Vehicle Dynamics Expo North America 2008
Novi, MI

DELPHI

DIVERSITY OF PASSIVE DAMPERS PERFORMANCE CHARACTERISTICS IN RESPONSE TO SPECIFIC RIDE AND HANDLING REQUIREMENTS

Slawomir Dzierzek
Marcin Knapczyk
Michał Maniowski

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2. Diversity of typical damping curves using standard valve systems
3. Compression balance in twintube dampers
4. Valve developments to achieve specific vehicle behavior
5. Summary

Delphi Technical Center Krakow

DELPHI CHASSIS DIVISION – Suspension systems, brake systems

TECHNICAL CENTER KRAKÓW, POLAND (OPENED IN 2000)

- Global engineering center for passive dampers, damper modules and controlled suspension components (MR dampers, ASBS systems)
- 200 engineers and technicians
- Product/process engineering, CAD/FEA/Simulation
- Prototype center and test labs
- Ride van/ride kits/ride session support

MAIN AREAS OF ENGINEERING ACTIVITIES

- Research and development
- Product engineering, process engineering, quality engineering, industrial engineering
- Prototyping, full scope of verification and validation testing

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Background of the presentation

- The presentation describes how modifications to typical damper performance characteristics can support different suspension tuning philosophies.

- It shows the impact on damper valve design and maximum utilization of tuning features, and also certain valve developments to achieve specific behavior of the vehicle.

- Suspension tuning philosophy diversifies vehicle manufacturers and vehicle segments in terms of achieved comfort vs. handling compromise. As dampers in a vehicle suspension have great impact on vehicle dynamics, each car manufacturer dedicates significant portion of vehicle development time on damper tuning.

- Passive damper tuning done to achieve specific requirements of vehicle manufacturers is usually based on subjective evaluation.

- Non-linearity of damping characteristics and interactions with other suspension components make analytical approach less effective and leave a lot of room for ride engineers to show their expertise in tuning suspension systems using subjective evaluation as the main development criteria.

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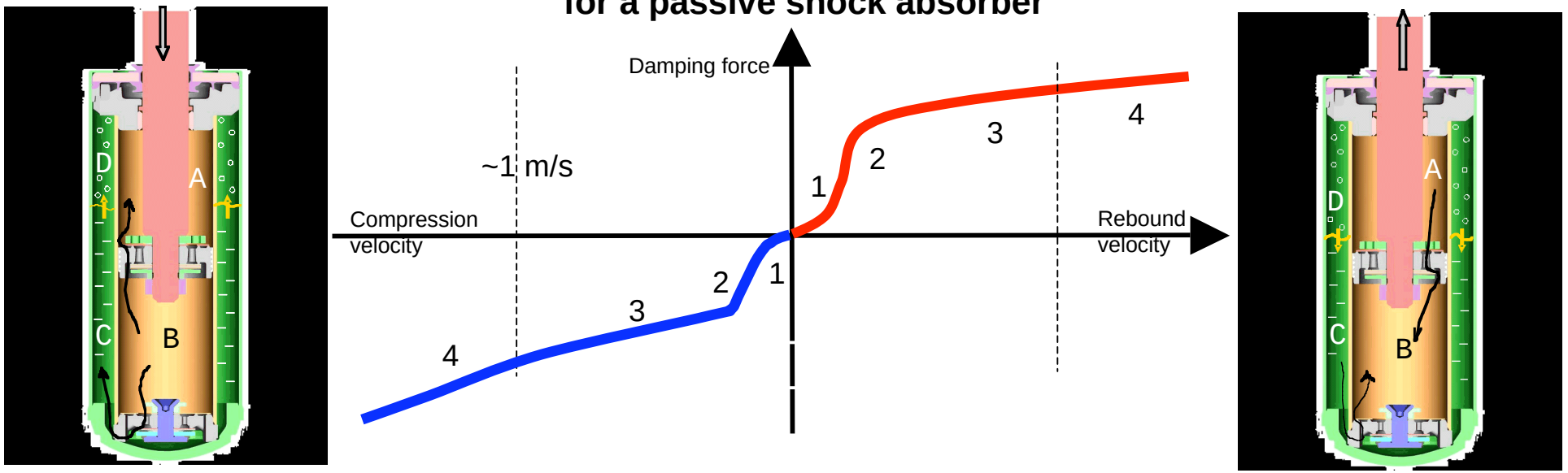
1. Introduction

Typical damping characteristics (damping force vs. piston rod velocity) for a passive shock absorber



Influence on vehicle ride & handling as perceived by ride development engineers

1. Transmission of road texture (harshness/plushness/isolation) and low speed body movements, steering on-center feel
2. Handling (low body velocities) and body control – heave, roll, pitch
3. Wheel control and handling
4. Extreme events (bumps), high frequency rolling comfort

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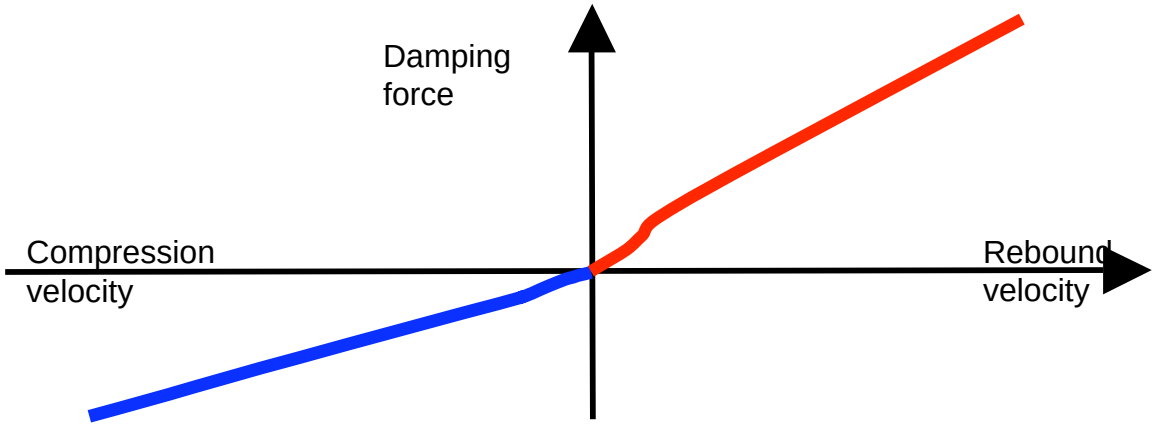
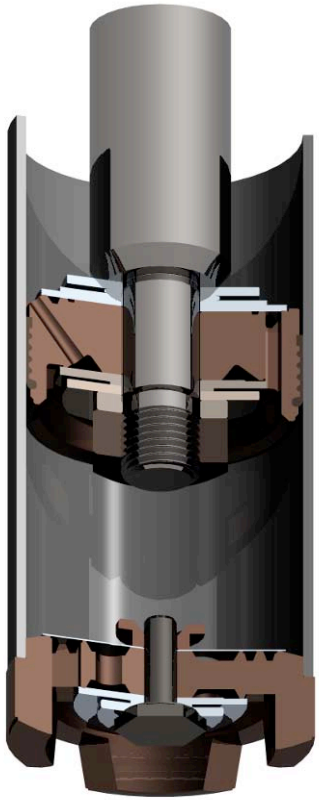
2. Diversity of damping characteristics

Linear damping characteristics





Most important attributes

1. Medium and high speed tuning dependency
2. Usually provides good secondary ride - plushness and wheel control
3. Primary ride very comfortable with significant heave
4. Handling limited due to lack of sufficient body control
5. Very effective on off-road type of vehicles with long suspension travel
6. Damping characteristic not very often used in modern road vehicles

Delphi design solution

- piston valve: deflective disc on rebound side, deflective disc on compression side, adjustable preload
- bottom valve: deflective disc, adjustable preload

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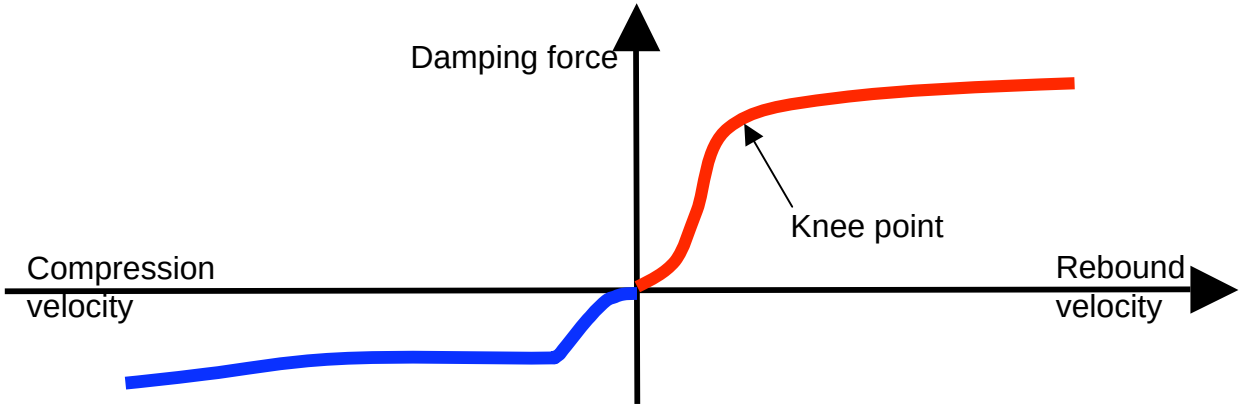
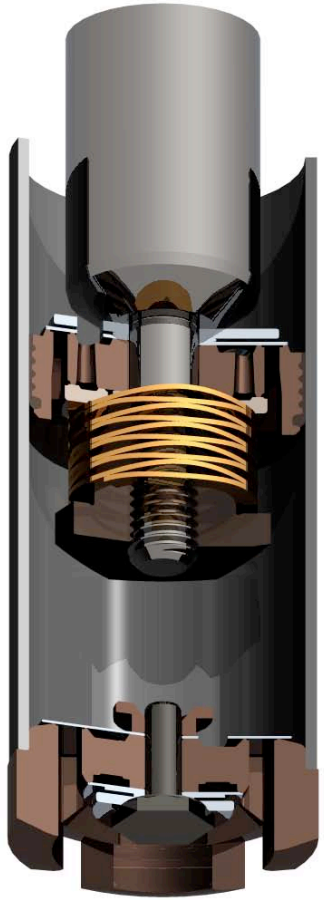
2. Diversity of damping characteristics

Degressive damping characteristics





Most important attributes

1. Typical sharp knee point and degressivity of high speed damping characteristic
2. Usually provides positive secondary ride – good plushness, but limited wheel control
3. Primary ride comfortable and with good body control
4. Good handling and roll control
5. Often used in sports-sedans

Delphi design solution

- piston valve: deflective disc (soft stack) plus spring or pure blow-off on rebound side, preloaded deflective disc on compression side
- bottom valve: preloaded deflective disc

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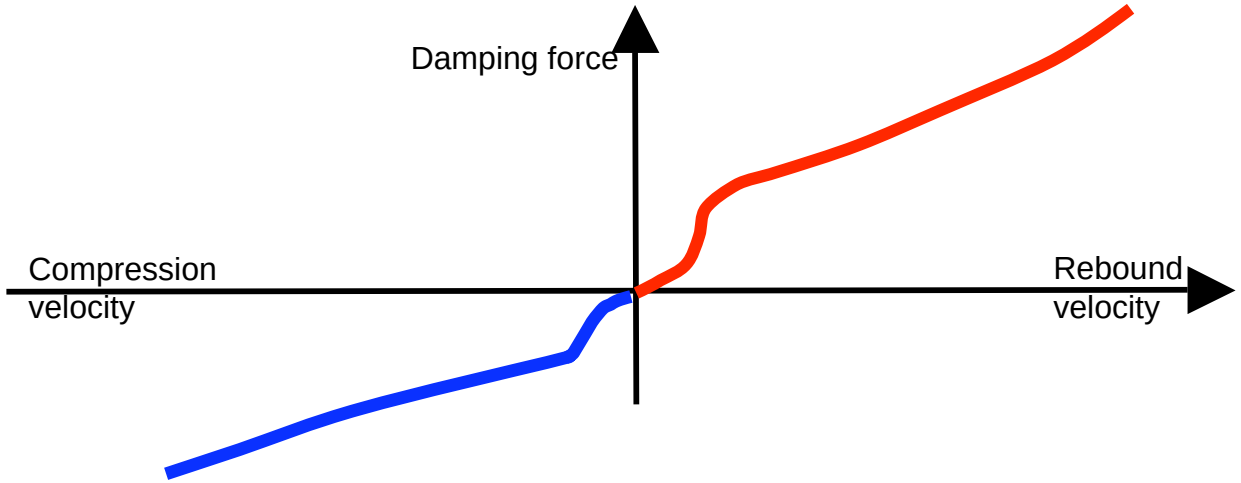
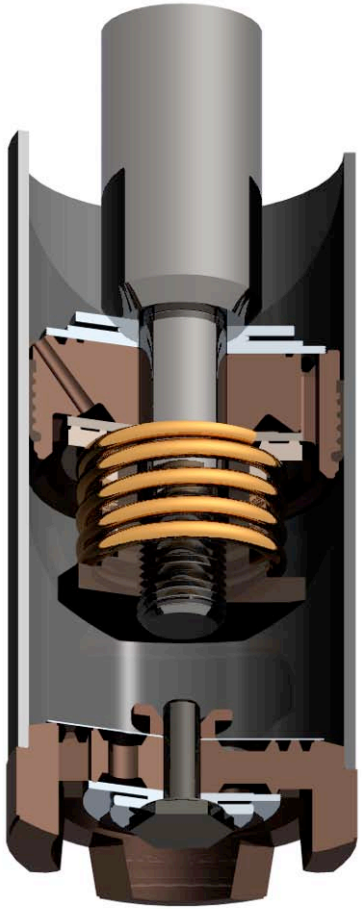
2. Diversity of damping characteristics

Progressive damping characteristics with a knee point





Most important attributes

1. Typical knee point and progressivity of high speed damping characteristic
2. Provides moderate secondary ride with good wheel control but with less effective texture isolation
3. Primary ride with sufficient body control
4. Good handling and roll control
5. Most common in modern vehicles

Delphi design solution

- piston valve: deflective disc plus spring on rebound side, preloaded deflective disc on compression side
- bottom valve: preloaded deflective disc

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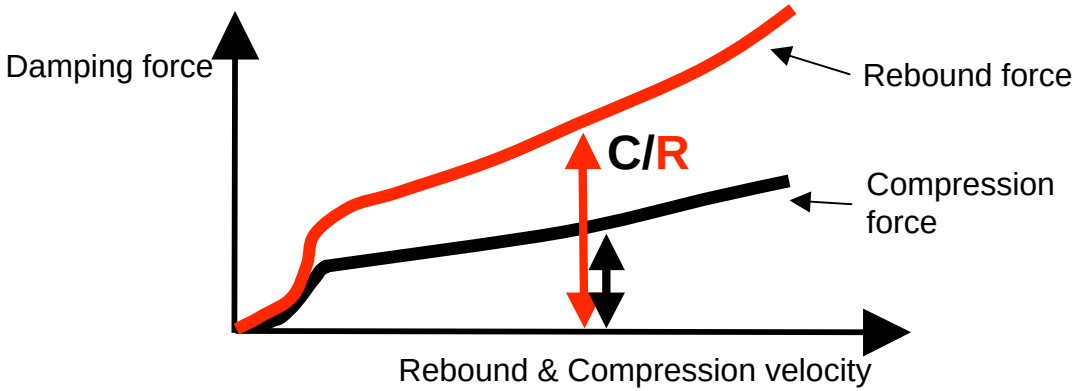
2. Diversity of damping characteristics

Compression-to-rebound damping ratio



Most important attributes

1. Typical damping compression-to-rebound ratio C/R is in the range from 1:1 to 1:3
2. Compression damping usually does not exceed rebound
3. The damping ratio is usually reverse-proportional to suspension stiffness characteristic in jounce movement
4. Ratios in range close to 1:3 is more often used on sports-sedans
5. Ratios close to 1:1 are used often on off-road

Delphi design solution

- Delphi valve systems can easily work in both ranges mentioned above (both twintube and monotube)
- While 1:3 ratio can be achieved with majority of valve systems available on the market, 1:1 ratio requires usually higher degree of piston compression valve utilization

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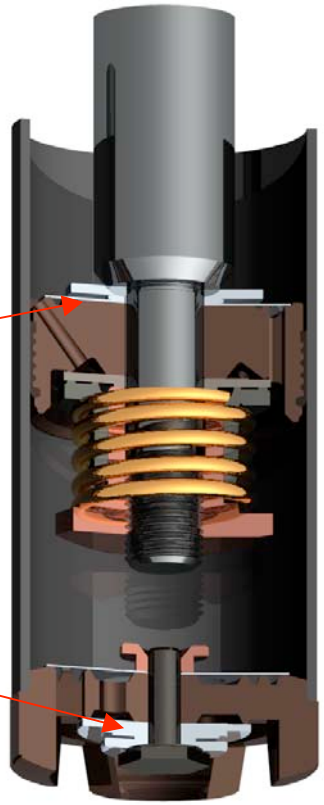
3. Compression balance in twin tube dampers

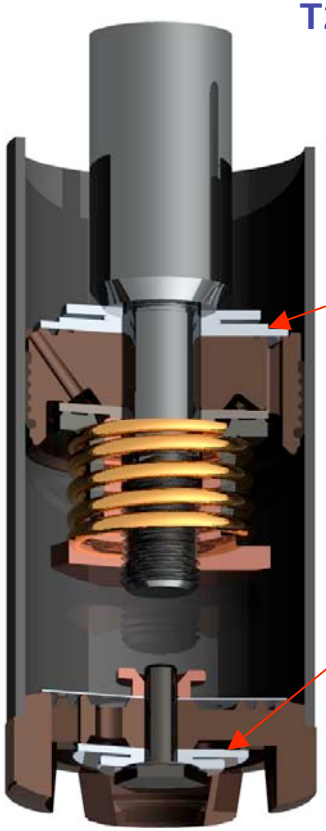
Two dampers (pressure chamber D=36mm) were prepared to achieve the same level of peak damping forces

T1: Twin-tube, code #1



The codes represent different balance between damping forces generated by piston compression valve and base valve.

T2: Twin-tube, code #2



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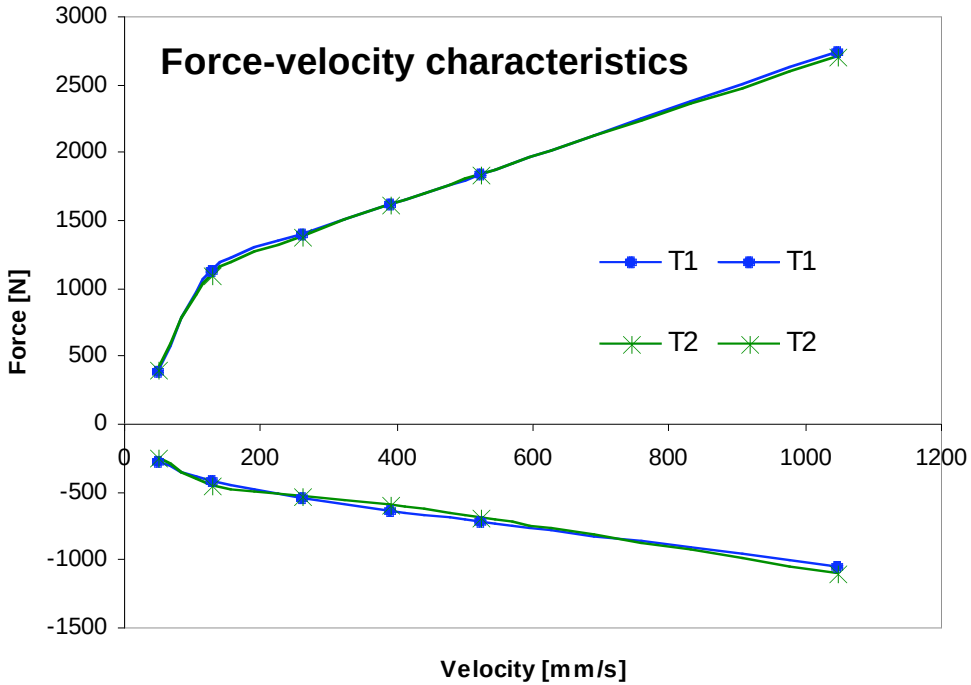
3. Compression balance in twin tube dampers



Performance test results of the prepared dampers

Test conditions:

- **sinusoidal excitation;**
- **stroke: 100mm;**
- **force at peak velocity recorded**

Questions:

- **Are these dampers the same in terms of vehicle ride?**
- **Which parameters influence damper dynamic behavior?**

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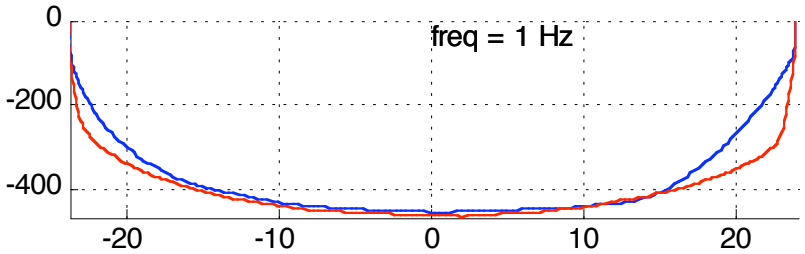
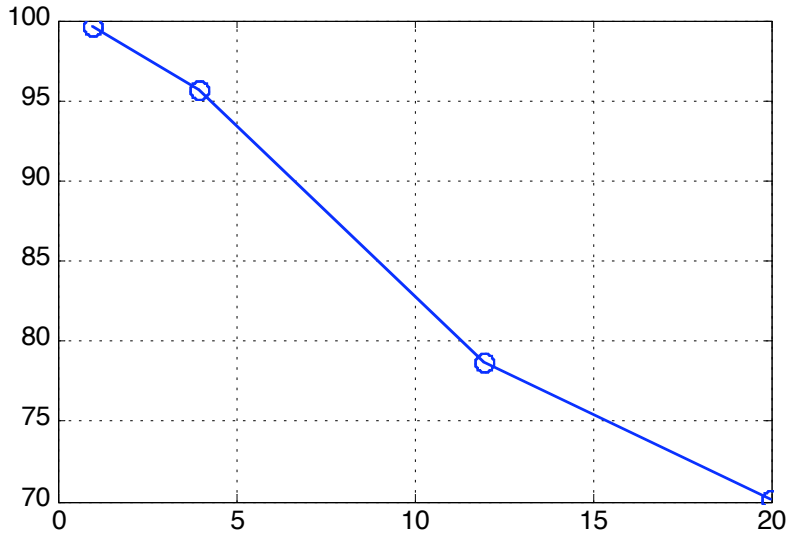
3. Compression balance in twin tube dampers

Force-displacement characteristics (compression stroke only)



Damping efficiency (measured by energy dissipated during compression stroke) of T1 damper as percentage of T2 damper



Test conditions:

- sinusoidal excitation;
- peak velocity: 150 mm/s;
- frequency: 1÷20Hz;
- stroke: variable;

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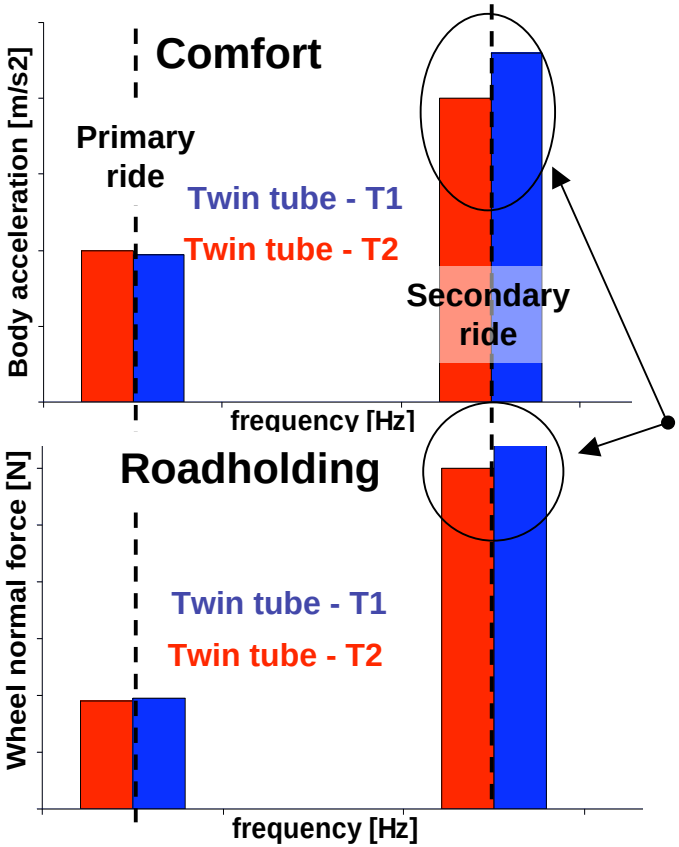
3. Compression balance in twin tube dampers

Influence on vehicle ride – quarter car simulation

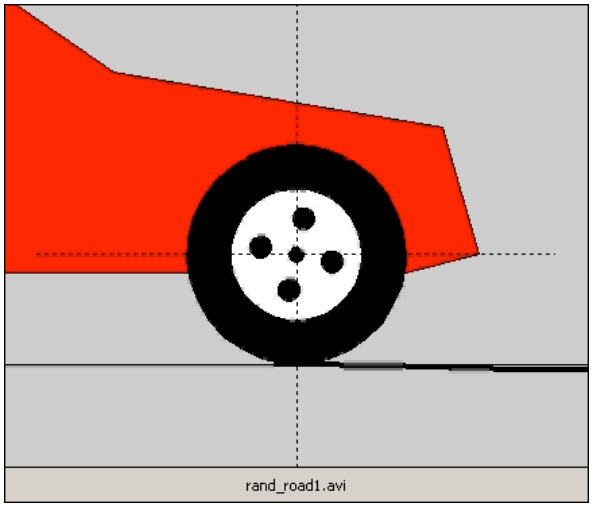
Evaluation of car body accelerations and tire normal force– simulation results for the two considered valve codes (T1 and T2)



Frequency spectra

Twin tube T2 demonstrates greater efficiency than T1 in higher frequency range

Randomly distributed road unevenesses



V_x = 55 km/h, randomly distributed road unevenesses

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3. Compression balance in twin tube dampers

Influence on vehicle ride – quarter car simulation

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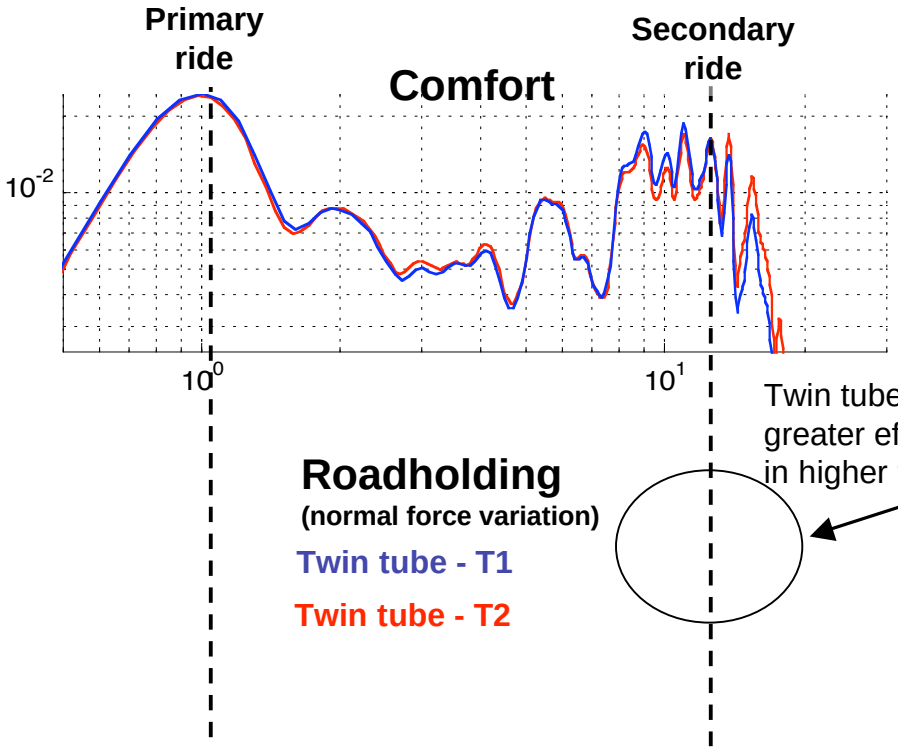

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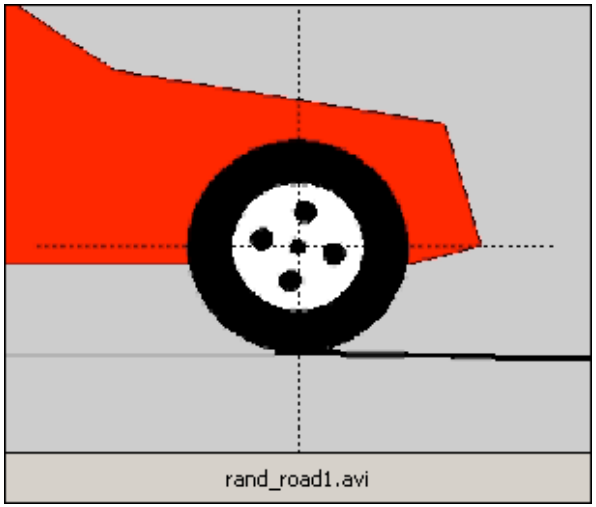

V_x = 55 km/h, randomly distributed road unevenesses

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3. Compression balance in twin tube dampers

Compression balance is a powerful tool to optimize ride and handling

- The considered passive dampers, described by the same peak damping forces, have significantly different impact on vehicle ride
- Compression balance (between piston compression and base valve) in twin tube dampers impacts its damping efficiency at higher frequencies responsible mainly for secondary ride control
- Twin tube damper with good compression balance (big share of the compression piston valve) shows higher damping efficiency

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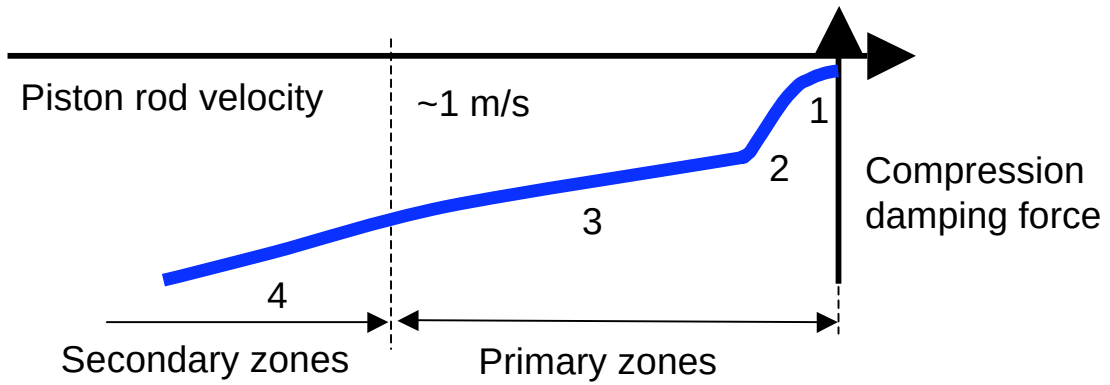
Towards desirable compression damping characteristics

The compromise between car ride and handling can be further improved with innovative valve designs modifying compression performance



Desired performance features of passive dampers in compression stroke

- degressivity of DF in mid-to-high velocity range
- smooth transition (knee point) from low to medium speed
- decoupling between low and medium speed tuning parameters
- body structure protection during extreme road impacts

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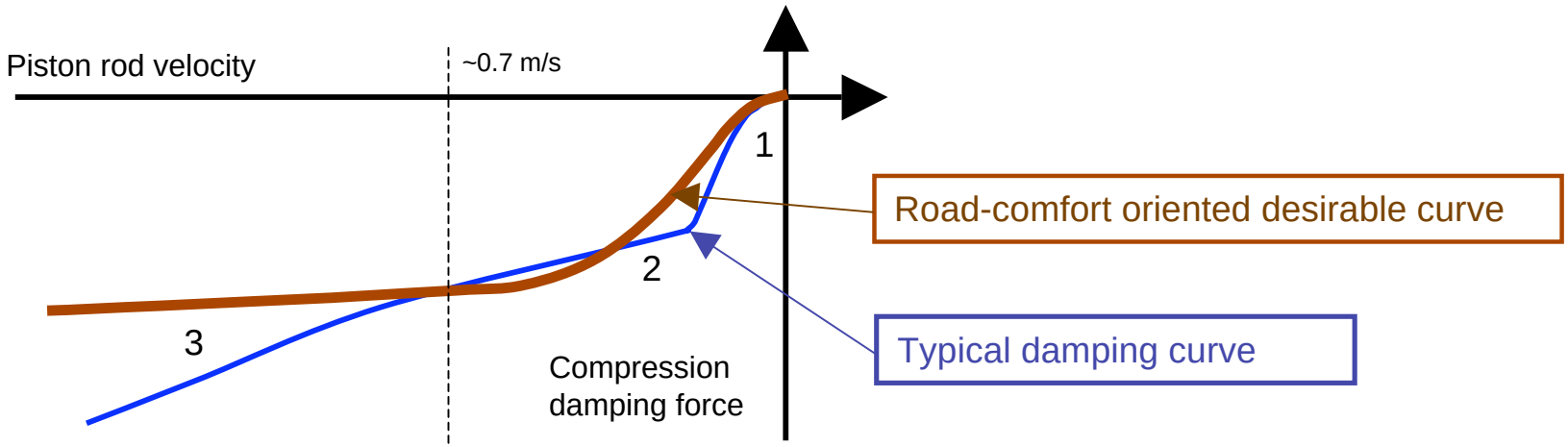
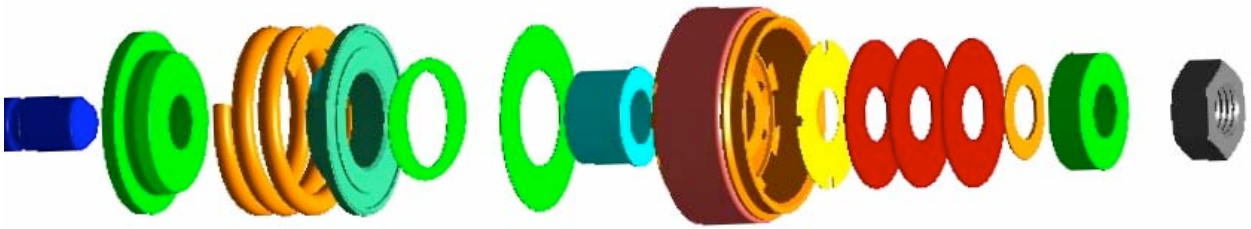
4. Innovative solutions – SuperDegressive valve

Desired modification of compression damping characteristics



Design solution

- Special blow-off piston compression valve ensuring minimum restriction to oil flow at higher velocities (zone 3)
- Variable orifice system improving low speed control (zone 2) – US Patent 6,655,512 B2



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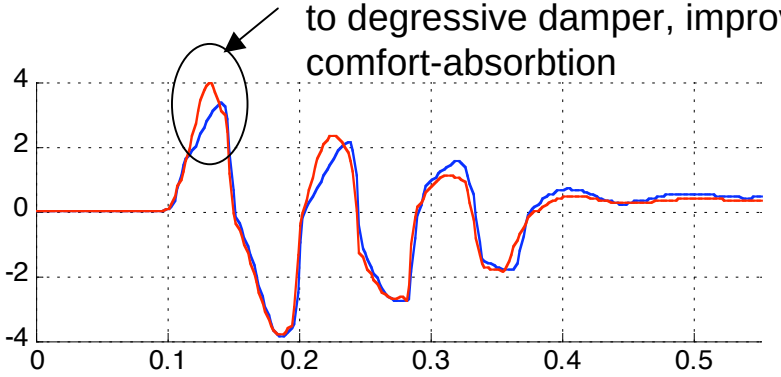
4. Innovative solutions – SuperDegressive valve

Influence on vehicle ride – quarter car simulation

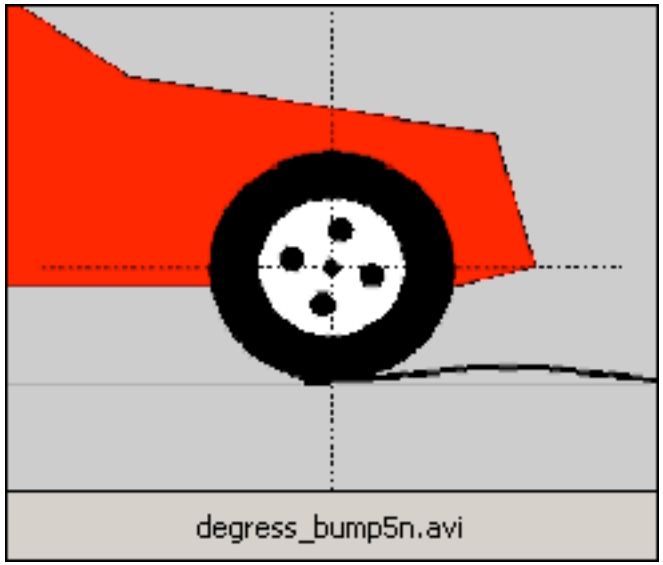
Peak acceleration decrease (~33%) due to degressive damper, improving comfort-absorbtion



Time histories

Increase of suspension deflection (~5%) in the suspension linear range due to degressive damper

Single bump event



V_x = 72 km/h, bump height = 0.04 m, bump lenght = 1 m

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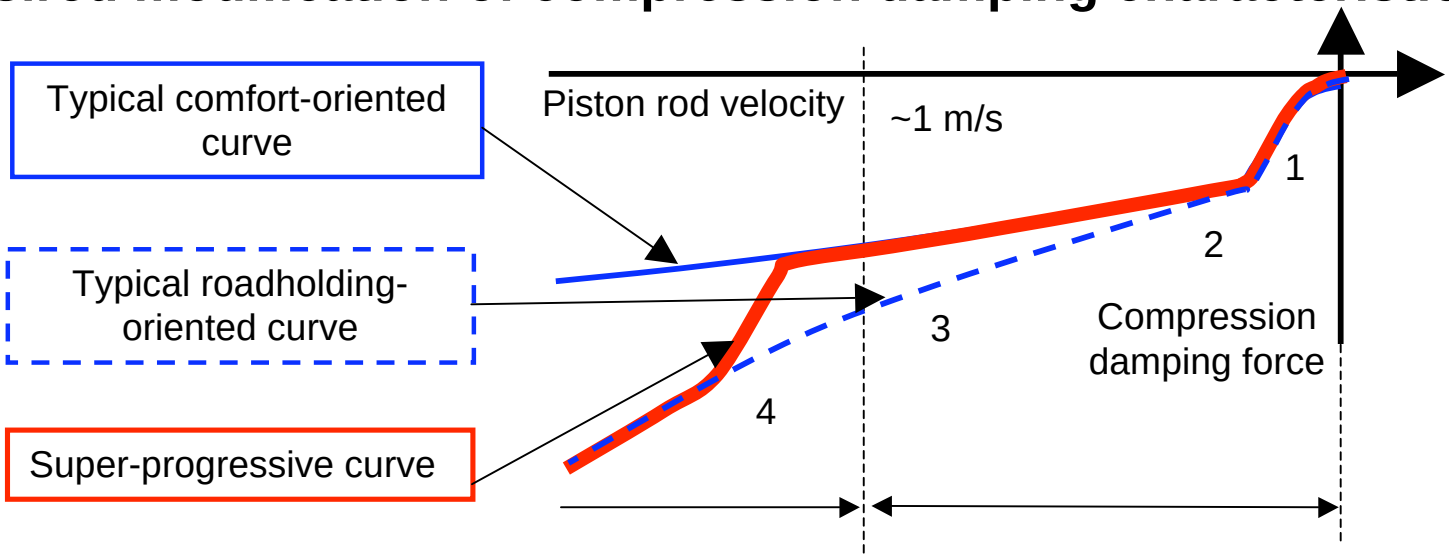
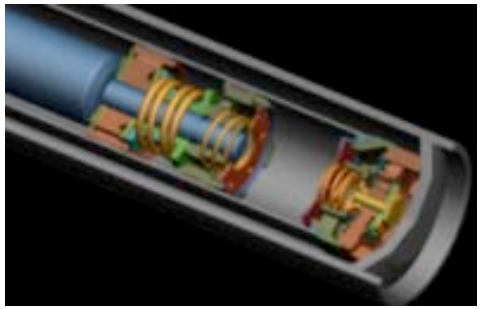
4. Innovative solutions – SuperProgressive valve

Desired modification of compression damping characteristics



Design solution

- Special, highly-restrictive, one-directional valve installed in series with piston compression valve or bottom compression valve, activated at certain, predefined speed (in zone 4), independently of piston rod position (patent pending)
- The valve does not affect the operation of standard damper valves in other velocity ranges (zones 1, 2, 3)



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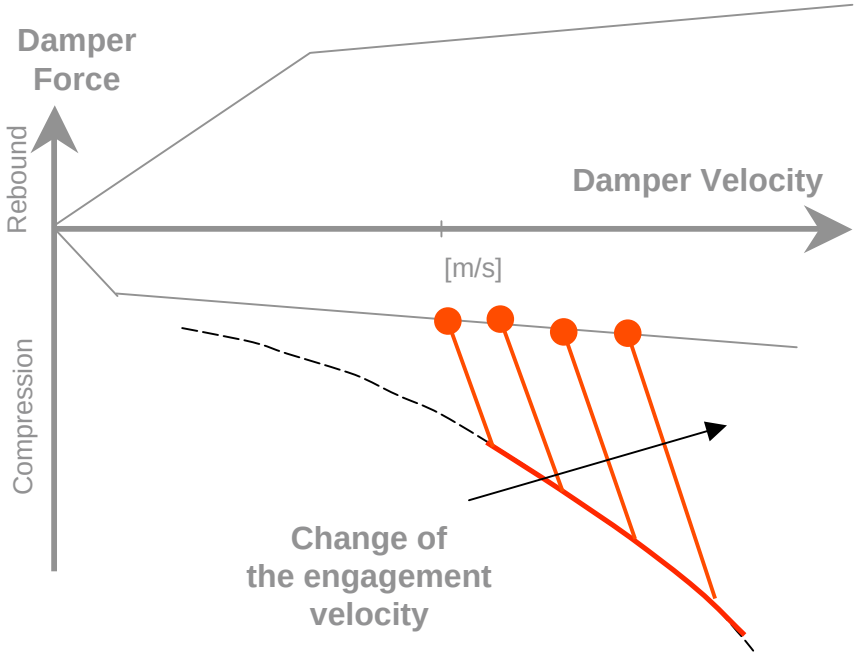
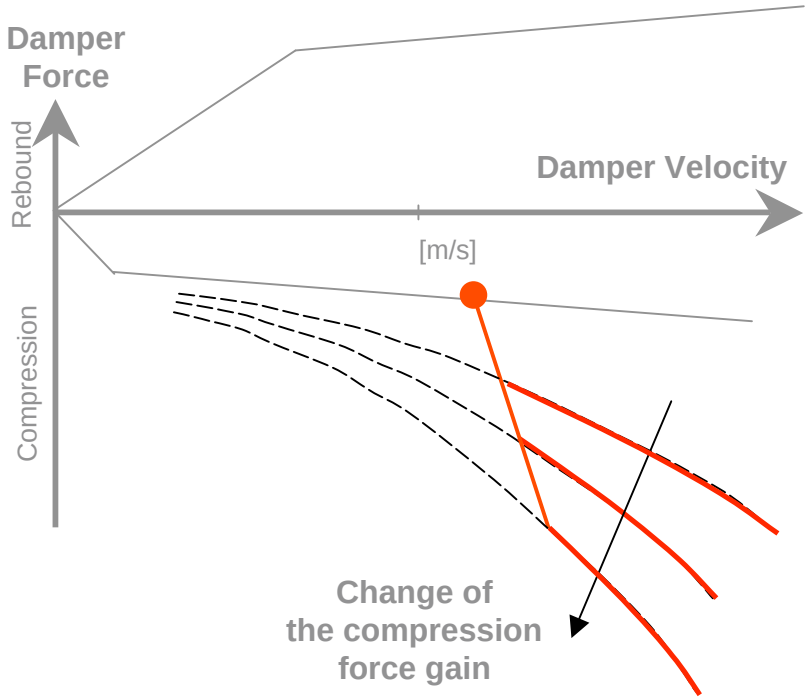
4. Innovative solutions – SuperProgressive valve

SP system tuning capabilities





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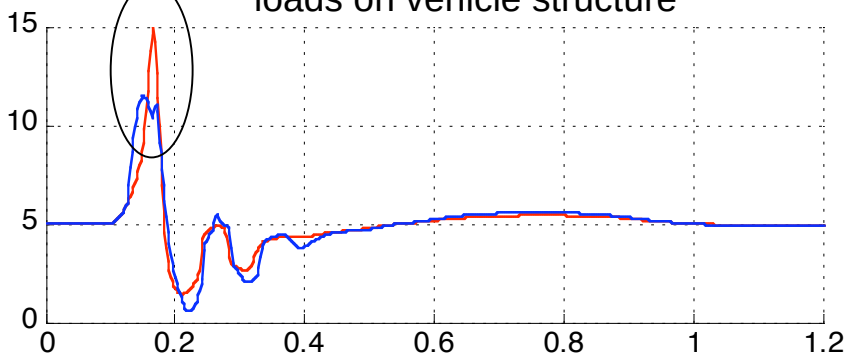
4. Innovative solutions – SuperProgressive valve

Influence on vehicle ride – quarter car simulation

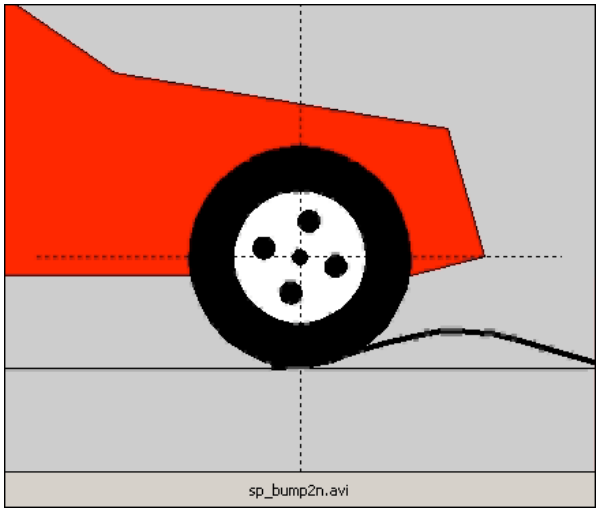
Peak force (spring+damper) decrease (~30%) due to SP system, reducing the loads on vehicle structure



Time histories

Decrease of suspension deflection (~15%) due to SP system, avoiding hitting travel limiters

Large bump impact



V_x = 55 km/h,
bump height = 0.1 m,
bump lenght = 1 m.

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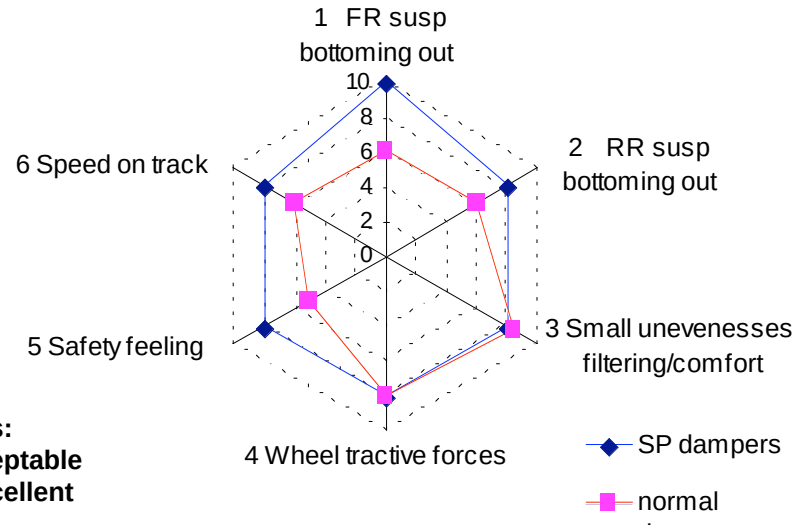
4. Innovative solutions – SuperProgressive valve

Testing and evaluation of Super Progressive system under extreme loadings in off-road rally



Ratings:
6 - acceptable
10 - excellent

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5. Summary

Problem:

How to achieve best compromise between ride comfort, road-holding and handling with passive suspension dampers considering specific customer requirements?

Solutions:

- ❑ Utlilize full range of valving system functionality to obtain required shape of damping curve and to maximize damping efficiency with otpimum pressure distribution in the damper.
- ❑ Further improvement can be obtained by modifications to typical damping characteristics, which usually involve upgrading the valving system with new solutions.
- ❑ DELPHI SuperProgressive and SuperDegressive valves address specific areas of vehicle behaviour to the extent that cannot be achieved with conventional valving systems.

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