

Simulating Advanced Damping Technologies

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Chassis Systems



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)



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Damper Modeling Tools @ BWI

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- 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

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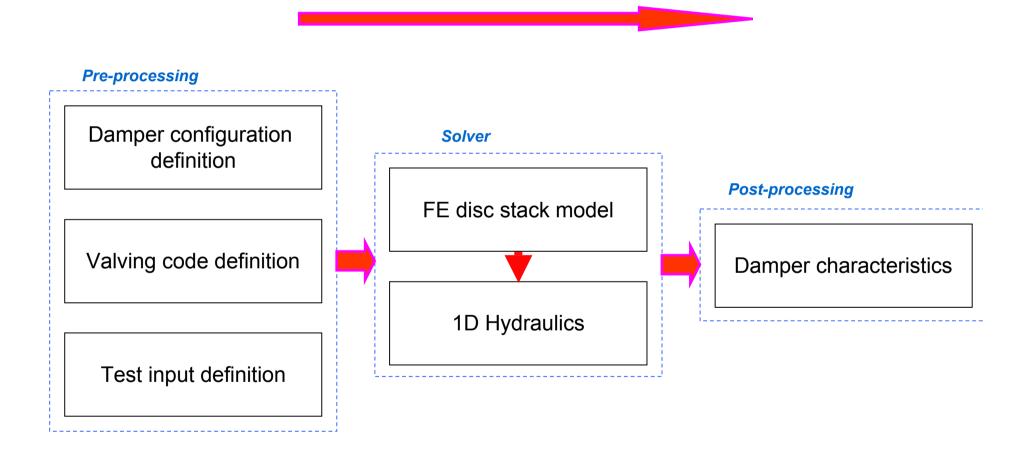
- TwinRide is our standard tool for damper design and modeling
- Unified User Interface with a connection to a database of components

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Typical Architecture



Passive dampers only

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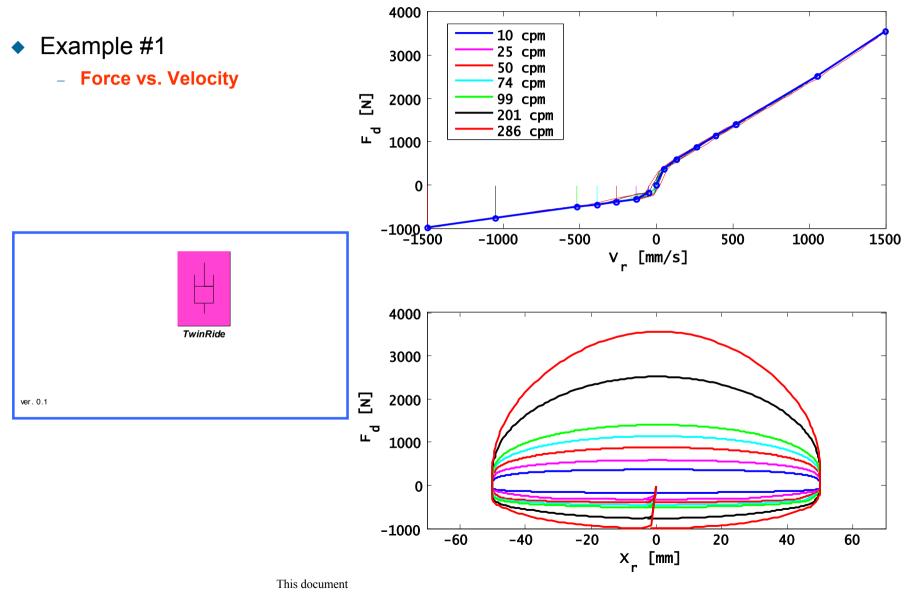


Modeling features

- 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



Application Examples

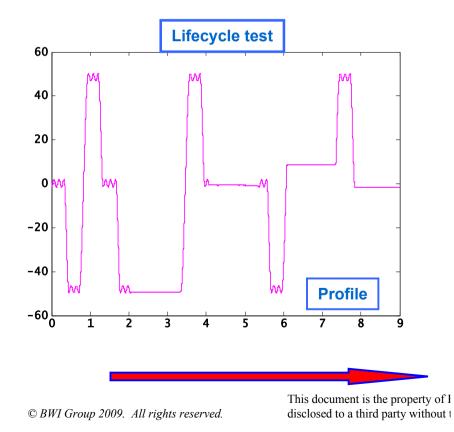


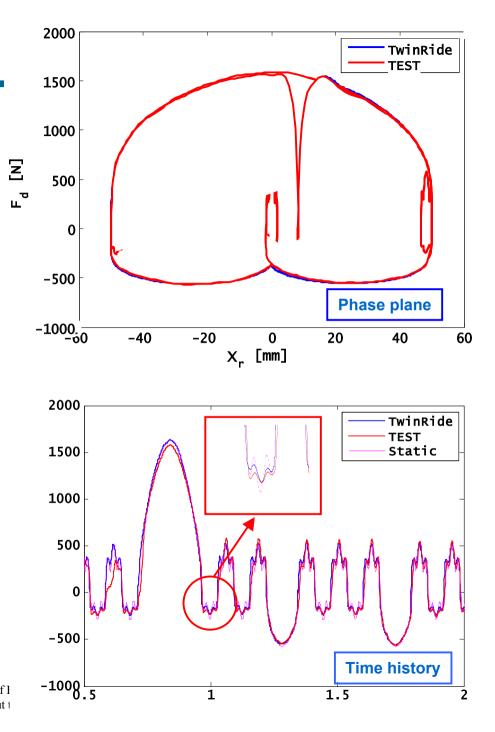
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- Example #2
 - Response to arbitrary road profiles

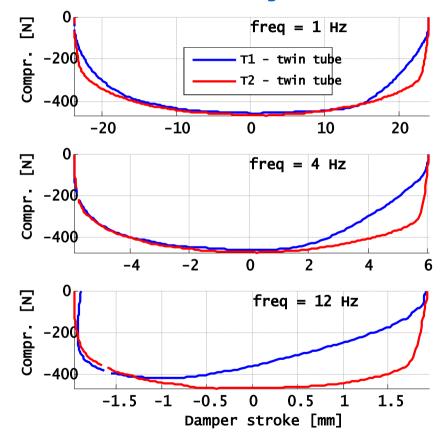






Application Examples

- 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

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Frequency Dependent Valving 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

In case of a twin-tube damper, it results in a system of 5 (or 6) ODE equations

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- through the FDV valve and the pressure drop across it FDV value is then incorporated into the shock absorber model ("damper-indamper" approach)
- can derive the relationship between the flow rate
- **Entry/exit restrictions** By balancing forces acting on the FDV piston, we

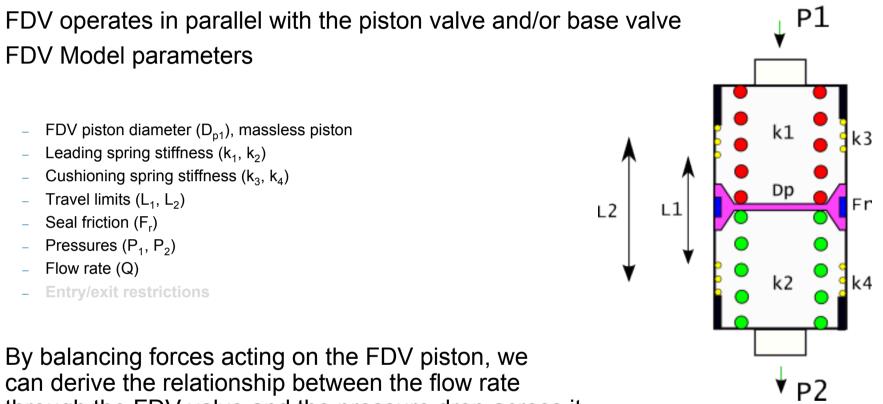
FDV piston diameter (D_{p1}), massless piston

that need to be solved simultaneously

Leading spring stiffness (k_1, k_2)

FDV Model parameters

- Cushioning spring stiffness (k_3, k_4)
- Travel limits (L₁, L₂)
- Seal friction (F_r)
- Pressures (P_1, P_2)
- Flow rate (Q)

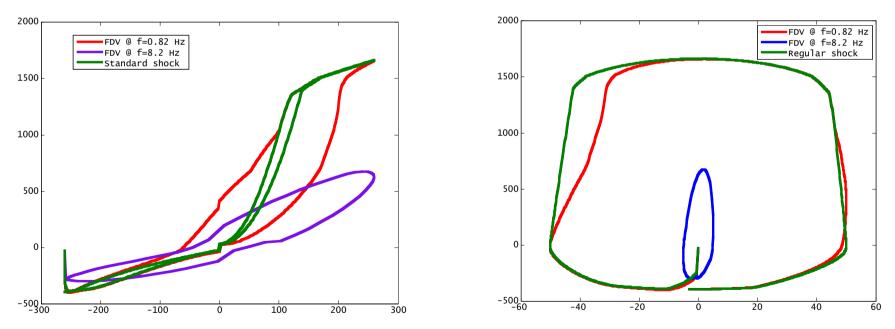




FDV Valve Model



- 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

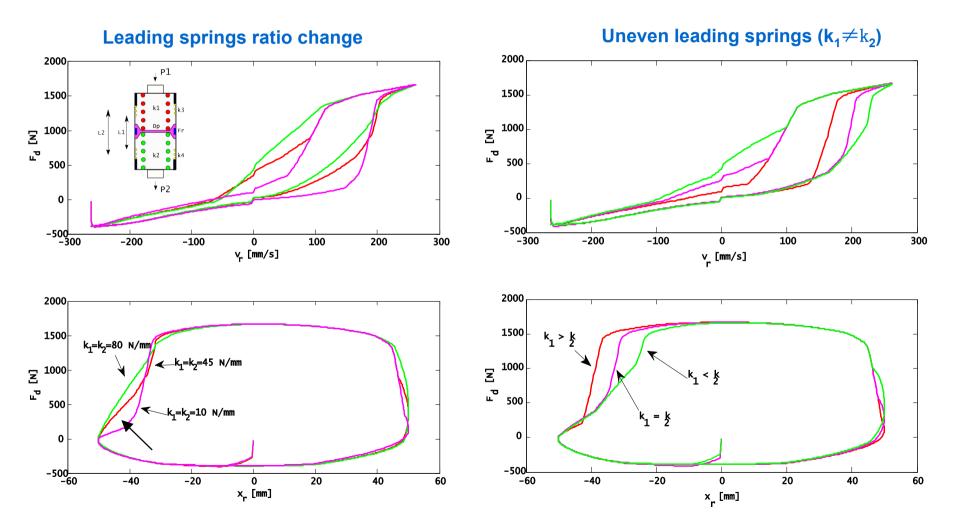


Twintube shock absorber, FDV valve

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Simulation results – leading springs (k₁, k₂)



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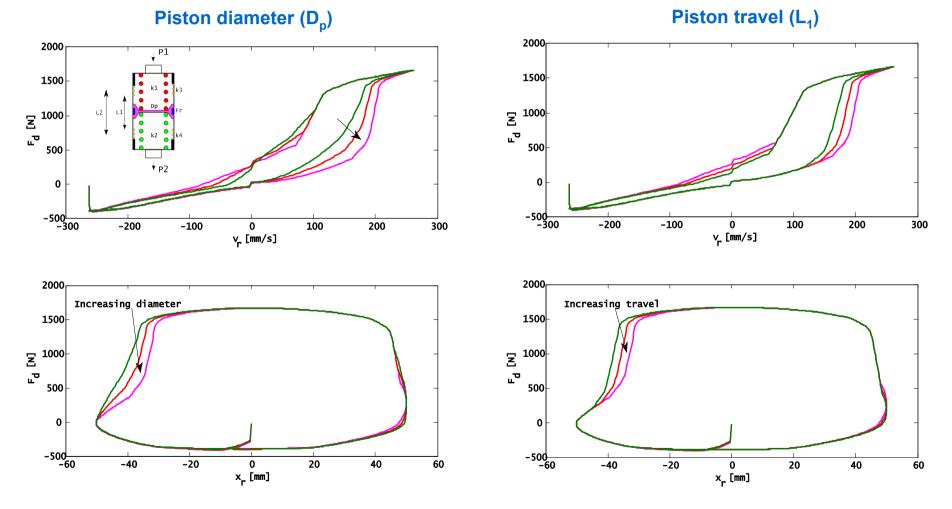
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FDV Valve Model

Simulation results – FDV piston diameter, piston travel



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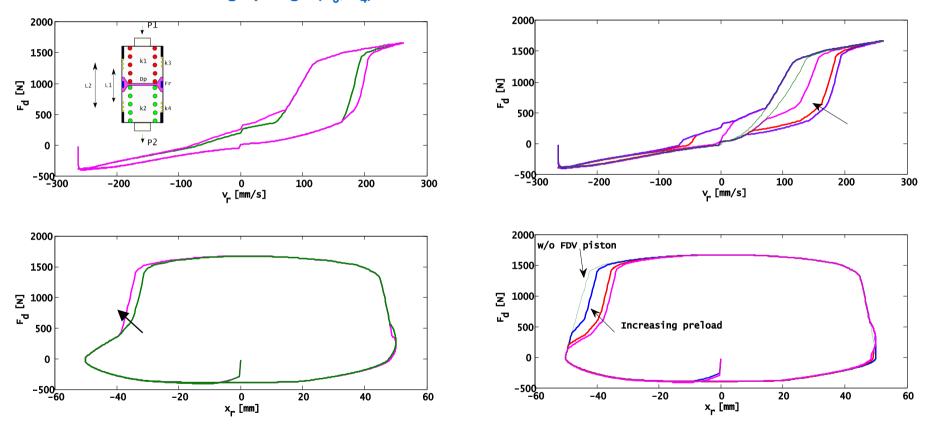
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FDV Valve Model

Simulation results – Cushioning springs, valve preload



Cushioning springs (k₃, k₄)

Preload change (entry/exit blow-offs)

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- 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