Simulating Advanced Damping Technologies

Janusz Gołdasz, Ph.D.

Vehicle Dynamics Expo 2010
22-24 June, Stuttgart, Germany

© BWI Group 2009. All rights reserved.

This document is the property of BWI Group. It may not be copied or disclosed to a third party without the explicitly written consent of BWI Group.

BWI Group and Technical Center Kraków

BWI Group acquired Suspension and Brakes business lines from Delphi in 2009
- 3 technical centers (Dayton, Paris, Krakow)
- 4 manufacturing plants (Krosno, Chihuahua, Luton, Fangshan (opens in 2011))

TECHNICAL CENTER KRAKOW:
- Passive Dampers & Damper Modules Global Engineering Center
- Suspension Components Engineering (MR dampers, ASBS components)

Suspension headcount: 231
- Product, Manufacturing, Industrial Engineering
- CAD & CAE & Simulation
- Prototype Center
- Test & Validation Lab
- Metrology & Materials Lab
- Valving Lab & Ride Vans
- Supporting Functions (Purchasing, Finance, Logistics, Administration)

© BWI Group 2009. All rights reserved.

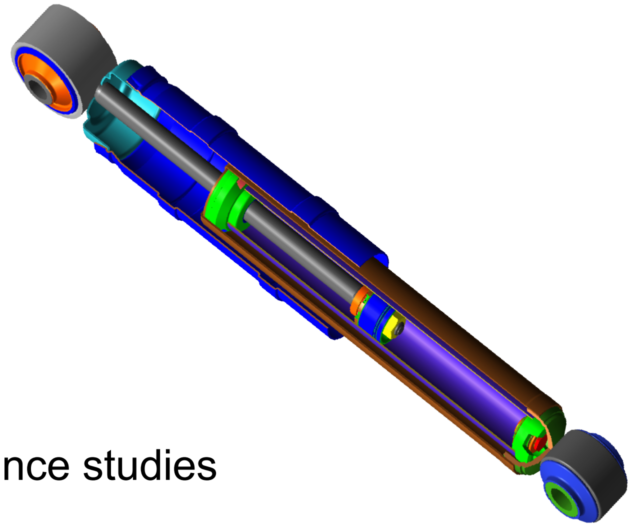
This document is the property of BWI Group. It may not be copied or disclosed to a third party without the explicitly written consent of BWI Group.

Damper Modeling Tools @ BWI

© BWI Group 2009. All rights reserved.

This document is the property of BWI Group. It may not be copied or disclosed to a third party without the explicitly written consent of BWI Group.

- BWI has utilized damper modeling tools since 1990s
  - Support for nearly every passive or semi-active shock absorber configuration developed in-house
- Own codes that have been under continuous development and updated (improved) over the years

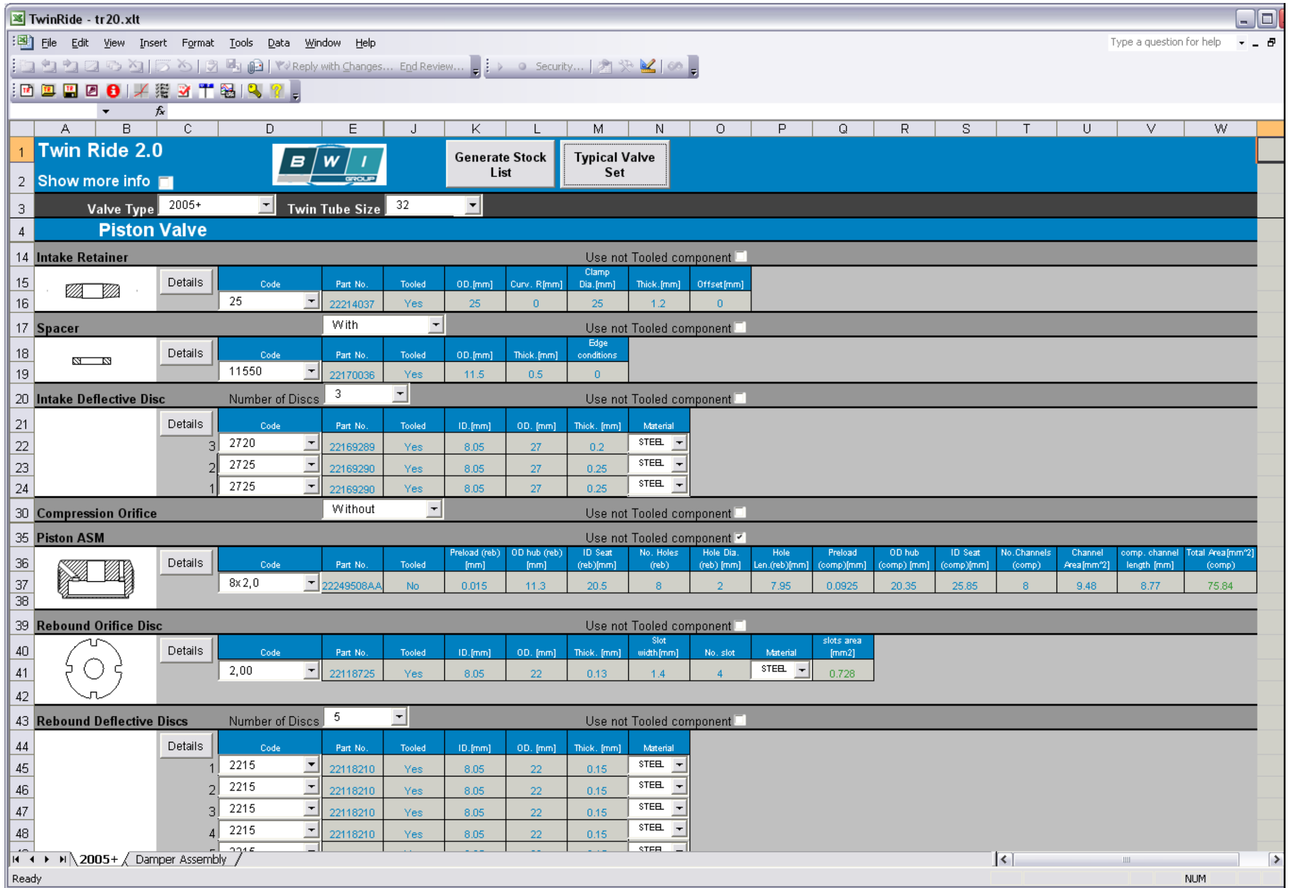


- Advantages
  - Accelerate damper & vehicle tuning, RFQ
  - Less iterations in the lab with the hardware
  - Valuable insight into damper physics
  - Analysis of damper design, incl. sensitivity and tolerance studies
  - Synthesis of damper design – design optimisation
  - Great learning tool for technicians and the engineering community
  - Valuable aid in valve code selection & proofing
  - Computer aided investigation, e.g. tracing assembly errors

© BWI Group 2009. All rights reserved.

This document is the property of BWI Group. It may not be copied or disclosed to a third party without the explicitly written consent of BWI Group.

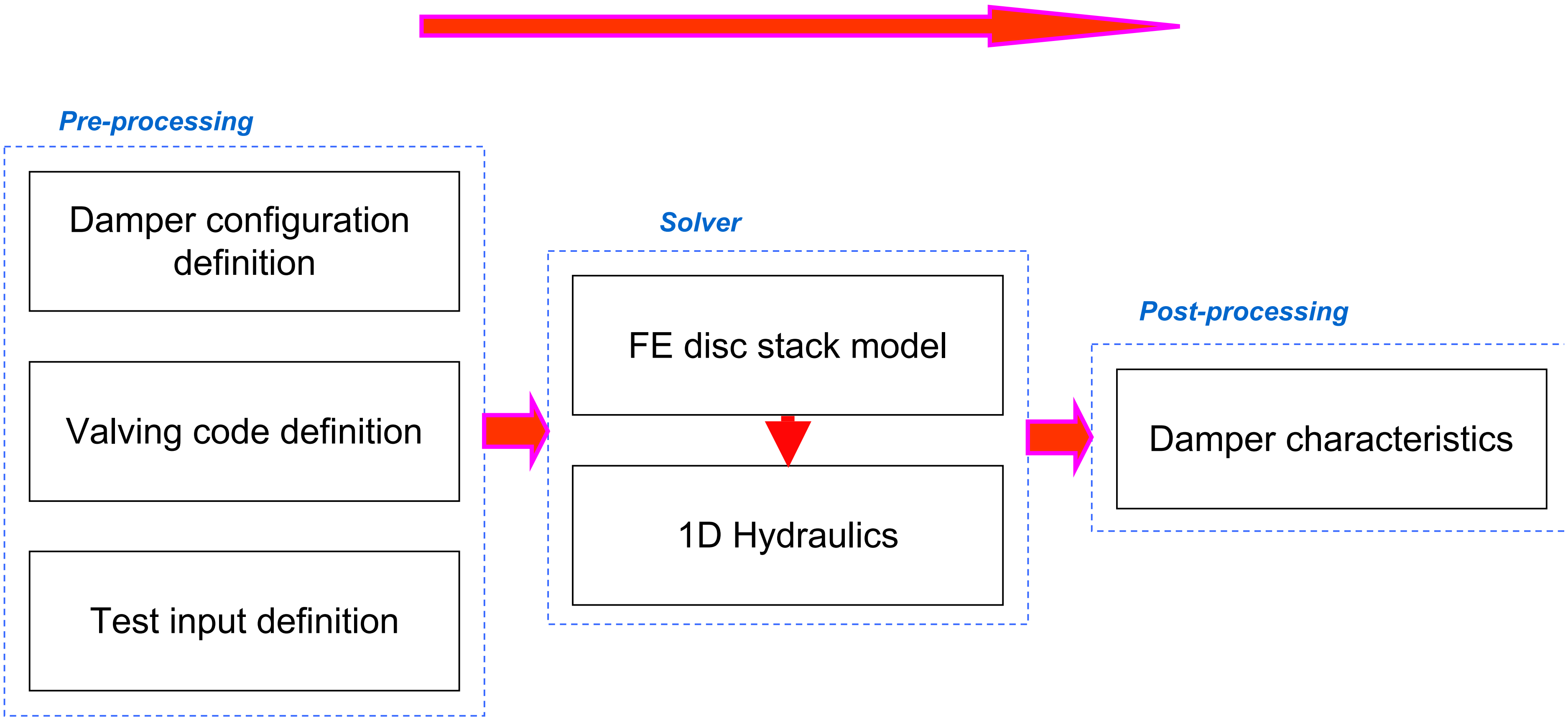
- TwinRide is our standard tool for damper design and modeling
- Unified User Interface with a connection to a database of components



© BWI Group 2009. All rights reserved.

This document is the property of BWI Group. It may not be copied or disclosed to a third party without the explicitly written consent of BWI Group.

Typical Architecture



Passive dampers only

© BWI Group 2009. All rights reserved.

This document is the property of BWI Group. It may not be copied or disclosed to a third party without the explicitly written consent of BWI Group.

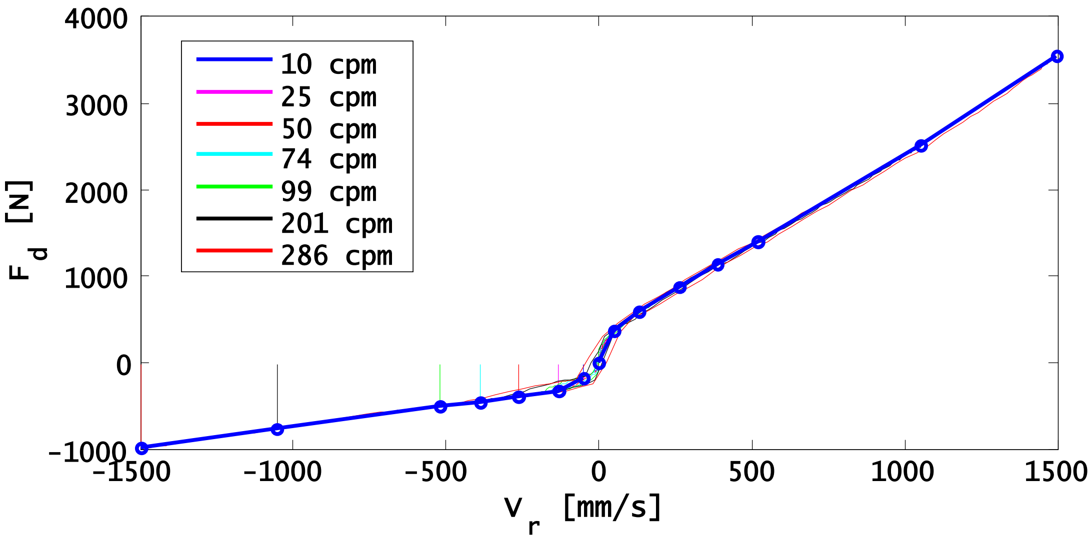
- Modeling features
  - Force vs. Velocity, Force vs. Displacement phase planes prediction (hysteresis)
  - Steady-state Force vs. Velocity curve prediction
  - Oil-gas mixture compressibility
  - Fluid aeration
  - Gas-to-liquid transformation equations
  - Global cavitation model
  - Tube flexibility (expansion with pressure)
  - Leakage rate past piston and rod guide assemblies
  - Piston, rod guide, spring seat friction
  - Functional math-based piston and base valve models
  - Deflection, stress characteristics for deflected disc assemblies

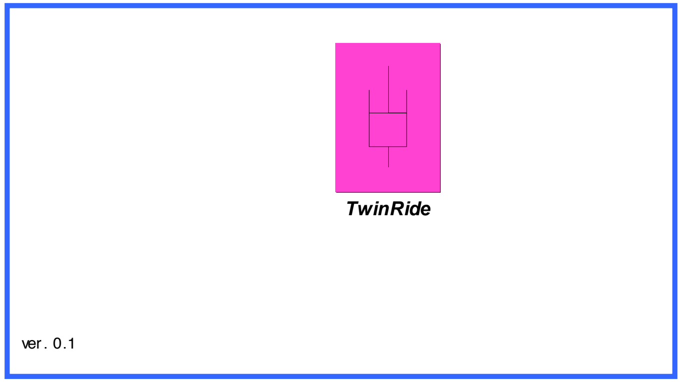
  - Access to all important geometry variables via a database interface
  - Unified user interface

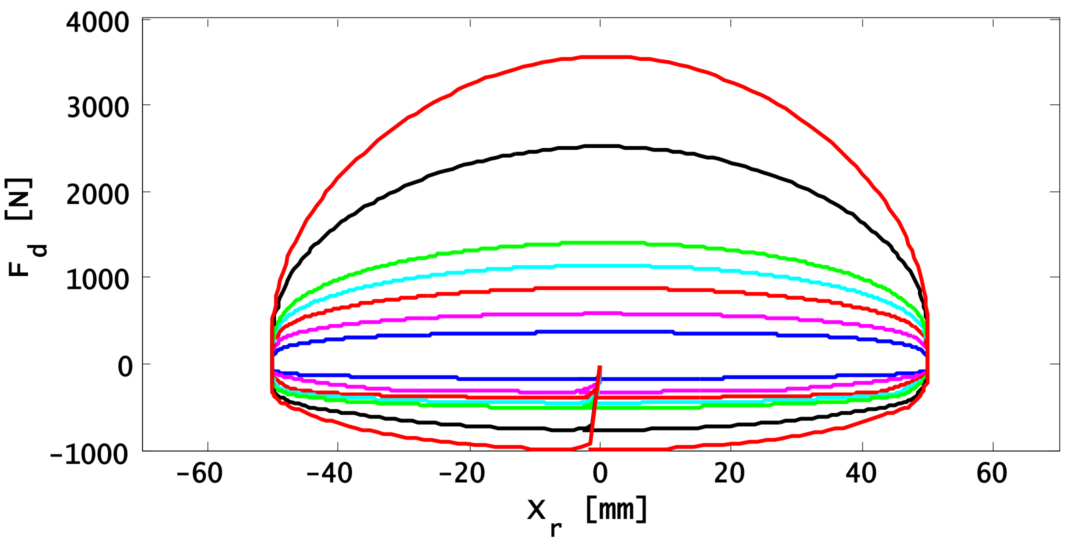
© BWI Group 2009. All rights reserved.

This document is the property of BWI Group. It may not be copied or disclosed to a third party without the explicitly written consent of BWI Group.

- Example #1
  - **Force vs. Velocity**



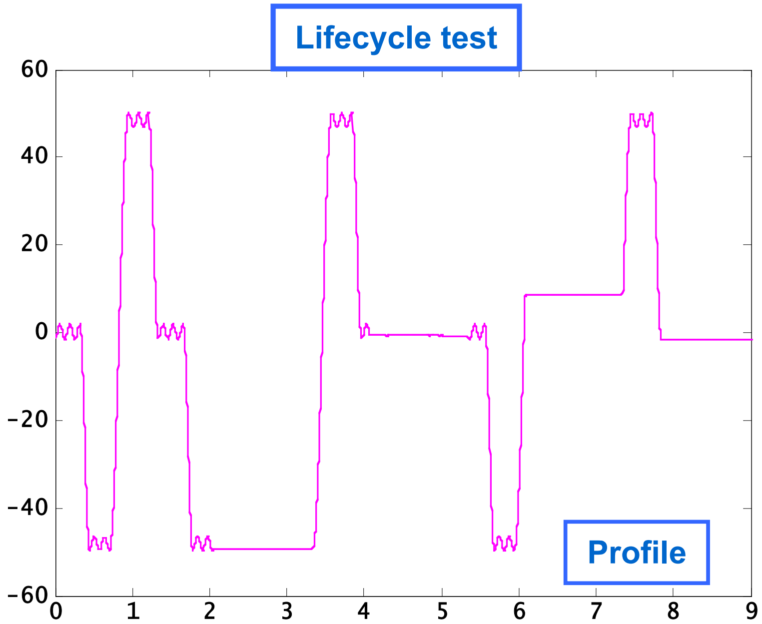


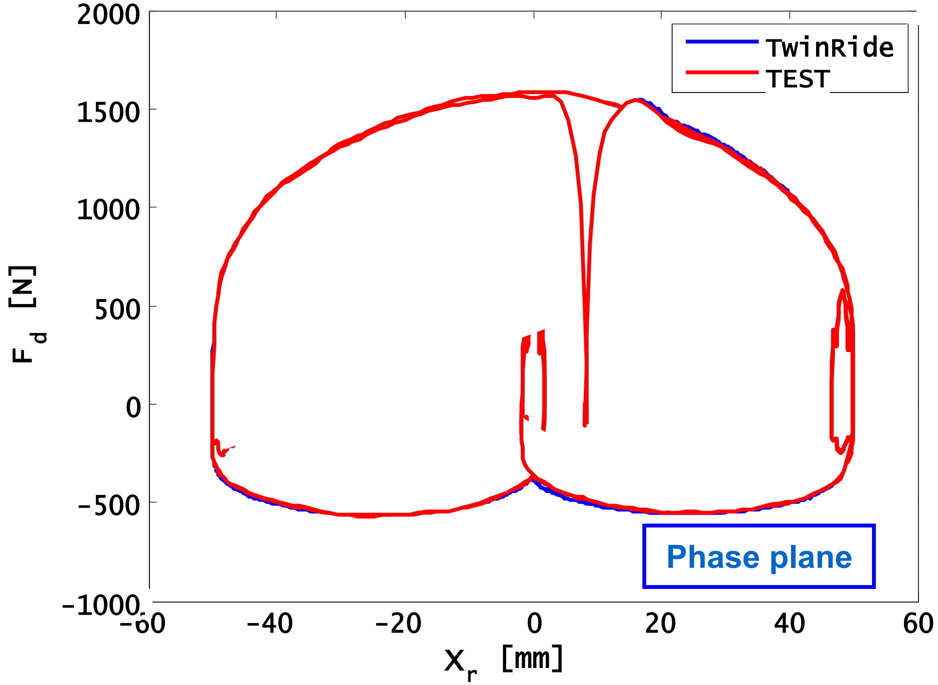


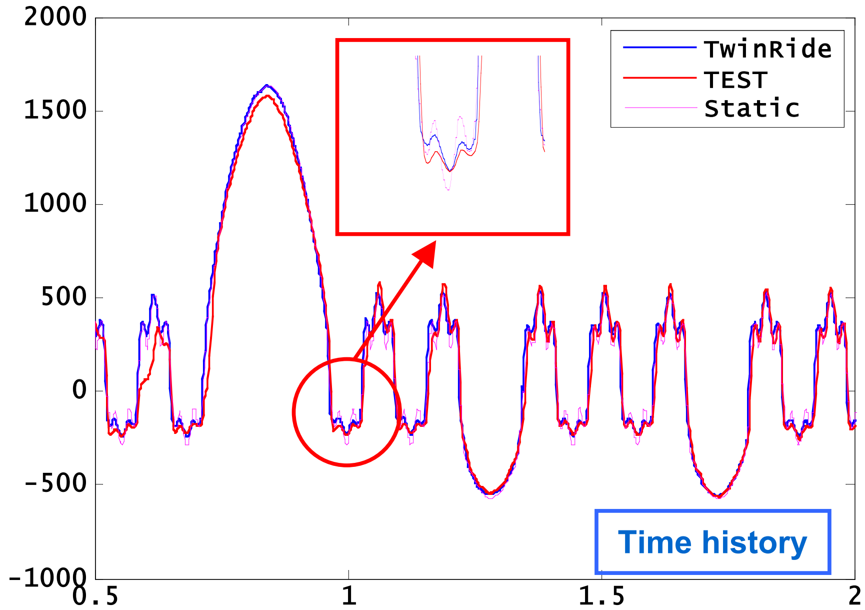
© BWI Group 2009. All rights reserved.

This document
disclosed to a third party without the explicitly written consent of BWI Group.

- Example #2
  - **Response to arbitrary road profiles**





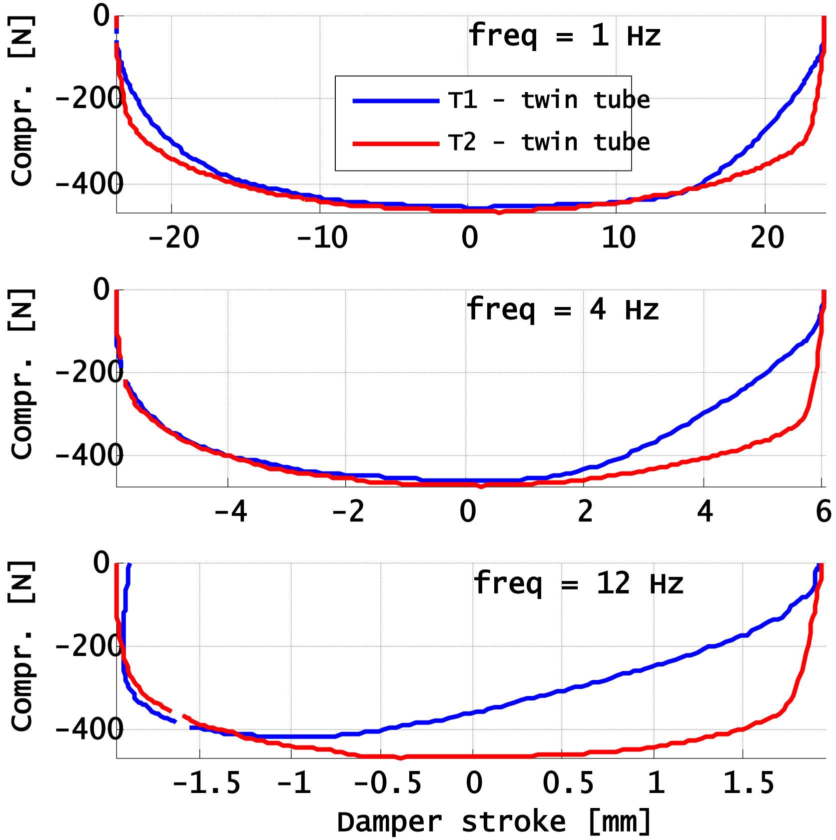


© BWI Group 2009. All rights reserved.

This document is the property of I
disclosed to a third party without t

- Example #3
  - **Vehicle tuning**
    - 2 twin-tube shock absorbers
    - **Identical** steady-state F-V curves, **different** valve balance
    - **T1** – *soft* compression piston valve, *stiff* base valve
    - **T2** – *stiff* compression piston valve, *soft* base valve
  - Quarter car results confirm the two codes have impact on vehicle ride
    - E.g. better comfort, and road holding with **T2**

Virtual tuning sessions



© BWI Group 2009. All rights reserved.

This document is the property of BWI Group. It may not be copied or disclosed to a third party without the explicitly written consent of BWI Group.

Frequency Dependent Valving Model

© *BWI Group 2009. All rights reserved.*

This document is the property of BWI Group. It may not be copied or disclosed to a third party without the explicitly written consent of BWI Group.

Frequency Dependent Valve Model

- Background information
  - Current market trends have indicated a need for simple, inexpensive add-ons in ordinary shock absorbers
  - Notable examples: inertia valves, displacement-dependent valves, amplitude-selective valves (ASD), frequency-dependent valves (FDV)

- So-called Frequency-Dependent Valving (FDV) is a simple valving concept that seems to attract interest from car makers
- FDV is claimed to improve ride comfort & enhance vibration isolation w/o loss of handling and safety degradation
- FDV allows for lower damping force at higher frequencies yet maintains high damping forces at lower frequencies

- Typically, it operates in parallel to the main valve (piston) and/or base valve if used on a twin-tube shock absorber

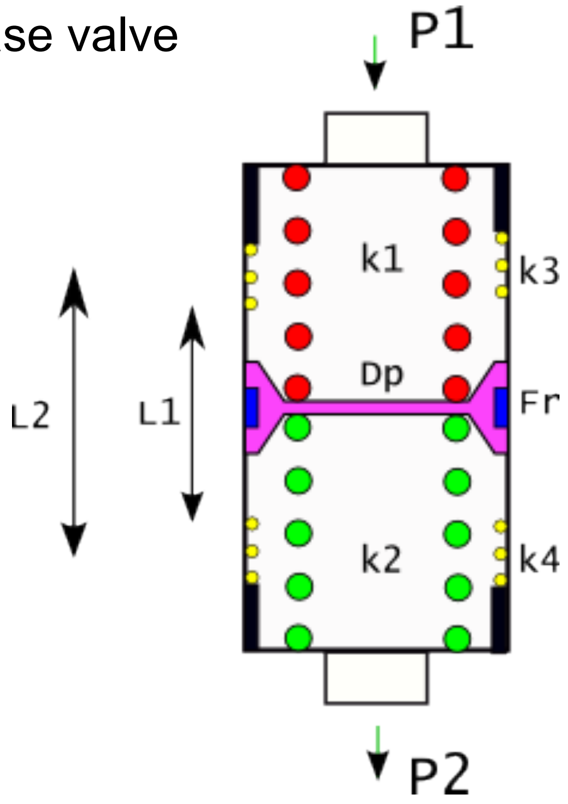
- BWI has been developing FDV systems since 2002
  - 2 generations of FVD developed so far

© BWI Group 2009. All rights reserved.

This document is the property of BWI Group. It may not be copied or disclosed to a third party without the explicitly written consent of BWI Group.

FDV Valve Model

- FDV operates in parallel with the piston valve and/or base valve
- FDV Model parameters
  - FDV piston diameter (D_{p1}), massless piston
  - Leading spring stiffness (k_1, k_2)
  - Cushioning spring stiffness (k_3, k_4)
  - Travel limits (L_1, L_2)
  - Seal friction (F_r)
  - Pressures (P_1, P_2)
  - Flow rate (Q)
  - Entry/exit restrictions

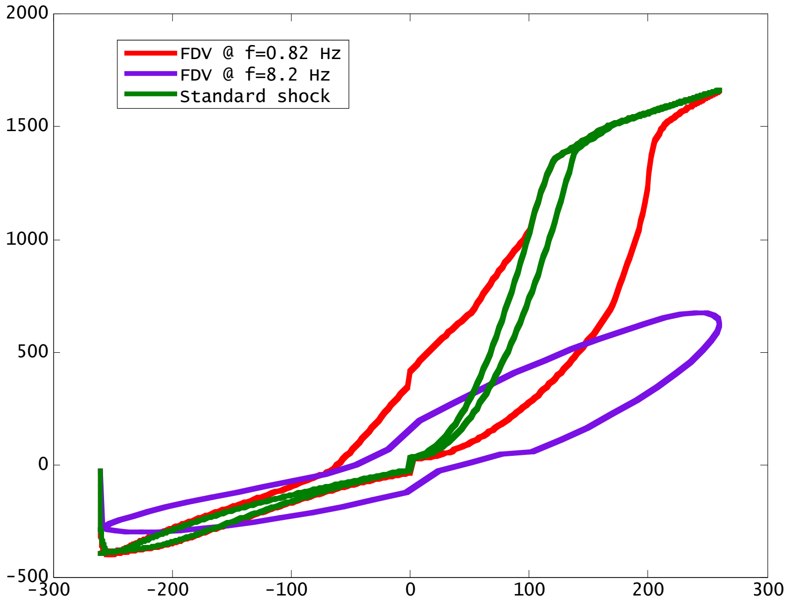


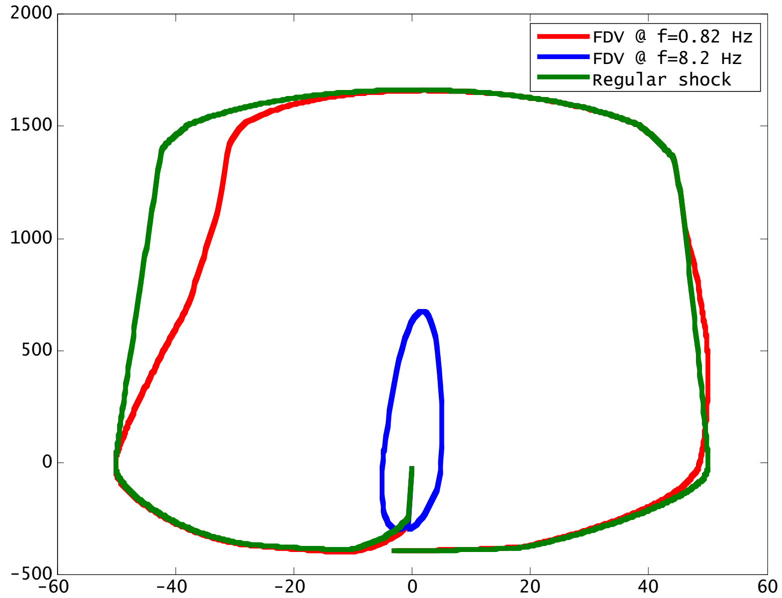
- By balancing forces acting on the FDV piston, we can derive the relationship between the flow rate through the FDV valve and the pressure drop across it
- FDV valve is then incorporated into the shock absorber model („damper-in-damper" approach)
- In case of a twin-tube damper, it results in a system of 5 (or 6) ODE equations that need to be solved simultaneously

© BWI Group 2009. All rights reserved.

This document is the property of BWI Group. It may not be copied or disclosed to a third party without the explicitly written consent of BWI Group.

- It can be proven by mathematical analysis FDV performance is frequency-dependent
- Application of FDV in a shock absorber may have big impact on vehicle dynamic behavior
- A model is essential for understanding the FDV impact





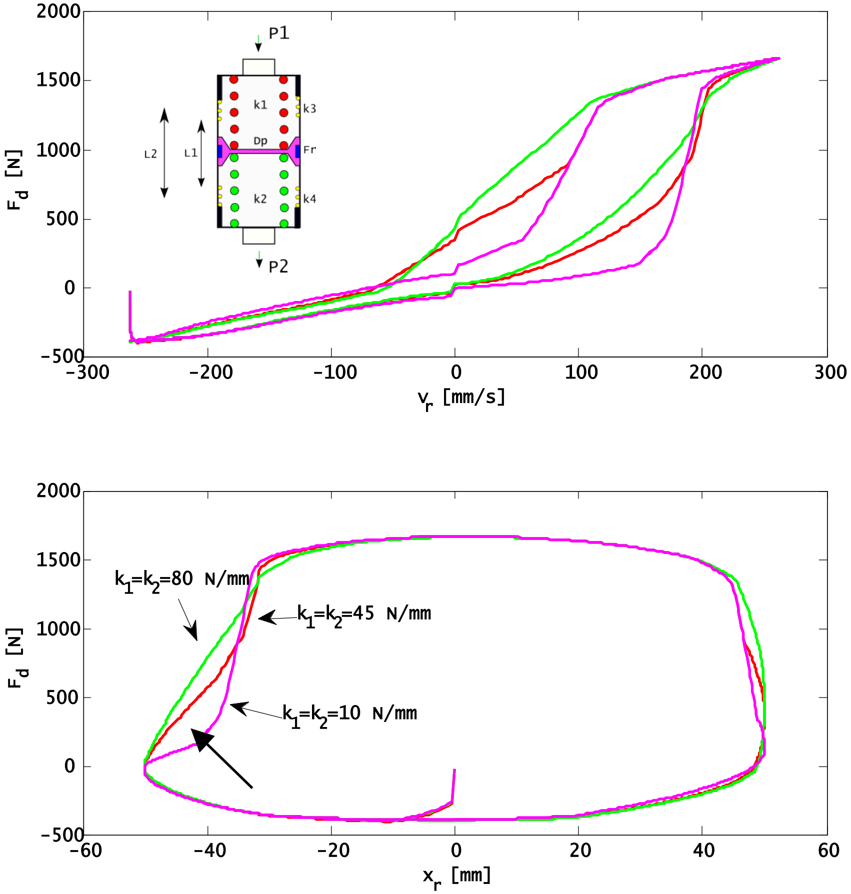
Twintube shock absorber, FDV valve

© BWI Group 2009. All rights reserved.

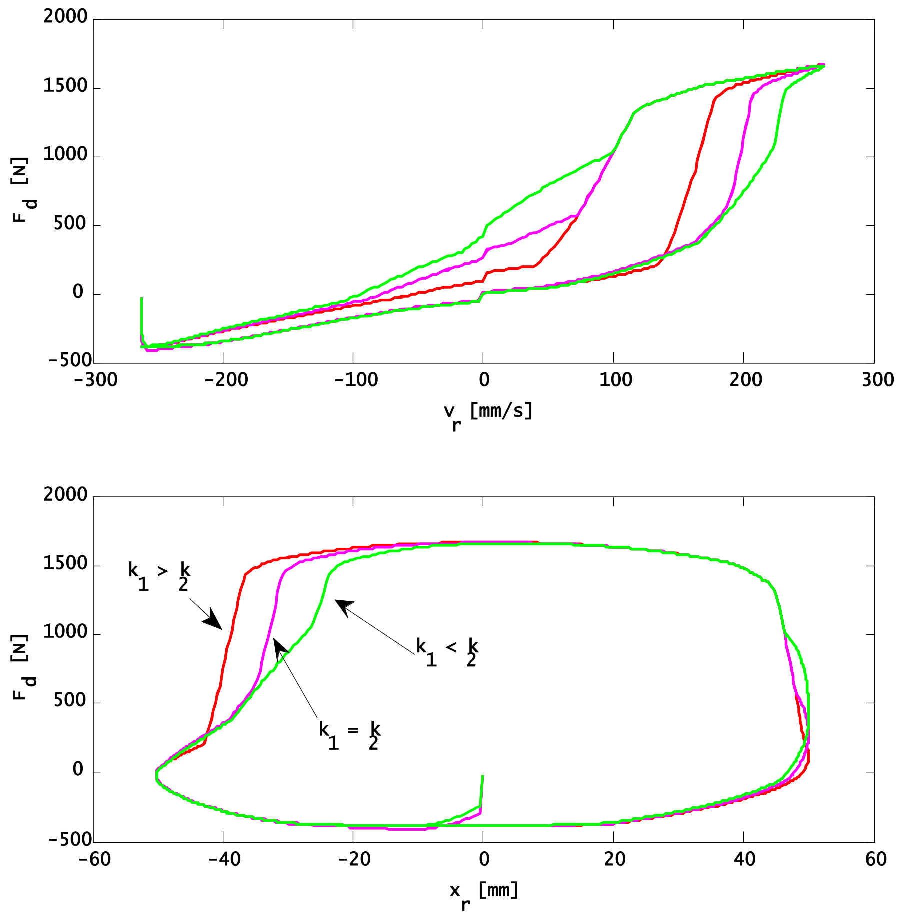
This document is the property of BWI Group. It may not be copied or disclosed to a third party without the explicitly written consent of BWI Group.

◆ Simulation results – leading springs (k_1, k_2)

Leading springs ratio change



Uneven leading springs ($k_1 \neq k_2$)

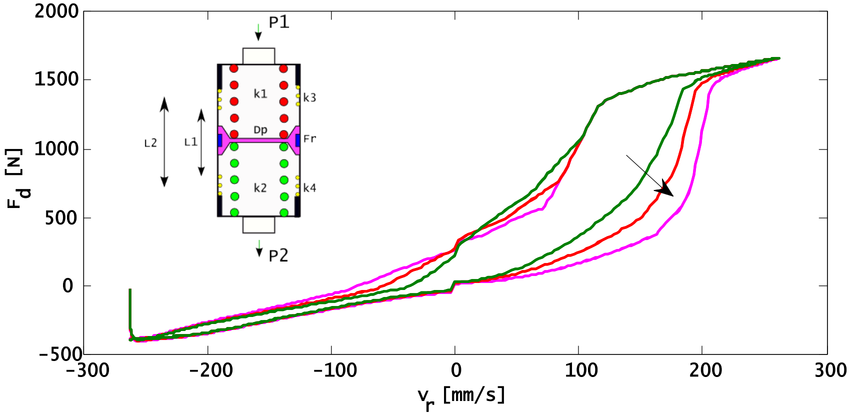


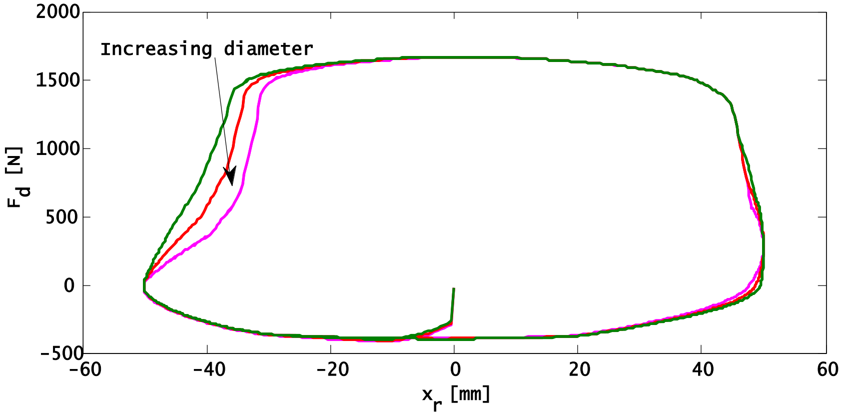
© BWI Group 2009. All rights reserved.

This document is the property of BWI Group. It may not be copied or disclosed to a third party without the explicitly written consent of BWI Group.

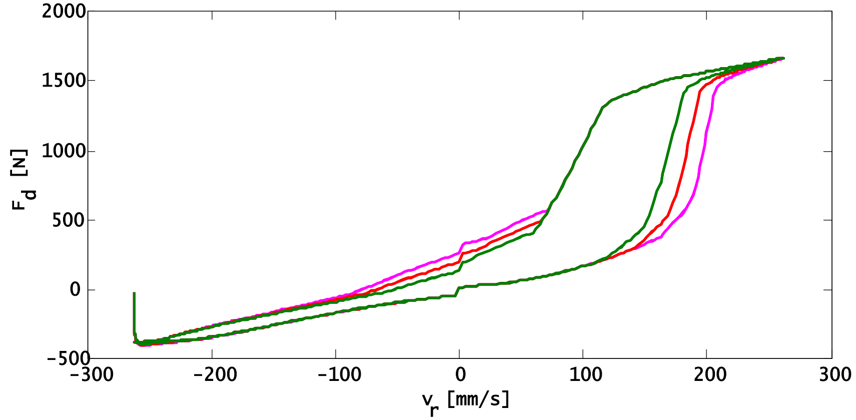
- Simulation results – FDV piston diameter, piston travel

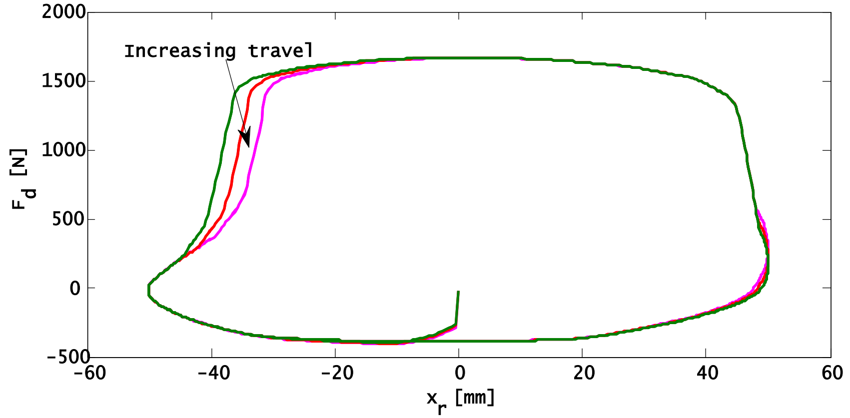
Piston diameter (D_p)





Piston travel (L_1)



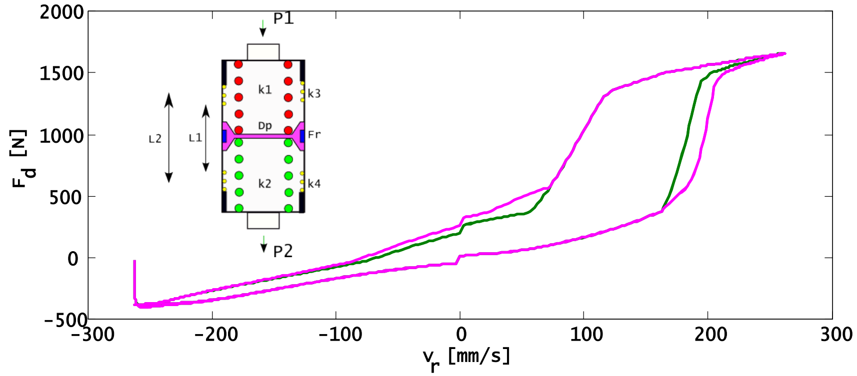


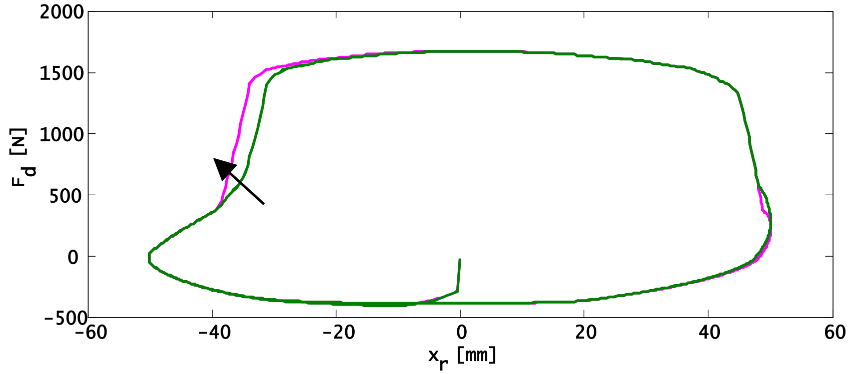
© BWI Group 2009. All rights reserved.

This document is the property of BWI Group. It may not be copied or disclosed to a third party without the explicitly written consent of BWI Group.

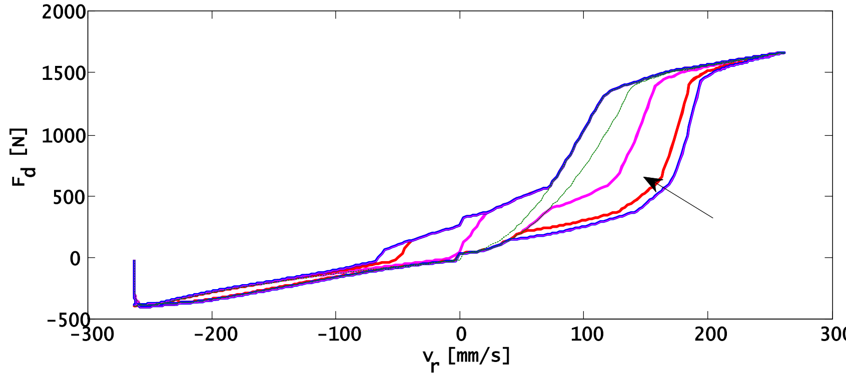
- Simulation results – Cushioning springs, valve preload

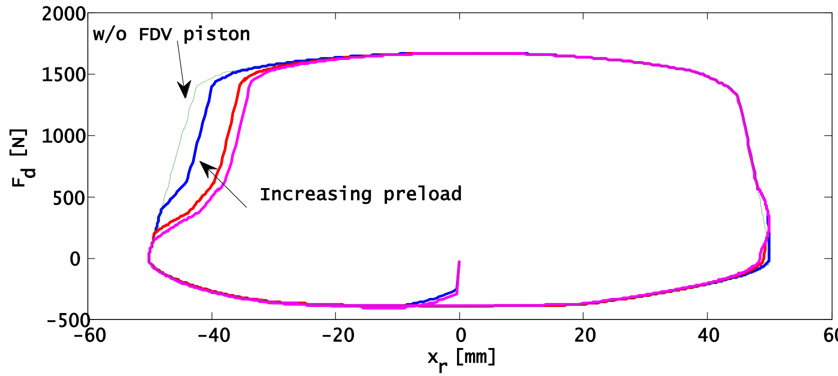
Cushioning springs (k_3, k_4)





Preload change (entry/exit blow-offs)





© BWI Group 2009. All rights reserved.

This document is the property of BWI Group. It may not be copied or disclosed to a third party without the explicitly written consent of BWI Group.

- Damper modeling tools
  - Damper modeling tools provide valuable insight into damper physics and interactions between its key components
  - The models form basis for simulating and developing more advanced passive & semi-active damping technologies
- Frequency-Dependent Valve (FDV) valve
  - FDV valves are a simple yet effective way of enhancing the performance of a passive shock absorber @ standard and elevated frequencies
  - Developing the model of an FDV valve was necessary to understand the influence design variables have on the valve performance
  - Preliminary vehicle studies have shown well-designed FDVs may contribute to better isolation from road inputs at frequencies above the wheel resonant frequency w/o any or little degradation of ride and handling metrics

© BWI Group 2009. All rights reserved.

This document is the property of BWI Group. It may not be copied or disclosed to a third party without the explicitly written consent of BWI Group.