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Procedure to verify the dynamic behaviour of the Suspension System on vehicle inspection

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Procedure to verify the dynamic behaviour of the suspension system on vehicle inspection

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Current situation

- The suspension system plays an important role in the safety drivability of a vehicle
- To maintain the system in correct safety conditions it is necessary to know its performance during the life of the vehicle
- The brake system has an objective check method and validation criteria, regulated by a CE directive that must be met for approval of the vehicle in order to determine the system effectiveness

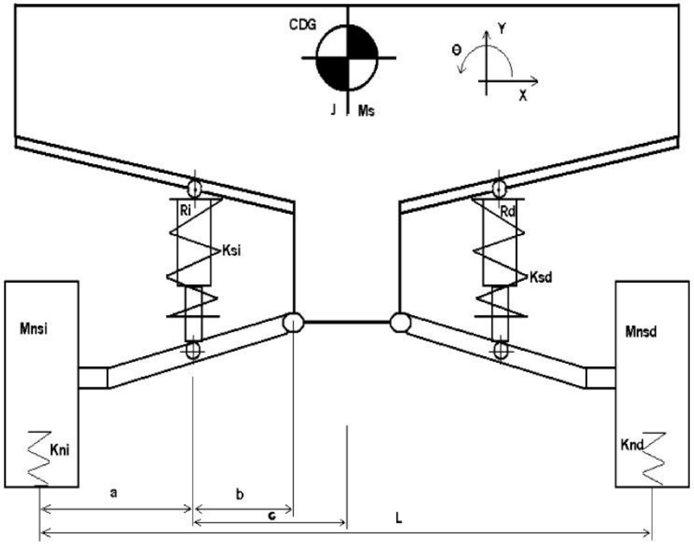
Current situation

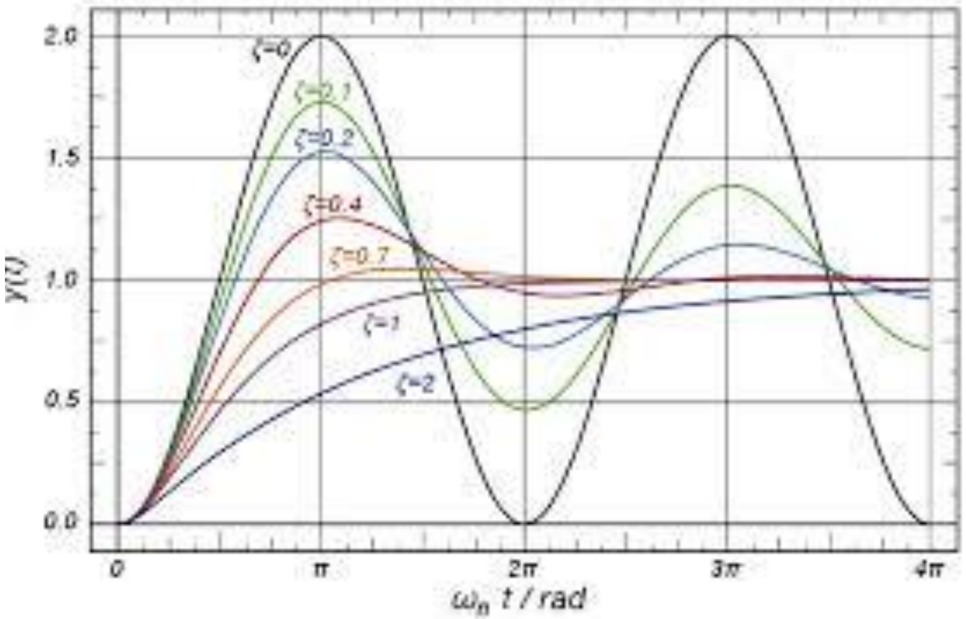
- To test the suspension, a vibrating platform test bench is currently being used, but the test method and validation criteria are not reliable at the present
- Two main systems coexisting in PTIs
  - Force measuring based systems
  - Displacement measure based systems
- In both cases the result of the test is based in a criteria in function of the maximum amplitude (resonance) in relation with the static value, expressed in percentage
- Both the test method and validation criteria are inadequate and can lead to results that may be false

New suspension measuring system (Damping coefficient)

- The procedure is to determine the damping coefficient of the suspension system.

- The damping coefficient, defined as the quotient of system damping and critical damping (damping with no oscillating movement)





New suspension measuring system (Damping coefficient)

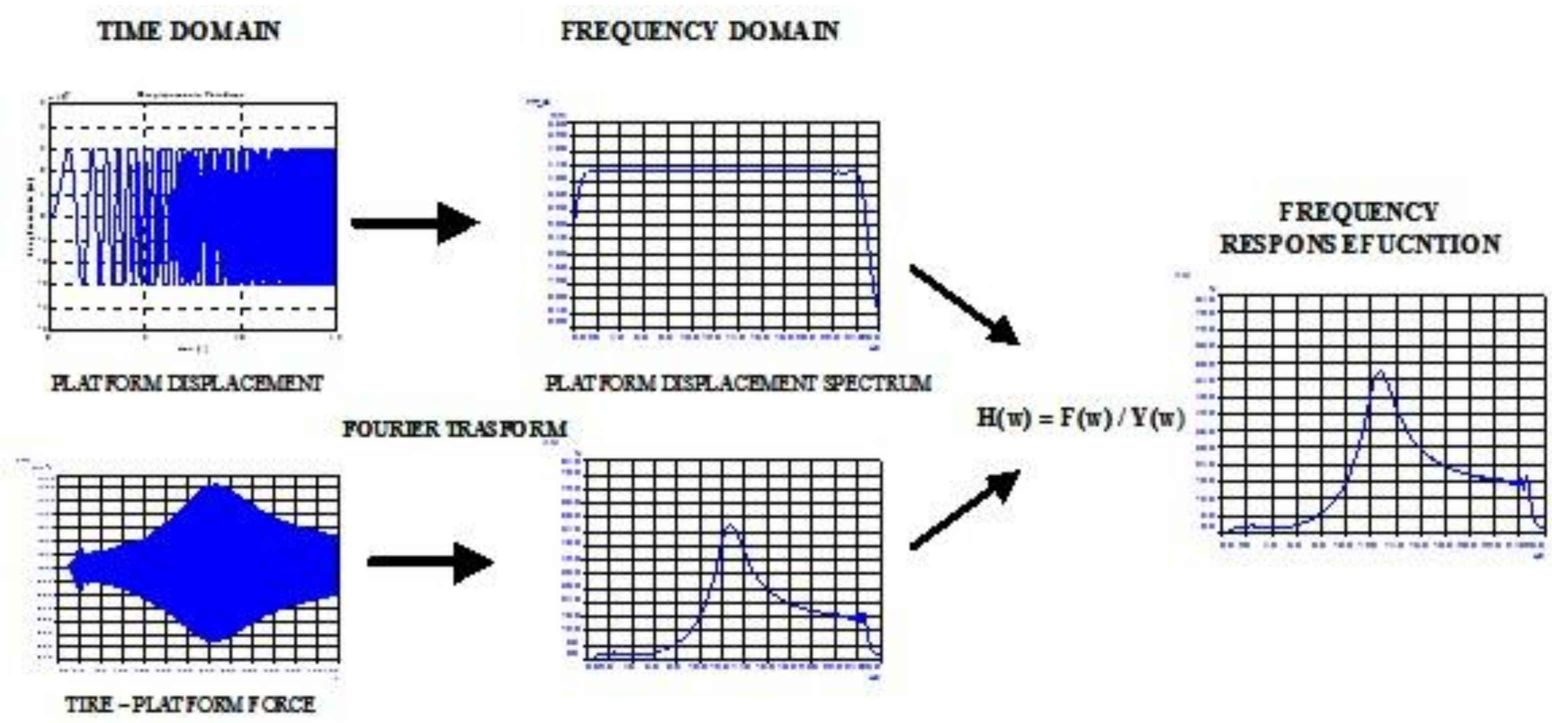
- To get the correct measurement is needed to excite the system with enough frequency broadband and energy

- Based on current Eusama bench. Following modifications have been made:

  - Excitation starting frequency has been decreased from 25Hz to 4 Hz
  - Excitation run has been increased from 6 to 25mm
  - Flywheel has been substituted by inverters to command the frequency slope down ramp (0.1Hz/s)
  - The platform-tire force has been measured
  - A new signal processing has been designed

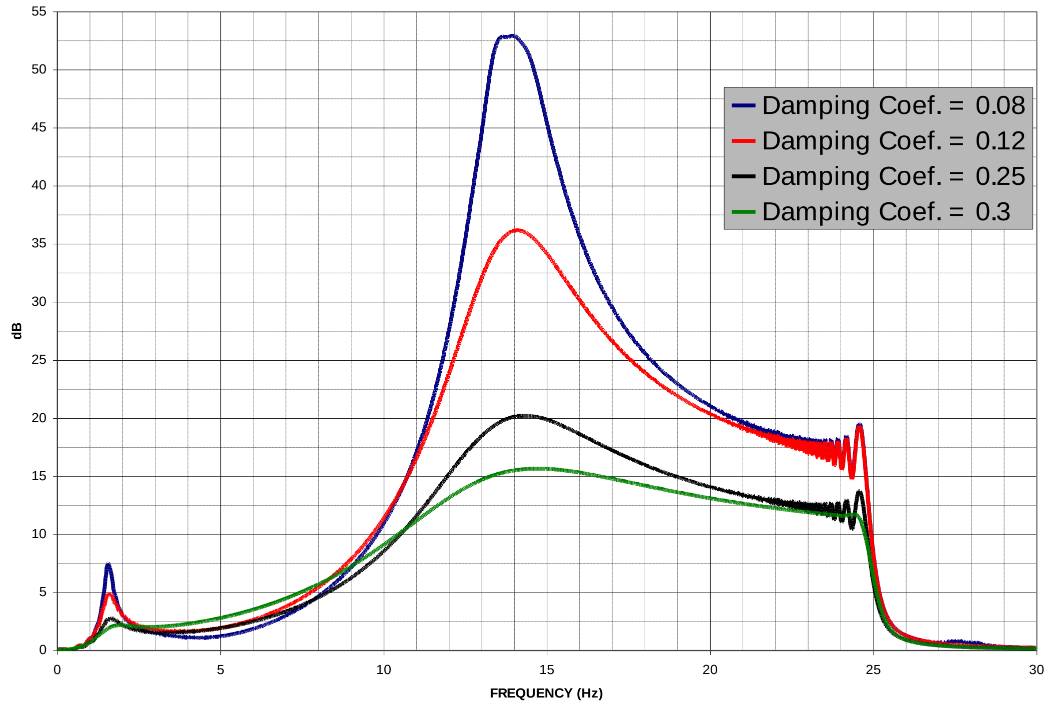
New suspension measuring system (Damping coefficient)

- The measured tire-platform force signal has been transformed to frequency domain through Fourier Transformer in order to obtain the Frequency Response Function (FRF)

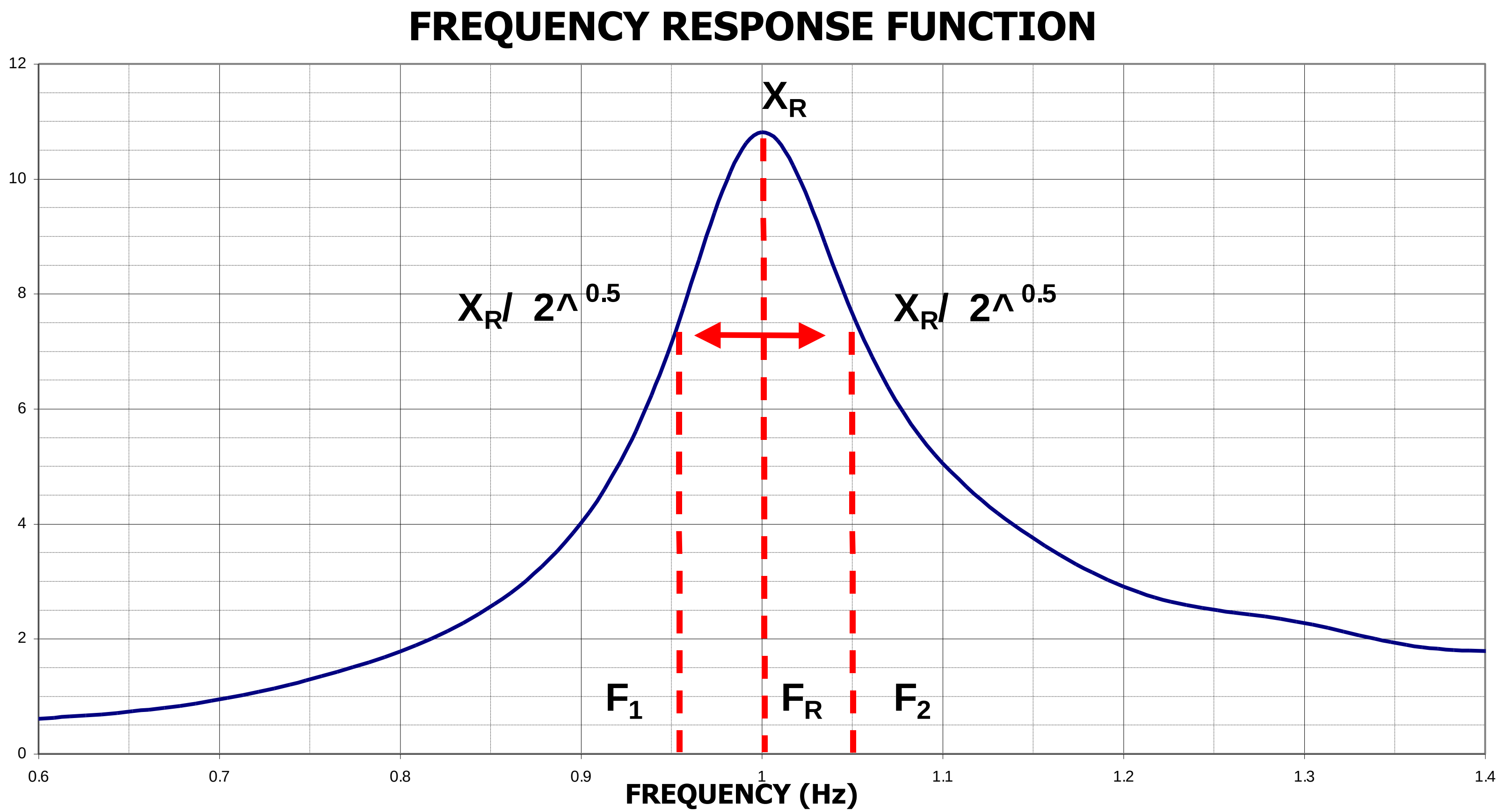


New suspension measuring system (Damping coefficient)

- When Damping Coefficient changes the sprung resonance peak shape varies significantly
- It allows to determining shock absorber damping coefficient



New suspension measuring system (Damping coefficient)



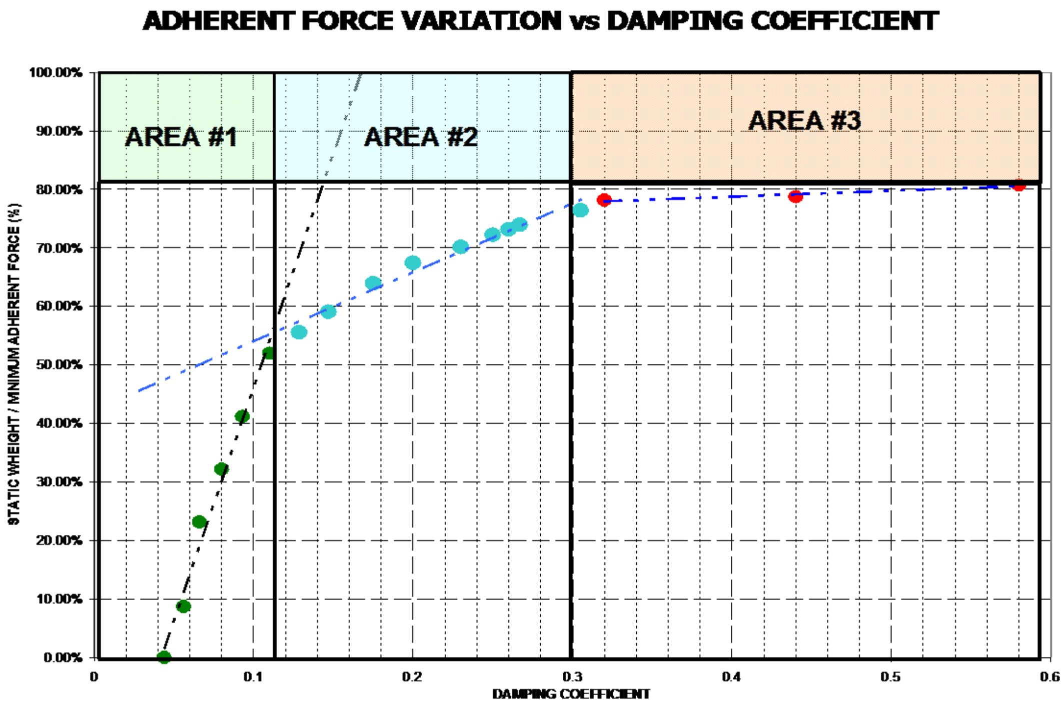
New suspension measuring system (Damping coefficient)

- This value could be estimated from the shape of the Resonance Peak on FRF.
- The Frequency (FR) and Amplitude (XR) value on the resonance peak is obtained.
- After the frequencies F1 & F2 have been determined by measuring the amplitude values that reduce half power from resonance peak.

$$\xi = \frac{(2*\pi*F_2)^2 - (2*\pi*F_1)^2}{4*(2*\pi*F_R)^2} \qquad \xi = \frac{C}{C_{critical}}$$

New suspension measuring system (Damping coefficient)

- Using as analysis parameters:
  - Minimum adherent force measured between tire and platform (time domain) called “Fad”
  - Damping coefficient measured by the method above indicated called “ξ”



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New suspension measuring system (Damping coefficient)

- Observing the behaviour of these parameters three different areas have been found:
  - Area #3. Corresponding with values of ξ >0.3. In this area variation of ξ do not modify significantly the value of Fad.
  - Area # 2. Corresponding to values between 0.2 < ξ < 0.3. In this area Fad varies significantly when ξ is modified.
  - Area # 1. Corresponding to values 0.15 < ξ. In this area loss of Fad when ξ changes is very significant. Little variation of ξ involves an important reduction of Force transmission capacity from tire to road.

New suspension measuring system (Damping coefficient)

- Using a different vehicle configuration, the inflection point between "Area #1" to "Area #2" maintains very similar values.

- This fact allows us to establish a minimum damping factor below which, suspension system performance decreases significantly and driving safety could be seriously affected.

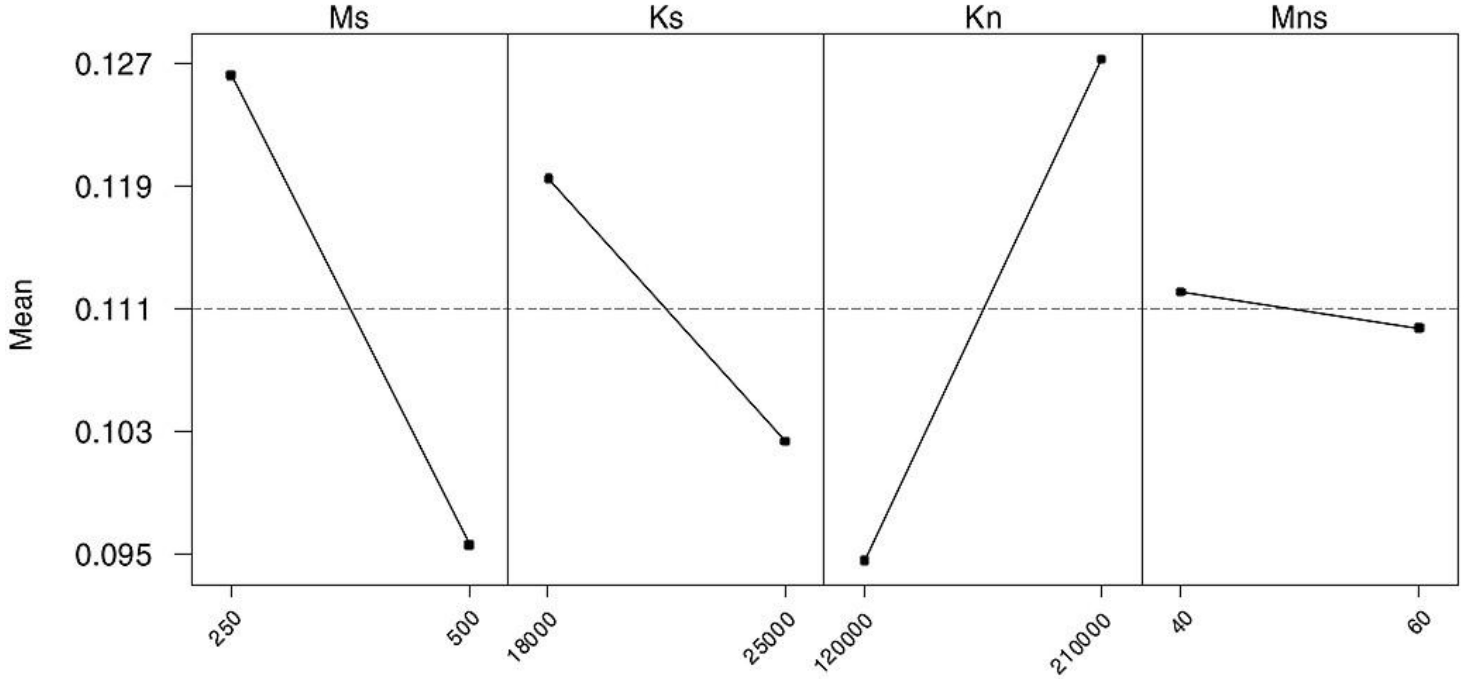
It will be called: "Limit Damping Coefficient" (ξ lim)

It is the damping coefficient value that produces the change from Area #1 to Area #2.

ξLimit = 0.12

New suspension measuring system (Damping coefficient)

- Through a Taguichi experiment design, we can study the influence of different design parameters

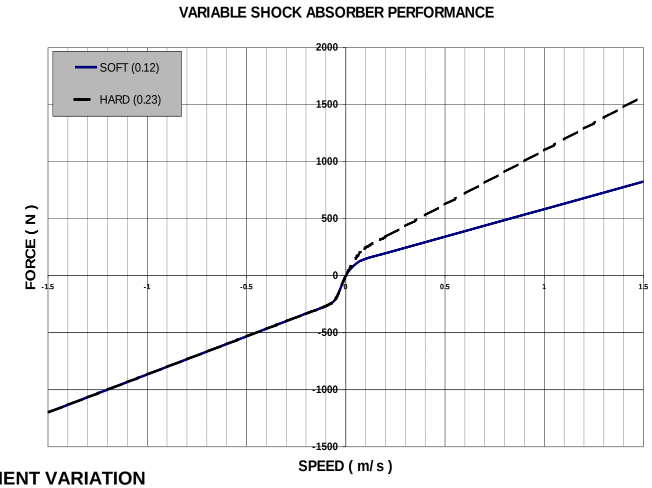


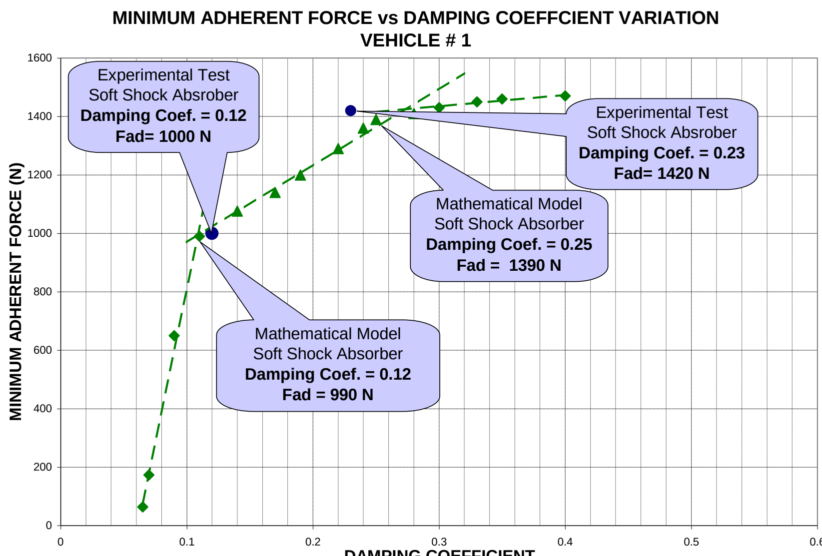
Ms→Sprung Mass(kg) Ks→Suspension stiffness(N/m) Kn → Tyre stiffness (N/m) Msn → Unsprung mass (kg)

Experimental tests

- Model based results have been verified by experimental tests.
- Using:
  - A prototype of vibrating platform test bench
  - A vehicle equipped with variable shock absorbers

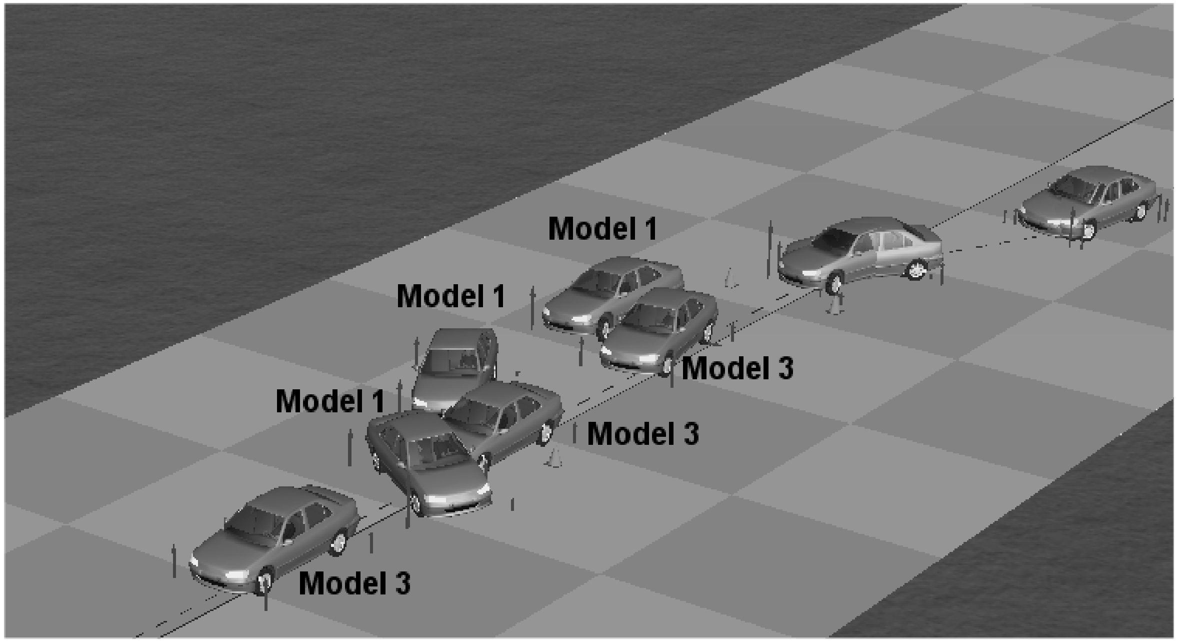
New suspension measuring system (Damping coefficient)





Experimental tests

- Lost of vehicle performance under "Limit damping Coefficient" has been confirmed by model based simulation (CarSim)



Experimental tests

- Vehicle lateral stability
  - Through an ISO double line change test
    - Reduce the overturn speed from 110 km/h (shock absorber in good condition) to 100 km/h (shock absorber under “Limit Damping Coefficient”)

- Vehicle longitudinal performance
  - Through a Directive 98/12 CEE brake test
    - Increase the brake distance from 77m (shock absorber in good condition) to 92m (shock absorber under “Limit Damping Coefficient”)
    - Test performed at rough road

Conclusions

- Suspension system status can be achieved by vibrating platform test bench
- Characterizing dynamic behaviour of suspension system in vibrating test bench is sufficient to excite sprung mass resonance
- Through FRF it is possible to determine the damping coefficient of the shock absorber
- A “Limit Damping Coefficient” as a validation criteria has been established, below which dynamic behaviour of vehicle demonstrates outstanding loss of performance.
- Computer model results have been confirmed by experimental test with enough accuracy

Thank you!