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A Method for Overcoming Limitations of Tire Models for Vehicle Level Virtual Testing

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Background

- Accurate MBD models are desired for predicting vehicle loads for durability evaluation early in the product development cycle.
- Accuracy of modeled results dependent on components
- Challenges Include
 - Damper Models
 - Tire Models



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Project Objectives

- Evaluate the use of Virtual Test and RPC to overcome tire modeling deficiencies
- Evaluate accuracy of Emprical Dynamic (ED) damper vs. spline damper in vehicle level MBD suspension model for three events
 - Belgian Block
 - Step
 - Three Bumps

SAE 2006-01-0499



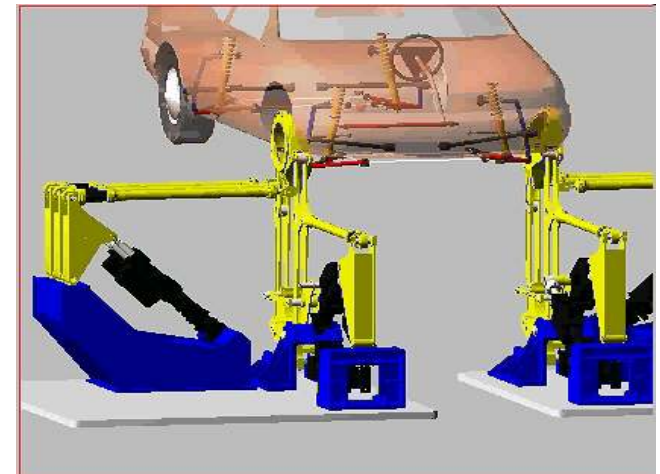
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Definition: Virtual Testing

Simulation of a real test using MBD software such as MSC.Software's ADAMS™ to obtain accurate loads in vehicle system





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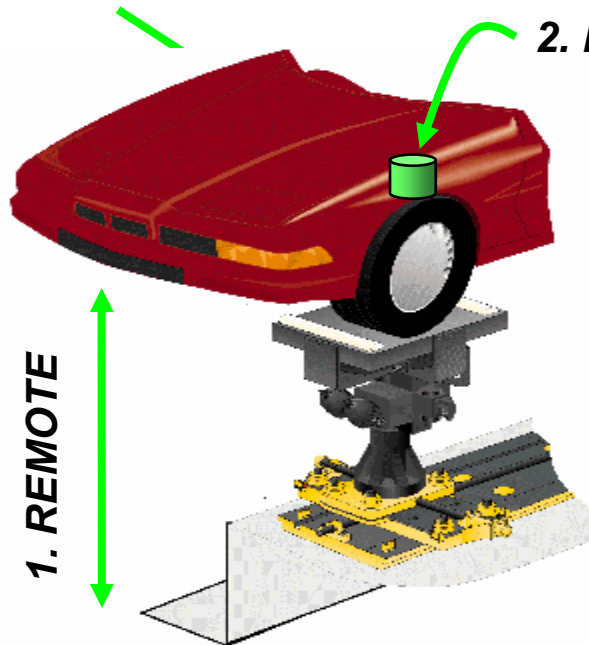


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Definition: RPC™ (Remote Parameter Control)

- Remote Parameter Control (RPC) is an advanced simulation technique used to repeatedly replicate and analyze “in service” vibrations and motions of a specimen using a dynamic mechanical system in a controlled laboratory or virtual environment.

.e.g. Accelerometer

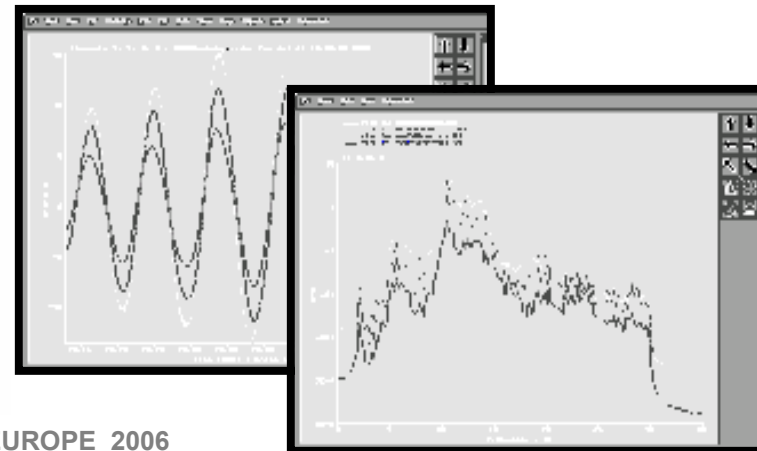


2. PARAMETER

3. CONTROL

Control of

- Amplitude Distributions
- Spectral Densities
- Multi-axial Phase Relationship





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Definition: Empirical Dynamic (ED) Damper Model

- Black box model between damper force and velocity
- Neural network based
- Model both frequency and amplitude nonlinear property
- Proven to be more accurate than traditional spline and FRF models in component level



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Direct Vehicle Level Correlation Steps

1. Gather proving ground data on instrumented vehicle over several surfaces
2. Reproduce measured proving ground events using a quarter car test system in the lab and RPC
3. Record actuator displacement signal at tire patch
4. Apply measured actuator displacement signal to a Virtual Test model of a quarter car test system
5. Evaluate results
 - Physical test to analytical test
 - ED model results compared to spline model results



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Quarter Vehicle Test System



- Gathered PG Data on body and suspension components
- Build ¼ Vehicle Test System
- Vertical input at Tire
- Body represented by mass (floating on mounts)

Lab testing system to provide benchmark for correlation study (tire is not shown)

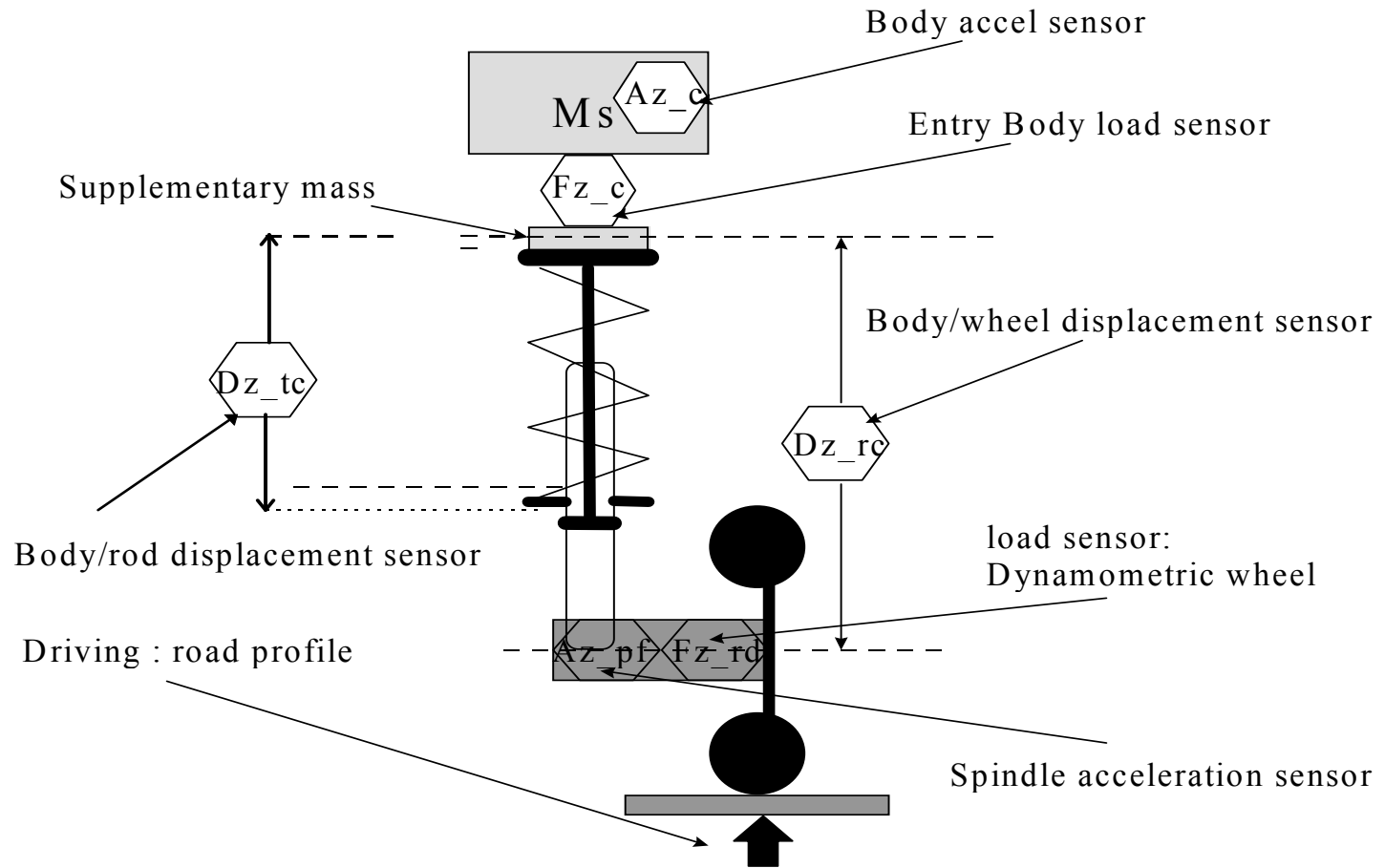


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Schematic Diagram of the Test System



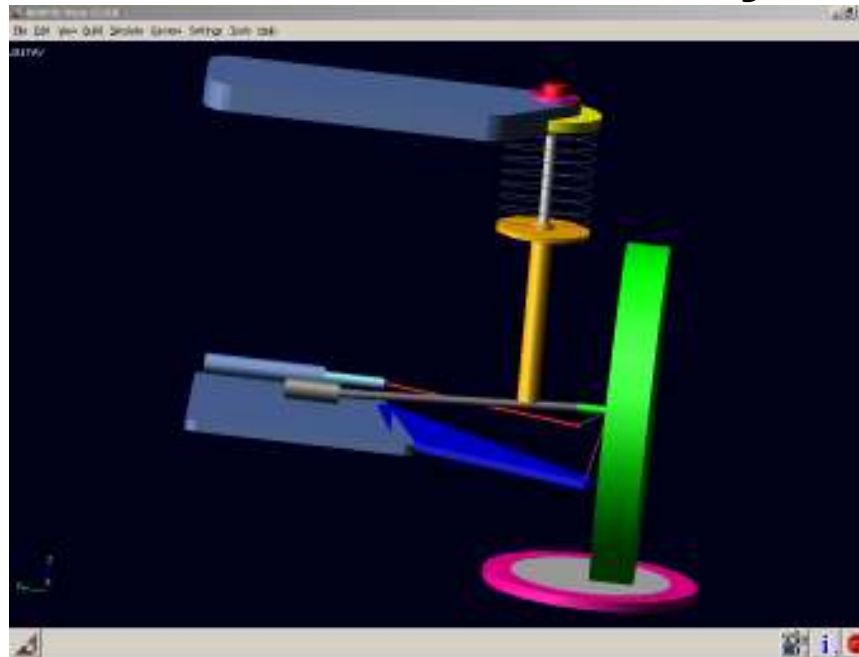


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ADAMS Model of the Quarter Car System



Virtual testing model with ED damper or spline damper model inside
ADAMS model includes quarter car, actuator
Tire was modeled by a simple impact function

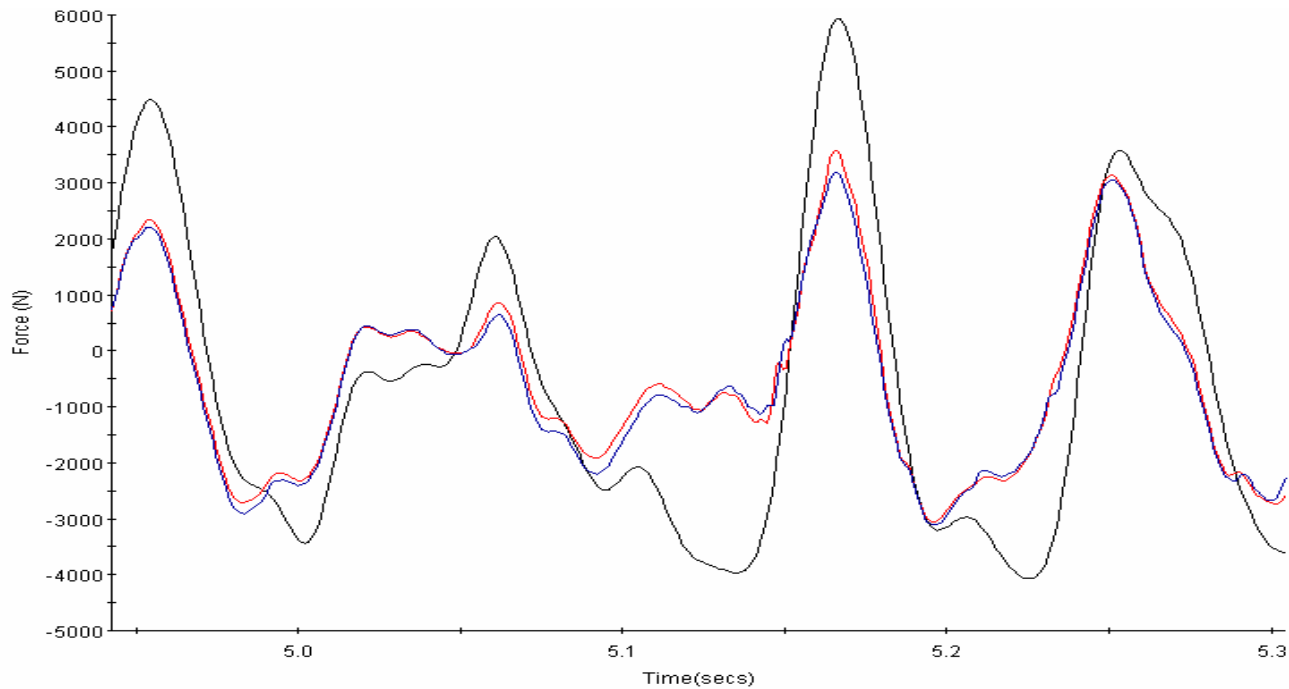


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Spindle Load Fz – Correlation & Comparison



Black: Test Result
Red: ED Model Result
Blue: Spline Model Result

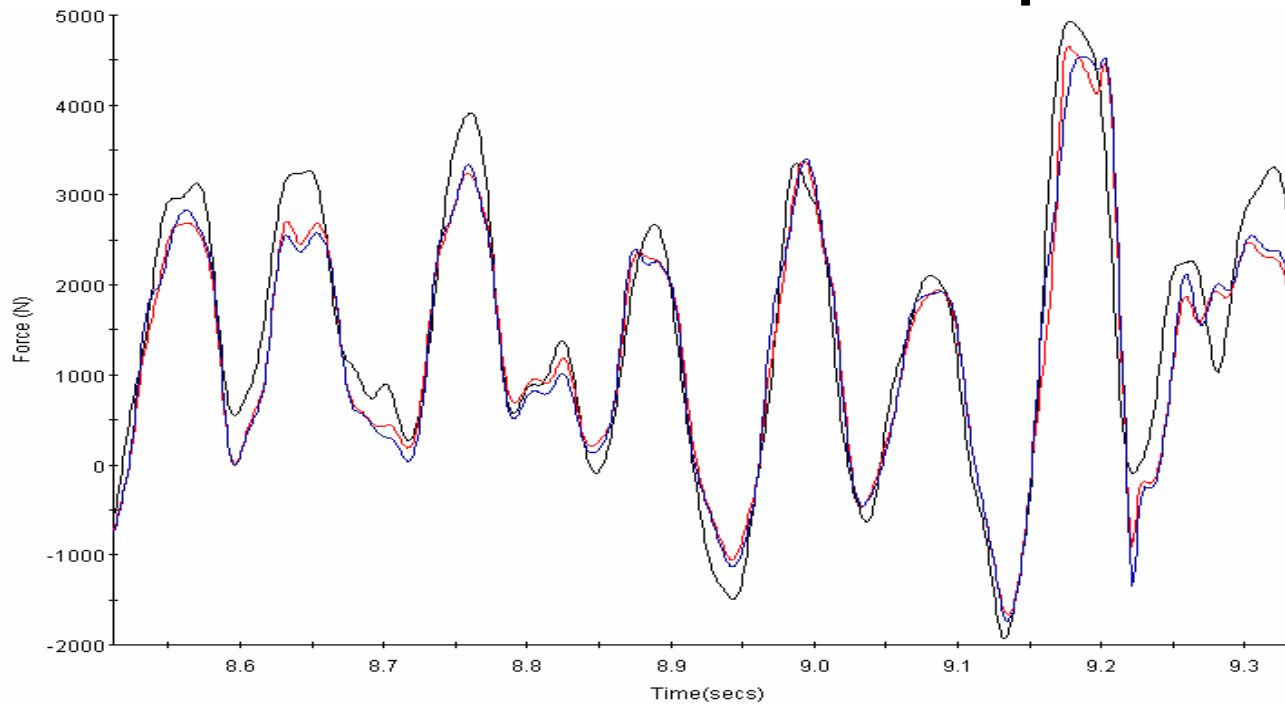


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Shock Tower Load – Correlation & Comparison



Black: Test Result
Red: ED Model Result
Blue: Spline Model Result

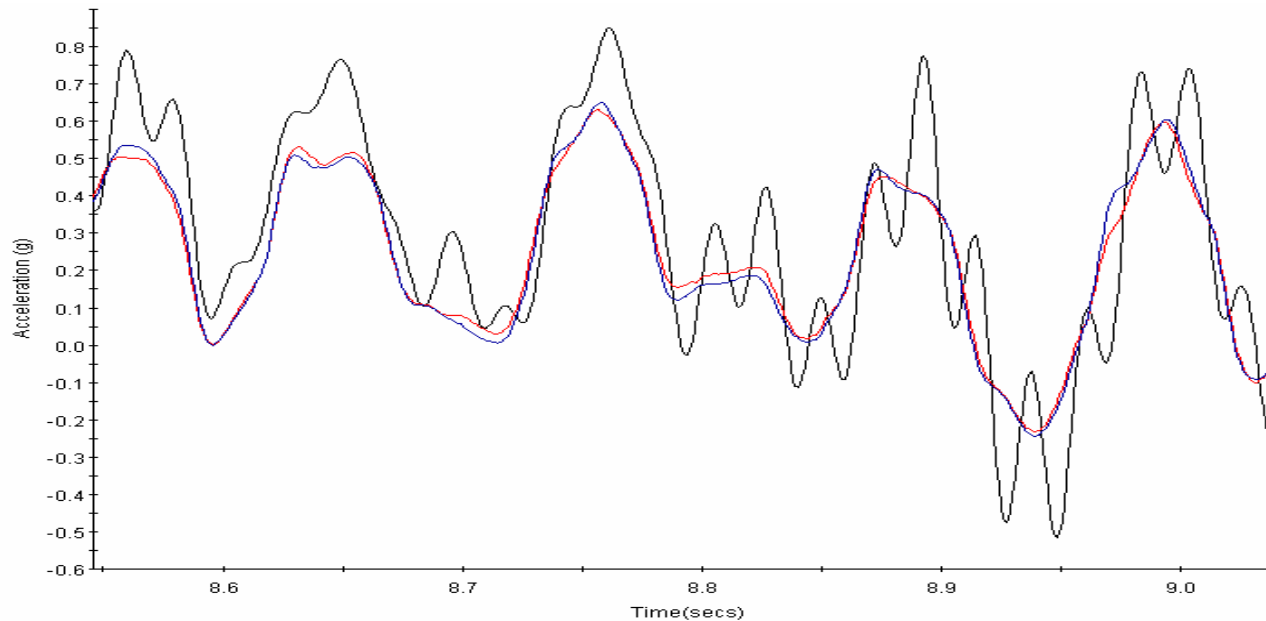


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Shock Tower Acceleration Comparison



Black: Test Result
Red: ED Model Result
Blue: Spline Model Result



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Direct Vehicle Level Correlation: Result

- Overall level of correlation was poor
- It was suspected that tire model was too simple and generated high level of error
- The error propagates to whole model
- Could not determine whether ED damper model is more accurate than the spline model



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Addressing the Inaccuracies of the Tire Model: - Use of RPC in Virtual Test: Steps

1. Use spindle acceleration and body to wheel displacement signals measured on proving ground events
2. Use RPC and the quarter car Virtual Test model together to reproduce the physical spindle acceleration and body to wheel displacement in ADAMS.
3. Compare reference signals above spindle
 - Physical test to analytical test
 - ED model results compared to spline model results.

Accuracy of the tire model is not important.



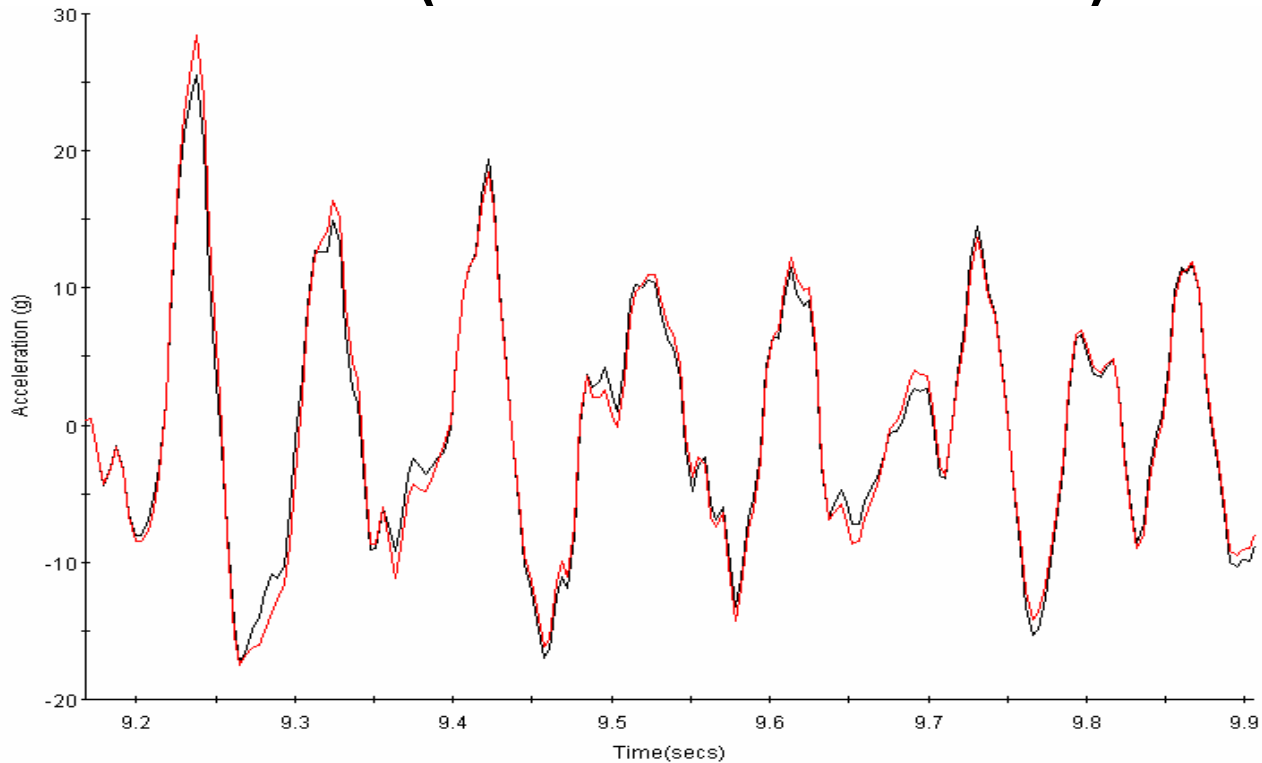
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Lab vs. RPC Virtual Test Comparison Spindle Acceleration (RPC Control Channel)

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Black: Test Measurement
Red: Achieved by RPC Iterations

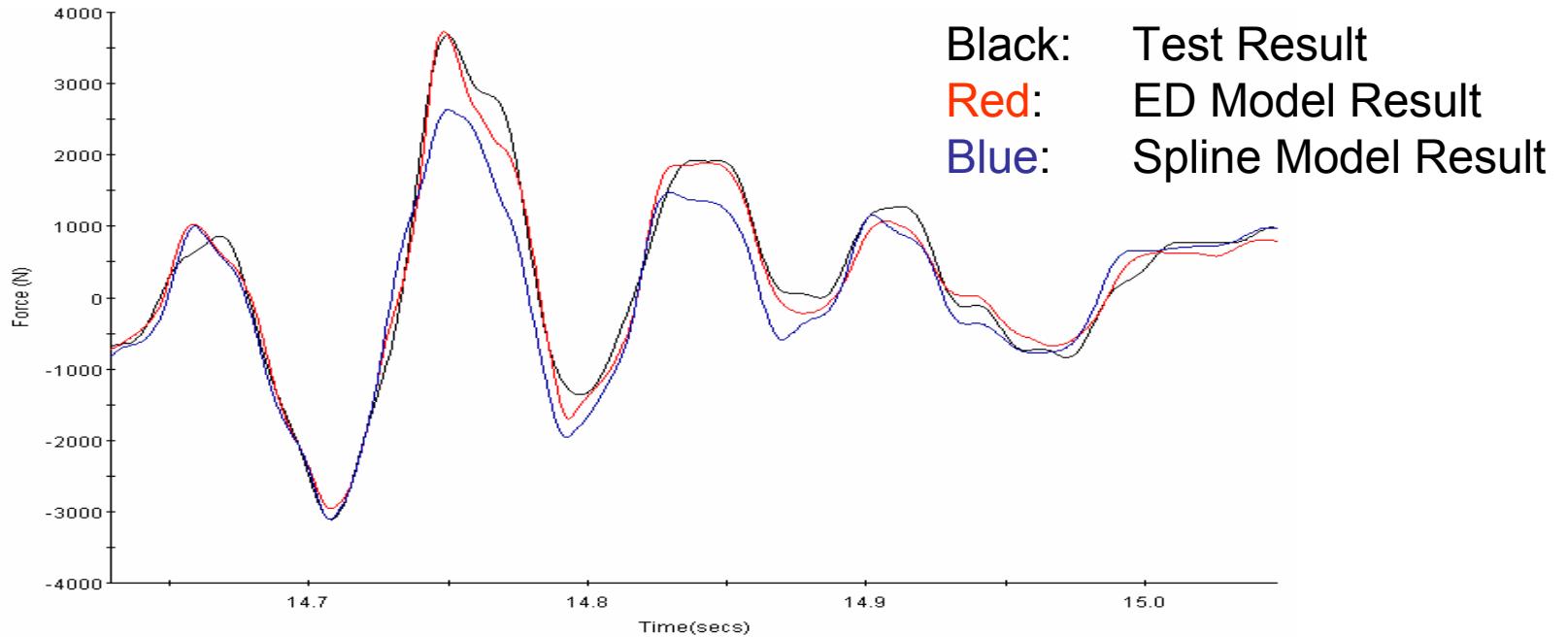


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Lab vs. RPC Virtual Test Comparison Shock Tower Force Comparison



Belgian Block Event

Peak value for test result =	3680 N
Peak value for ED model result =	3730 N
Peak value for spline model result =	2640 N



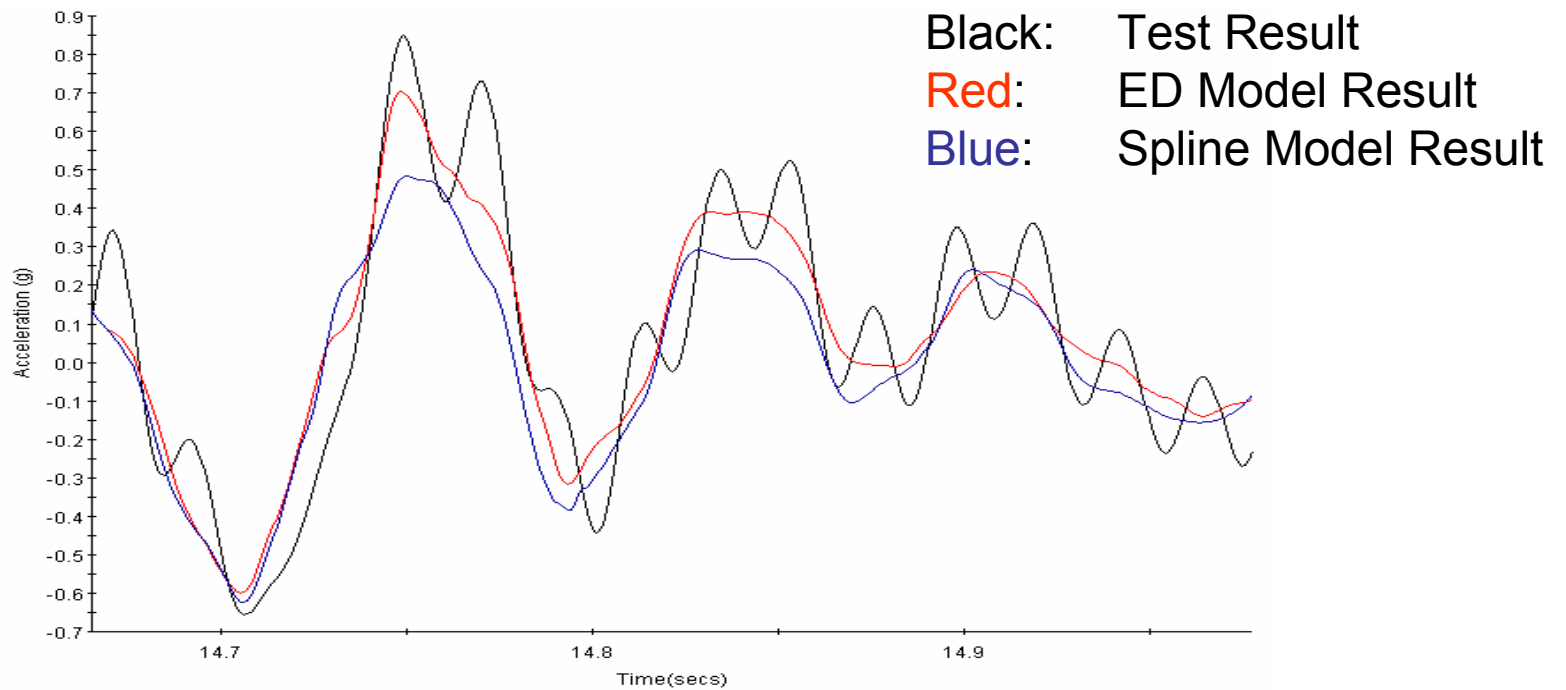
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Lab vs. RPC Virtual Test Comparison Shock Tower Acceleration Comparison

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Belgian Block Event

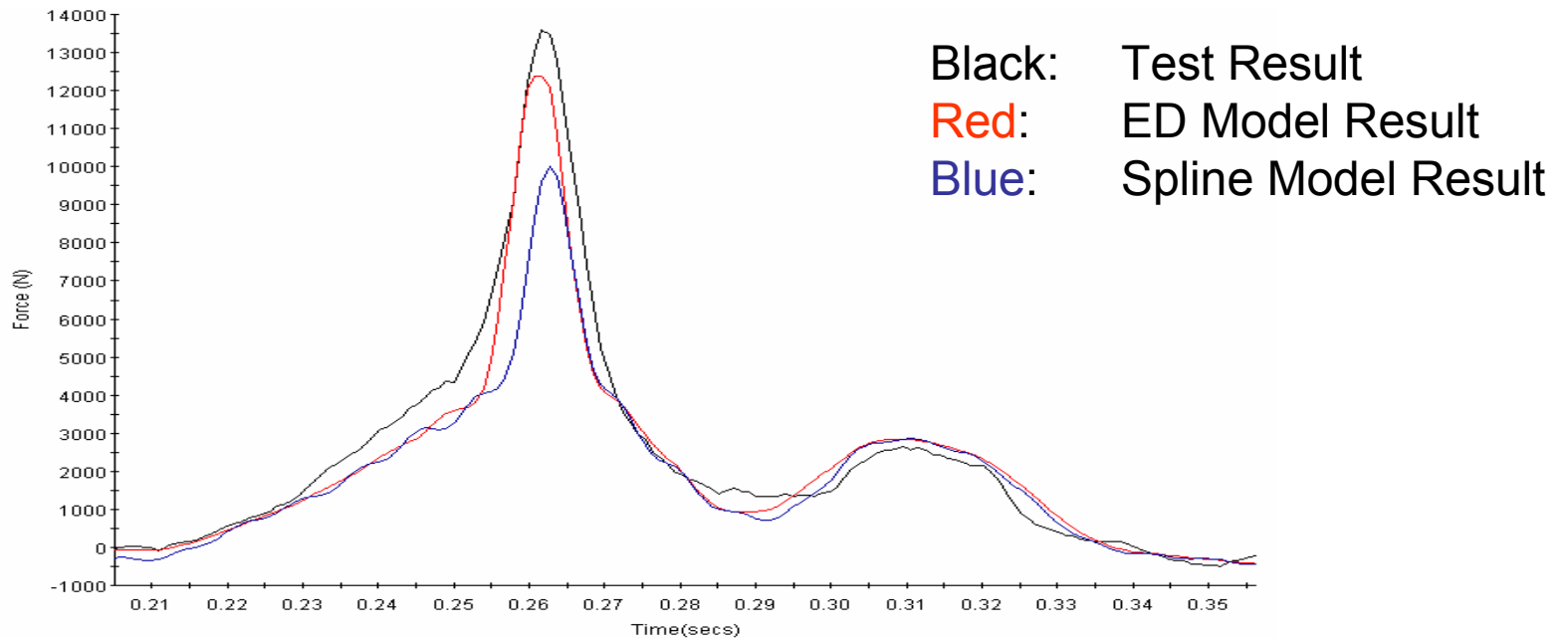


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Shock Tower Force Comparison



Step Event

Peak value for test result = 13600 N
Peak value for ED model result = 12400 N
Peak value for spline model result = 10100 N



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Lab vs. RPC Virtual Test Comparison Belgian Block and Step - Result

- For high damper load condition, model with ED damper is more accurate
- For low damper load condition, both ED damper and spline damper models are similar because damper is in linear range

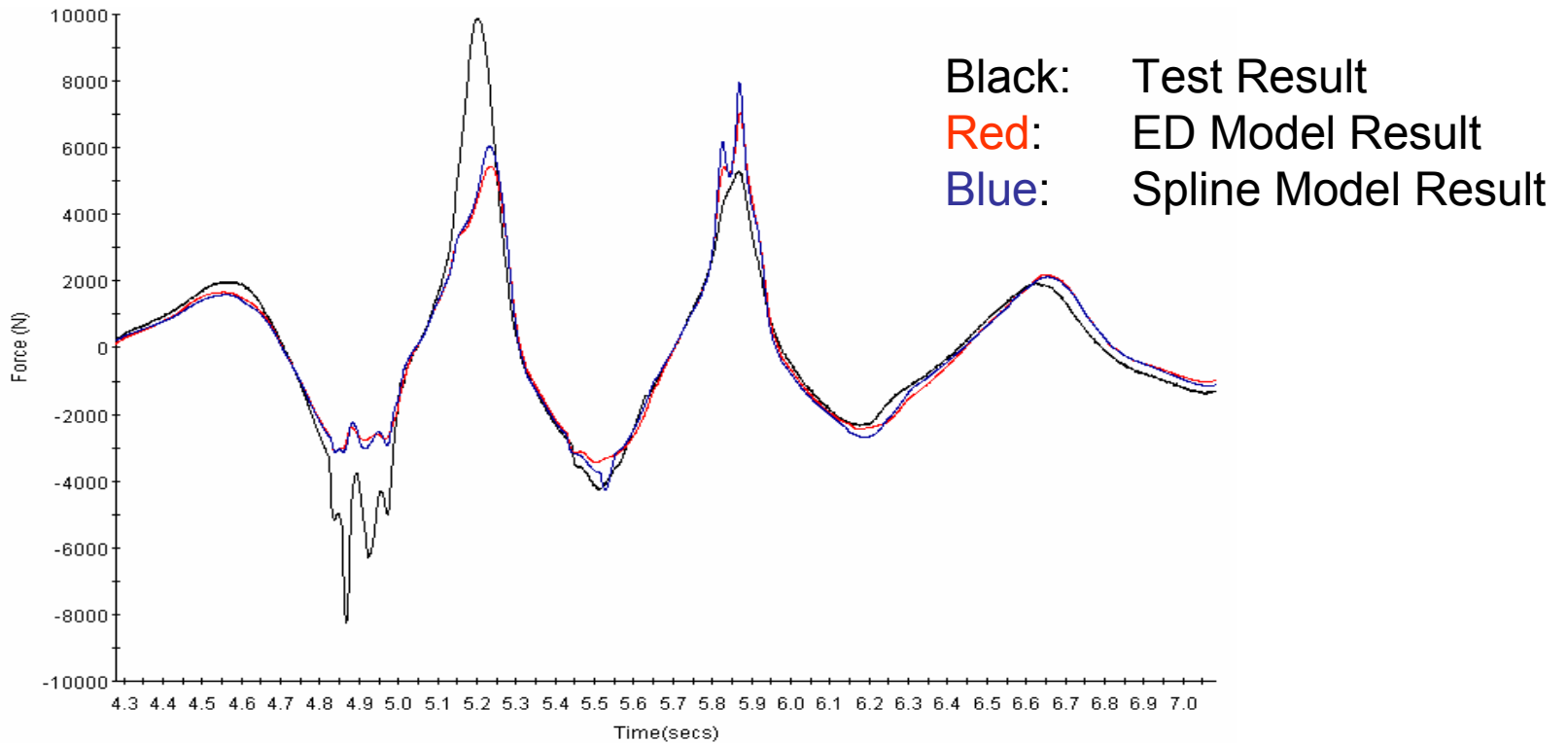


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Shock Tower Force Comparison



Three Bumps Event

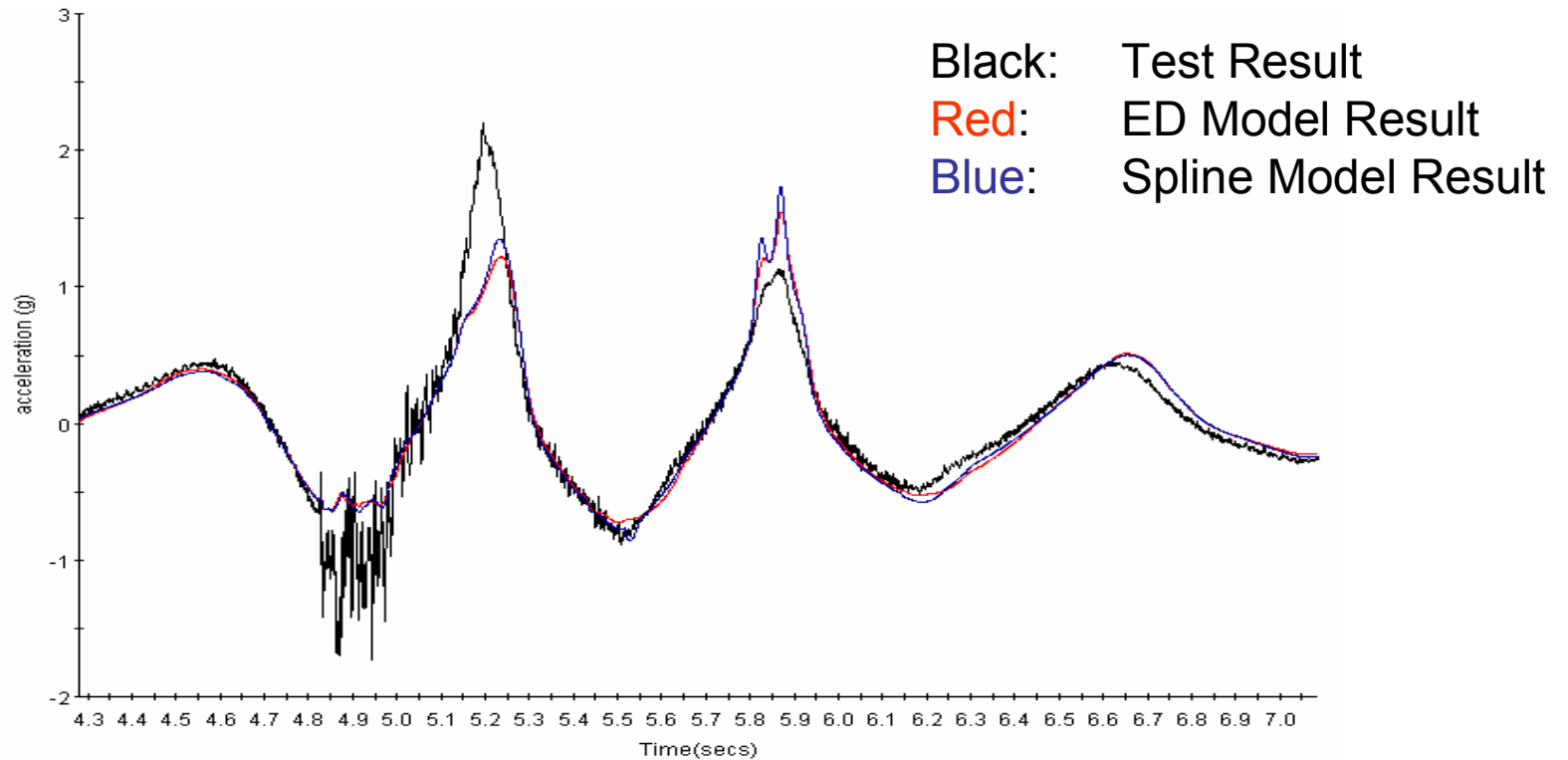


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Shock Tower Acceleration Comparison



Three Bumps Event



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Three Bumps RPC Approach Result

- Jounce bumper impact occurred. The vehicle model did not model the jounce bumper geometry & impact accurately.
- As a result, virtual test result accuracy was poor
- Comparison of ED and Spline dampers inconclusive



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Moving Forward

- ED modeling technique could be used to develop an improved model of the tire to provide more accurate MBD model for the test system
- Generic road approach could be used to transfer road load data for existing vehicle to a concept vehicle to avoid data acquisition
- RPC approach could be used to reproduce road data using virtual testing to obtain component load and evaluate concept vehicle design



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Virtual Testing Benefits: Analysis

- Analysis and test personnel using a common tools
- Possible to avoid modeling complicated elements (proving ground surfaces, tires, and etc.)
- The test rig can provide easier to model constraints
- Easier Physical / Analytical correlation analysis
- Existing testing software tools can be used in analysis



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Virtual Testing Benefits: Test

- Allows evaluations of test setup and fixture designs prior to building
- Allows evaluations under extreme load situations
- Reduce of test time using virtual results



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Project Conclusions

- Accurate vehicle model is essential for virtual testing
- RPC iteration process can bypass problematic elements such as tire models
- ED damper model is more accurate than spline damper model for high damper load conditions
- ED damper model and spline damper model results similar for low damper load conditions