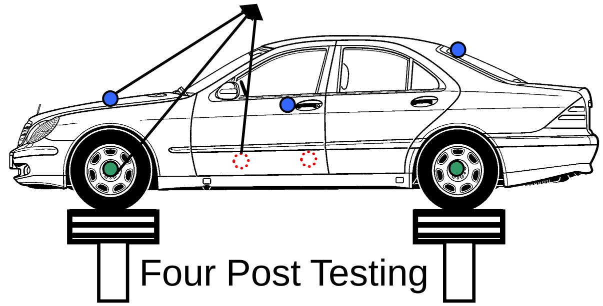


6 Analysis and Post processing

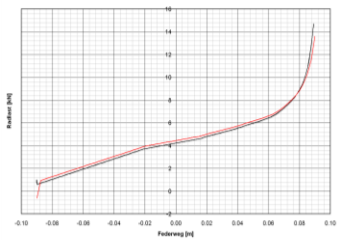
Real Vs Virtual Models

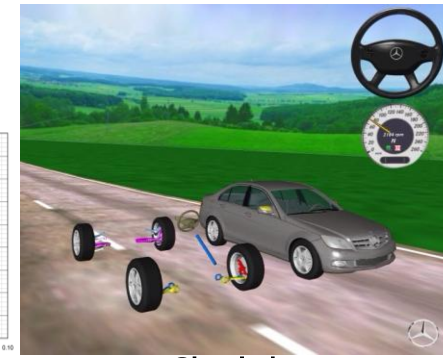


Sensor Locations for Vertical Accelerations



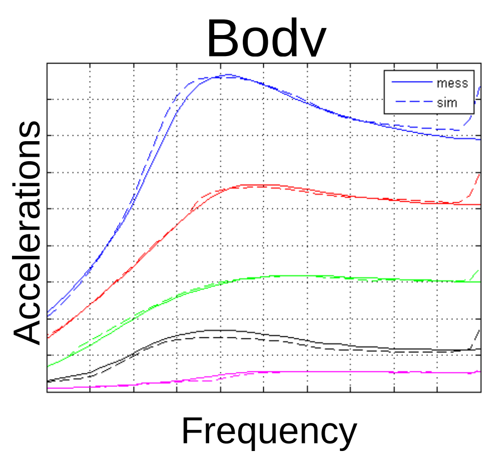
Measurement

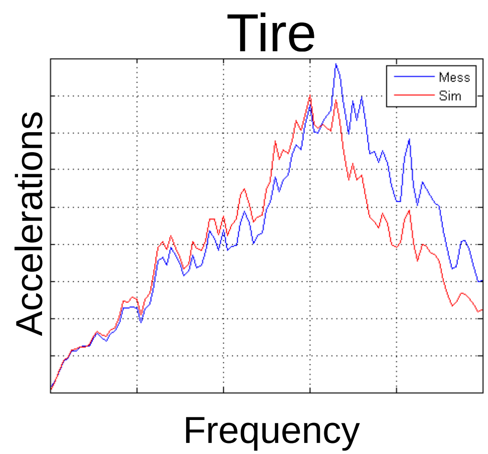




Simulation

Suspension K&C Simulations vs measurement





Varying Parameters used for the investigation

Input Parameters

Front Axle

- Guide Bearing Axial Stiffness
- Guide Bearing Radial Stiffness
- Guide Bearing Damping
- Comfort Bearing Stiffness
- Comfort Bearing Damping
- Damper Characteristics
- Bump stop stiffness
- Spring Stiffness
- Damper top mount damping
- Damper top mount stiffness
- Stabilizer Bar Stiffness

…

Rear Axle

- Torque Strut Mount Stiffness
- Torque Strut Mount Damping
- Upper Control Arm mount stiffness
- Lower Control Arm Mount Stiffness
- Spring Control Arm Mount Stiffnes
- Control Arm Mounts Damping
- Damper Characteristic
- Bump stop stiffness
- Spring Stiffness
- …

Miscellaneous

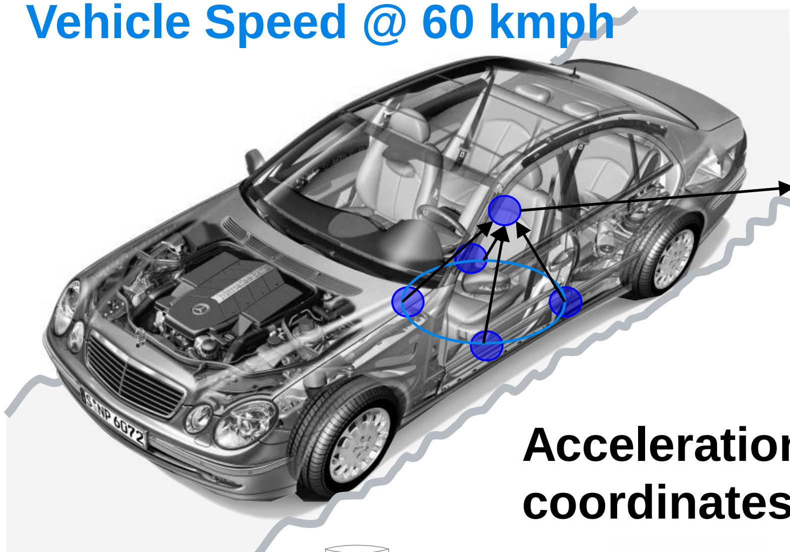
- Vehicle Clearence
- Engine Mount Axial Stiffness
- Engine Mount Radial Stiffness
- Gear Box Mount Axial Stiffness
- Engine Mount Radial Stiffness
- Engine/GearBox Mount Damping
- Engine Support Stiffness
- Vertical Tire Stiffness

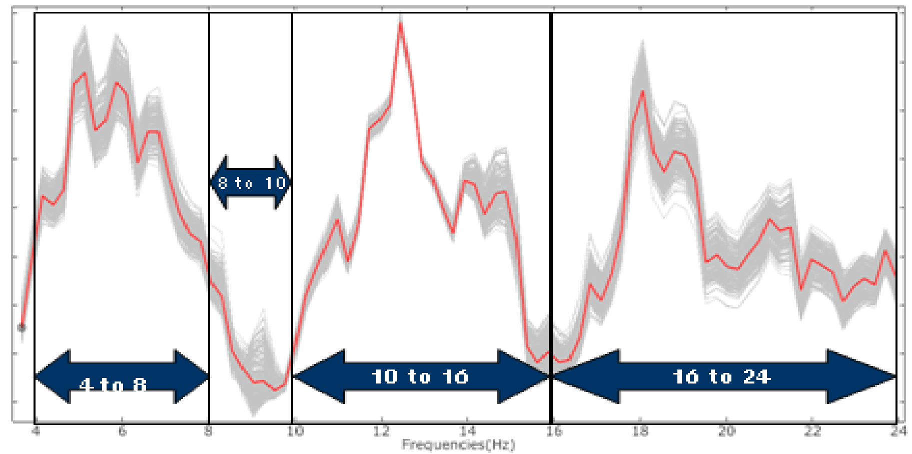
…

****The ride parameters and their tolerances are selected based on the real time testing experiences and from the supplier data.**

Virual-Lab to optiSlang

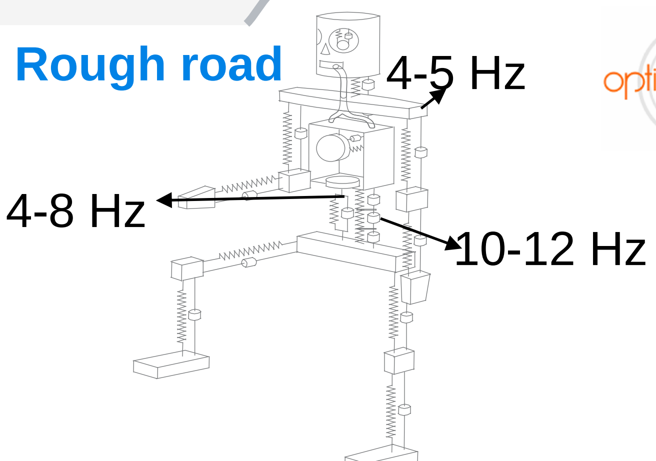
Vehicle Speed @ 60 kmph



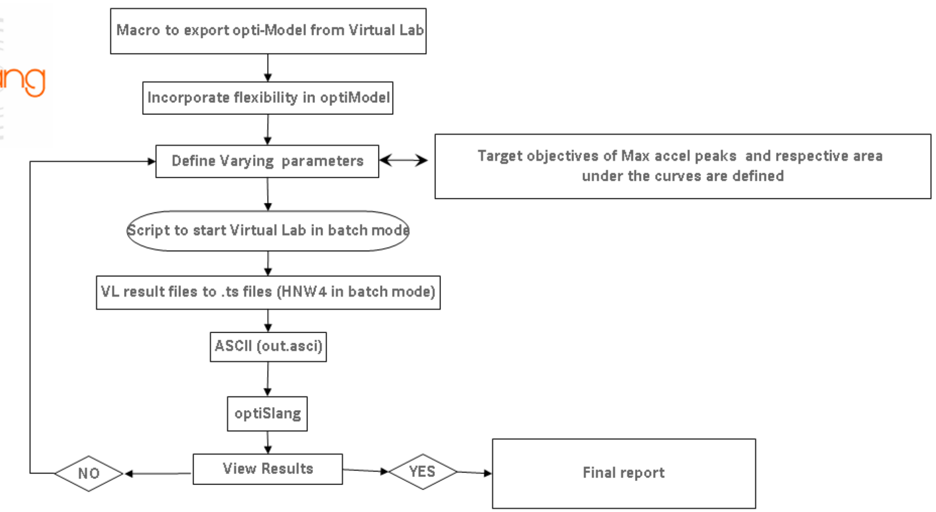


Accelerations are measured at the floor and coordinates transformed to the driver chest level

Rough road

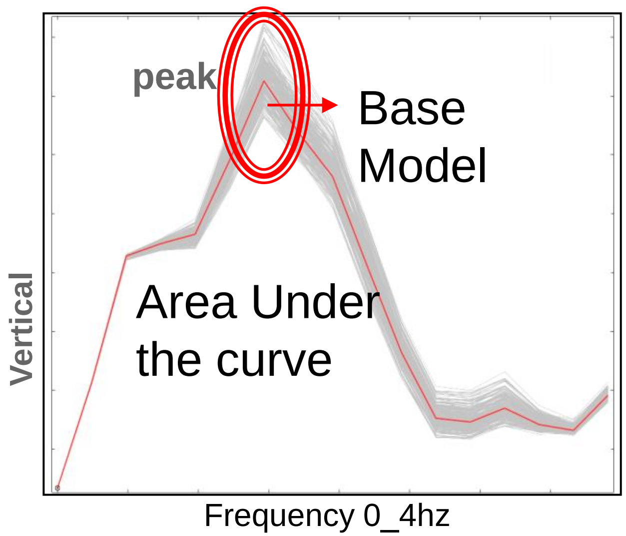


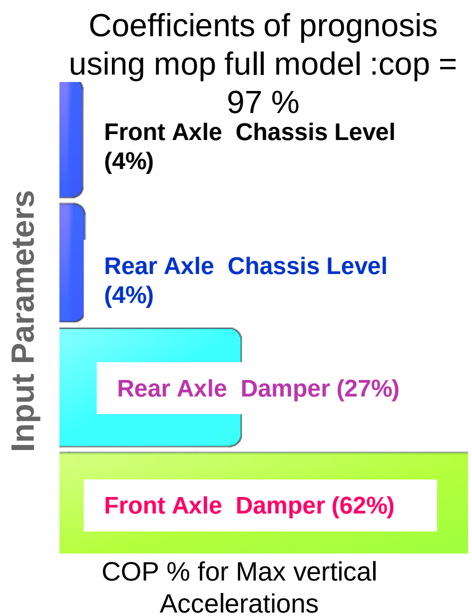
Human Sensitivity to vibrations

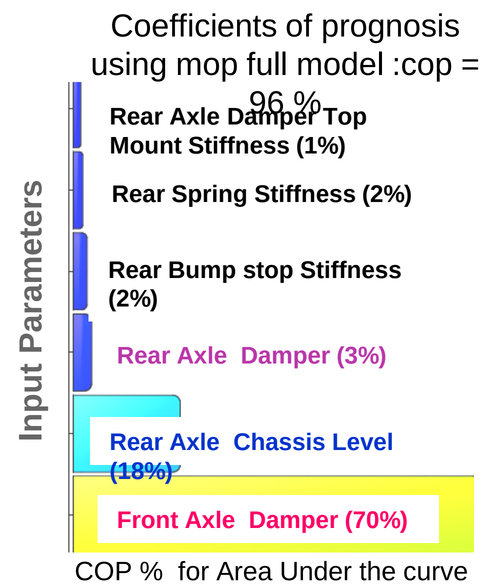


Prognosis 0–4 Hz

- ➢Change in acceleration peak– max 13% & min 9%
- ➢Change in Area– max 8.5 % & min 6.15 %







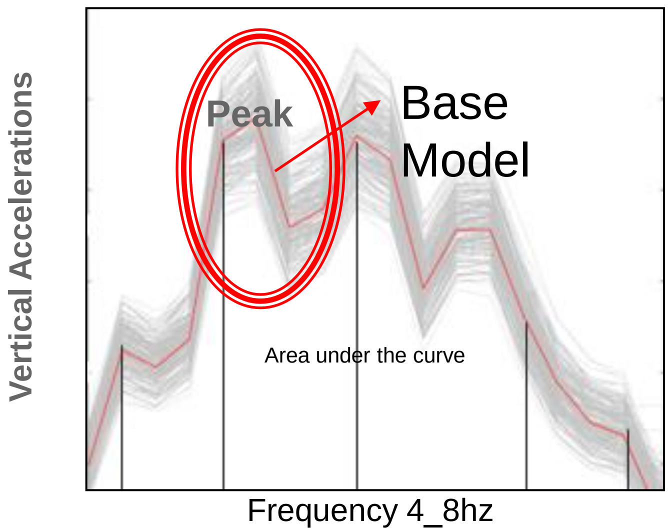
- The coefficient of prognosis for the peak max acceleration in “0 to 4”Hz show that this value is influenced primarily by the front dampers followed by the rear axle dampers.

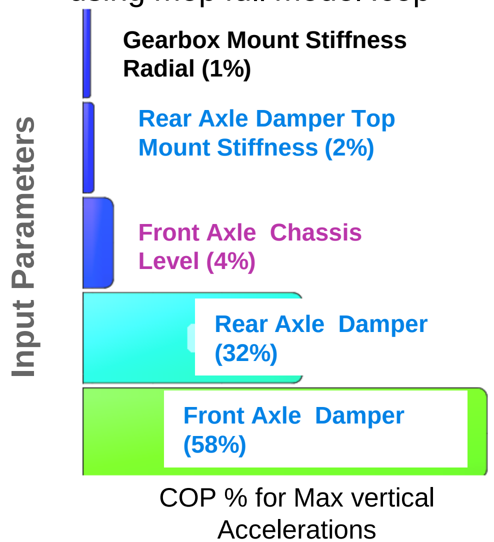
- The coefficient of prognosis for the area is influenced primarily by the front axle dampers followed by the chassis level.

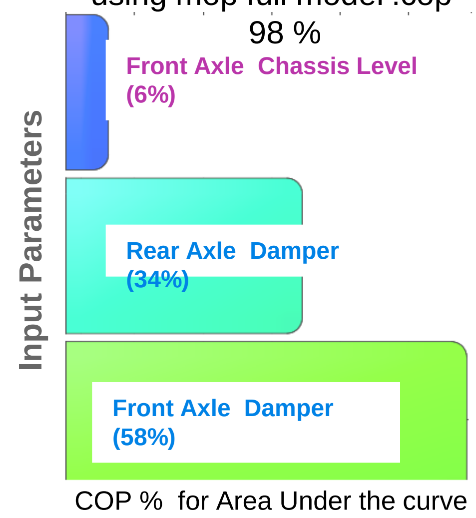
Prognosis 4–8 Hz

➢Change in acceleration peak– max 9.5% & min 10%

➢Change in Area– max 8.5 % & min 8.7 %



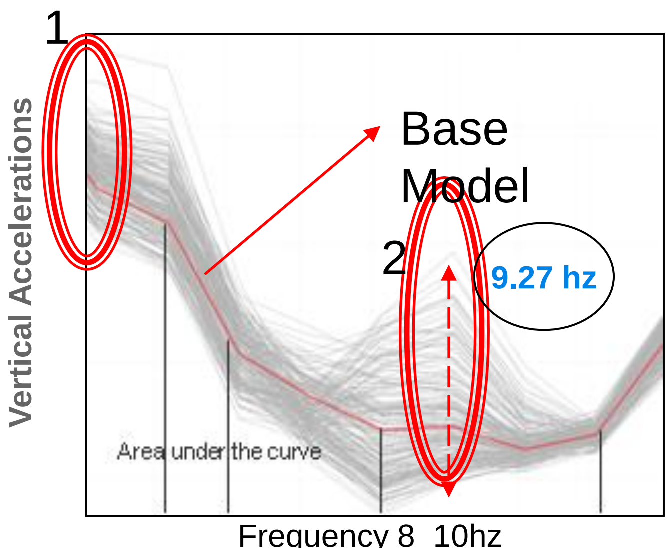




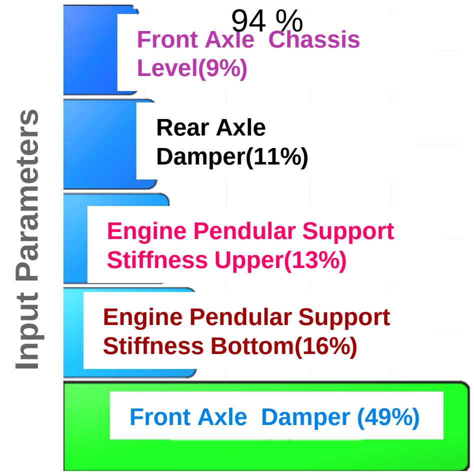
- Front axle damper followed by the rear axle damper are the primary and secondary influencing parameters in the frequency range of 4 to 8 Hz.

Prognosis 8–10 Hz

- Change in acceleration peak– max 16% & min 8.2%
- Change in Area– max 10 % & min 8 %

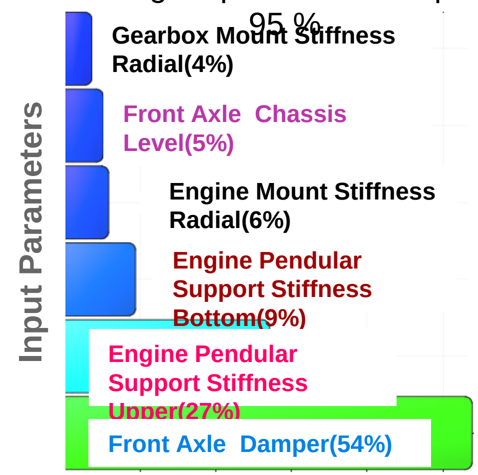


Coefficients of prognosis using mop full model :cop = 94 %

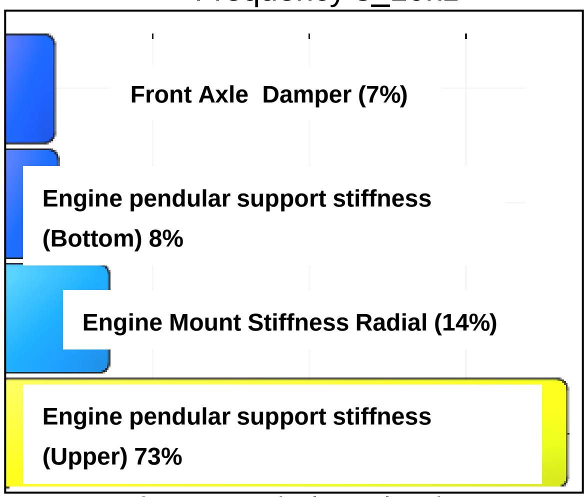


COP % for Max vertical Accelerations @1

Coefficients of prognosis using mop full model :cop = 95 %



COP % for Area Under the curve

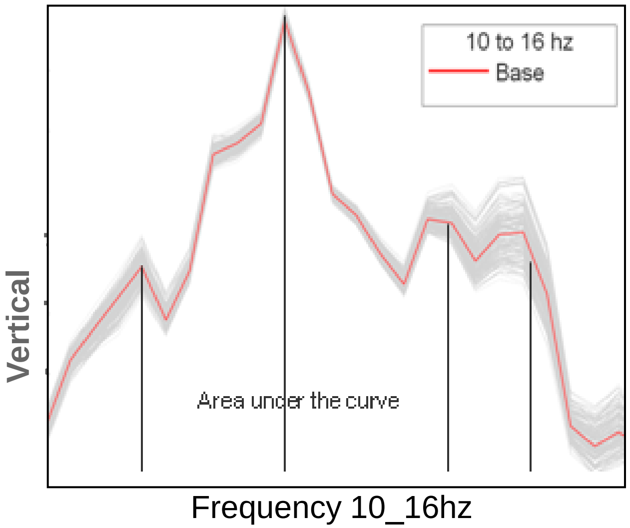


COP % for Max vertical Accelerations @ 2

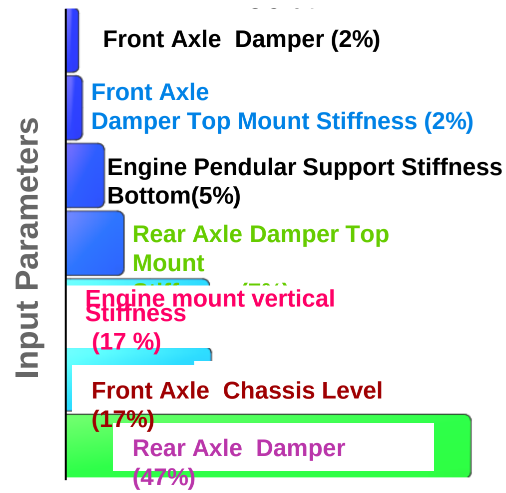
- In the frequency range of 8-10Hz the front damper is the most influencing parameter.
- Engine support bushing which provides longitudinal stiffness is the major influencing parameter for the peak acceleration at 9.27 Hz

Prognosis 10–16 Hz

- ➢Change in acceleration peak– max 2.19% & min 2.17%
- ➢Change in Area– max 4.79 % & min 3.4 %



Coefficients of prognosis using mop full model :cop =



COP % for Max vertical Accelerations

Coefficients of prognosis using mop full model :cop = 98 %

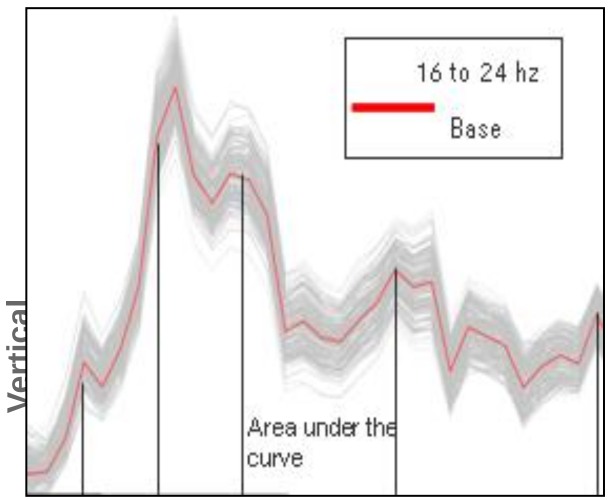
COP % for Area Under the curve

- The prognosis plots show that the max acceleration is influenced primarily by rear dampers followed by engine mount characteristics.

- Front axle comfort bearing is primarily contributing to the area under the response curve followed by rear axle torque strut mount stiffness.

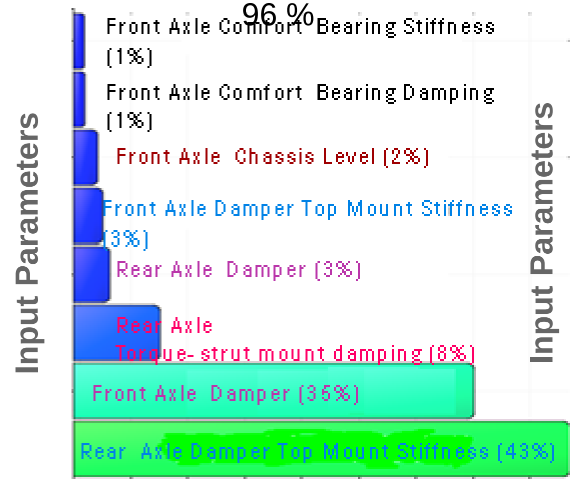
Prognosis 16–24 Hz

- ➢Change in acceleration peak– max 10. 5% & min 11.5%
- ➢Change in Area– max 9.38 % & min 11.87 %



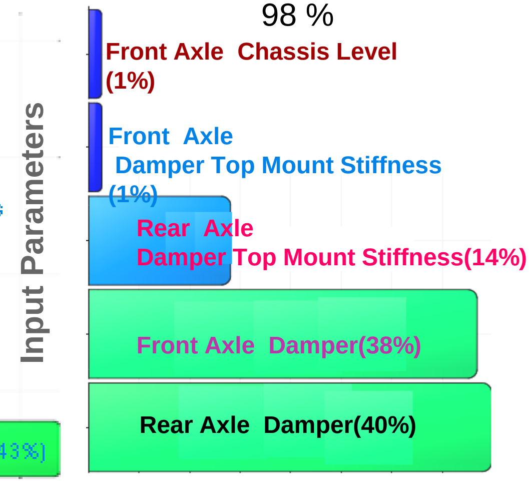
Frequency 16_24hz

Coefficients of prognosis using mop full model :cop = 96 %



COP % for Max vertical Accelerations

Coefficients of prognosis using mop full model :cop = 98 %



COP % for Area Under the curve

- The prognosis plots show that the peak response acceleration is influenced primarily by rear axle damper top mount stiffness followed by front axle damper.
- Rear dampers are primarily contributing to the area under the response curve followed by front axle dampers

Conclusion

- The CAE model is very robust in the frequency range of 10-16Hz with minimum variations in the response.
- At 4-8Hz where the maximum human sensitivity to vertical vibration is perceived, the response due to the variations in the engineering tolerances are in the range of +/-10% .
- The maximum effect of the variation in the tolerances are visible in the frequency range of 8–10Hz where the change in maximum vertical accelerations are up to 16%.
- The investigations show that the damper characteristics has the biggest influence on ride comfort.

Future Scope of the work

- To implement the robustness process in all the car variants so as to investigate the effect of critical parameters and their tolerances effect on ride comfort.