Virtual Testing by Using Virtual Spindle Coupled Road Simulator and Remote Parameter Control

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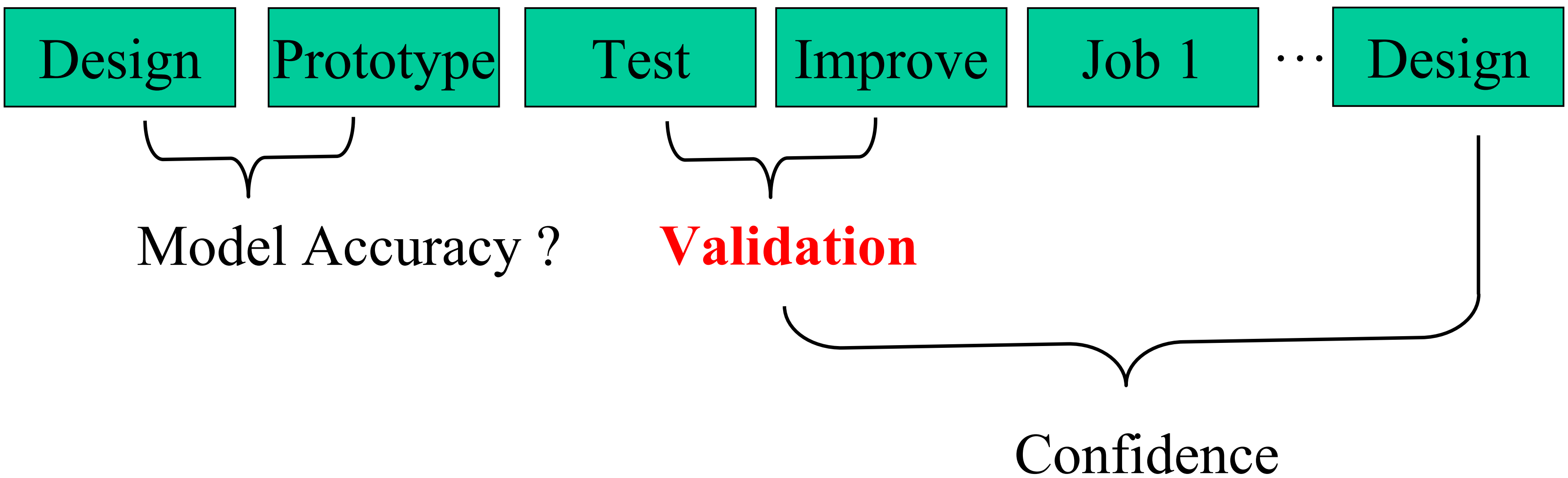
Motivation

Design Process and Validation



Virtual Testing Process

- Test rig tuning with dumbbell specimen
- Full vehicle simulation by using tuned test rig to identify problems related to the vehicle model and the test
- Fix the problems and conduct full vehicle simulation again
- Other applications such as reducing physical RPC iteration numbers, load path analysis, and virtual durability prediction

Advantages of Virtual Tests

- **Virtual testing can evaluate the design early in development when the prototype is not available**
- **Virtual testing can help when setting up the physical test to better utilize the testing equipment**
- **Virtual testing can be conducted faster and cheaper than physical testing**
- **Boundary and load conditions can be obtained easier and faster by virtual test**
- **Virtual testing results can be validated with data from the physical test it modeled.**

Why Model the Test Rig

- Unified tool set between analysis and test users
- Avoid modeling complicated proving ground surfaces
- Avoid modeling highly nonlinear tires
- The test rig can provide proper constraints to the vehicle
- The analysis result can be validated by the physical test.
- VTL can reproduce over determined system through non-square RPC iteration.
- With proper modeling technique, virtual 329 test rig can apply a distributed load to the spindles.

Why Model the Test Rig

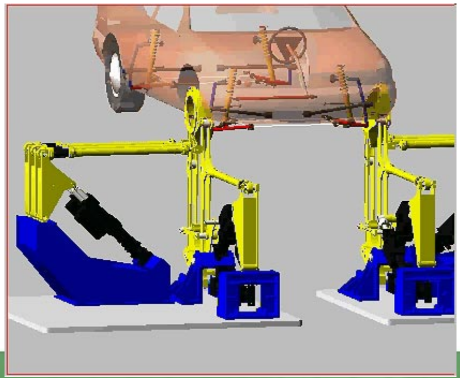
- Identification of test conditions that are unrealistic (e.g. study of fixture mass influence)
- Evaluations under extreme load situations
- Optimization of physical test program prior to start of test

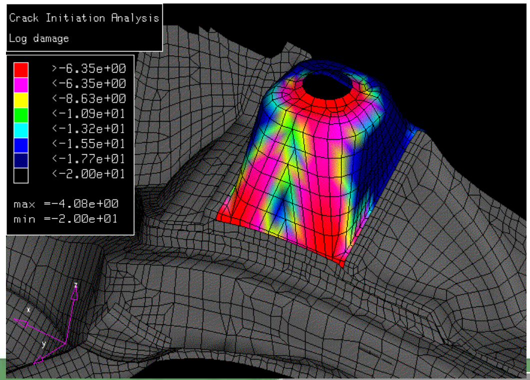
  (limit setting, event choices, order of events, superposition of events)
- Statistical evaluations of multiple runs

Virtual Durability Prediction

- RPC iteration to reproduce spindle loads
- Record component loads for concerned components
- Conduct FE analysis on the components
- Predict fatigue damage based upon the load time history and FE result

Environment → **Spindle Loads** → **Component Loads** → **Fatigue Life**



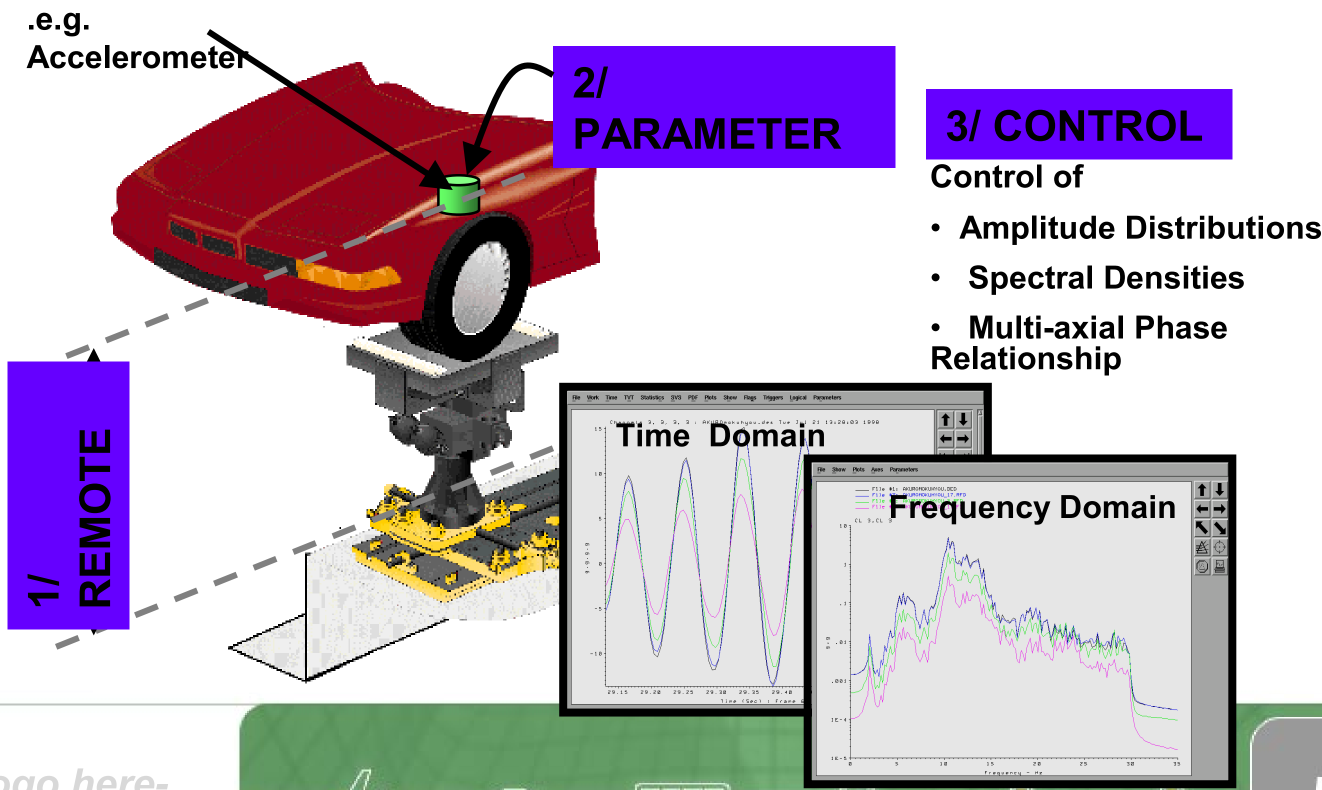


RPC ITERATION WITH VTL

What is 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 environment.

There are 6 Distinct Steps

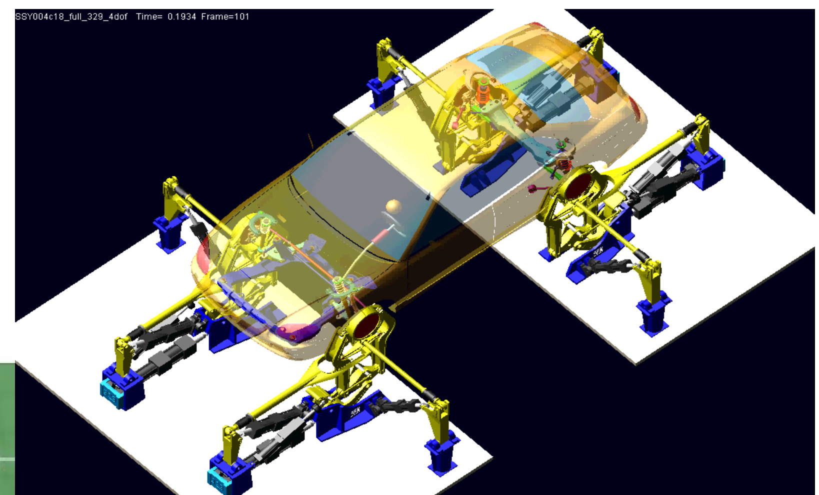


RPC With Physical Spindle Coupled Rig

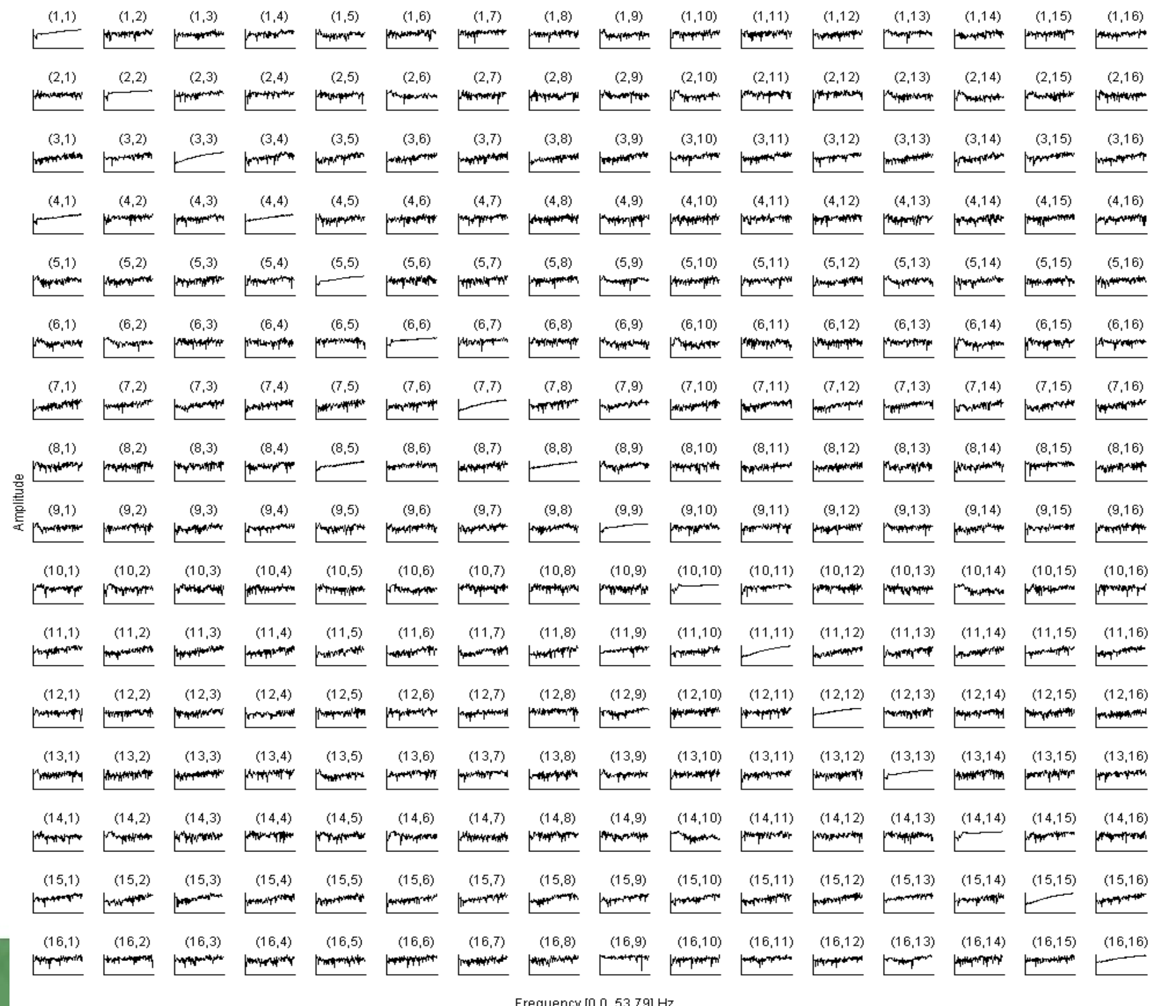
- RPC is widely used in the physical labs
- With physical spindle coupled system, RPC is able to reproduce spindle loads and other signals

RPC Iteration with VTL

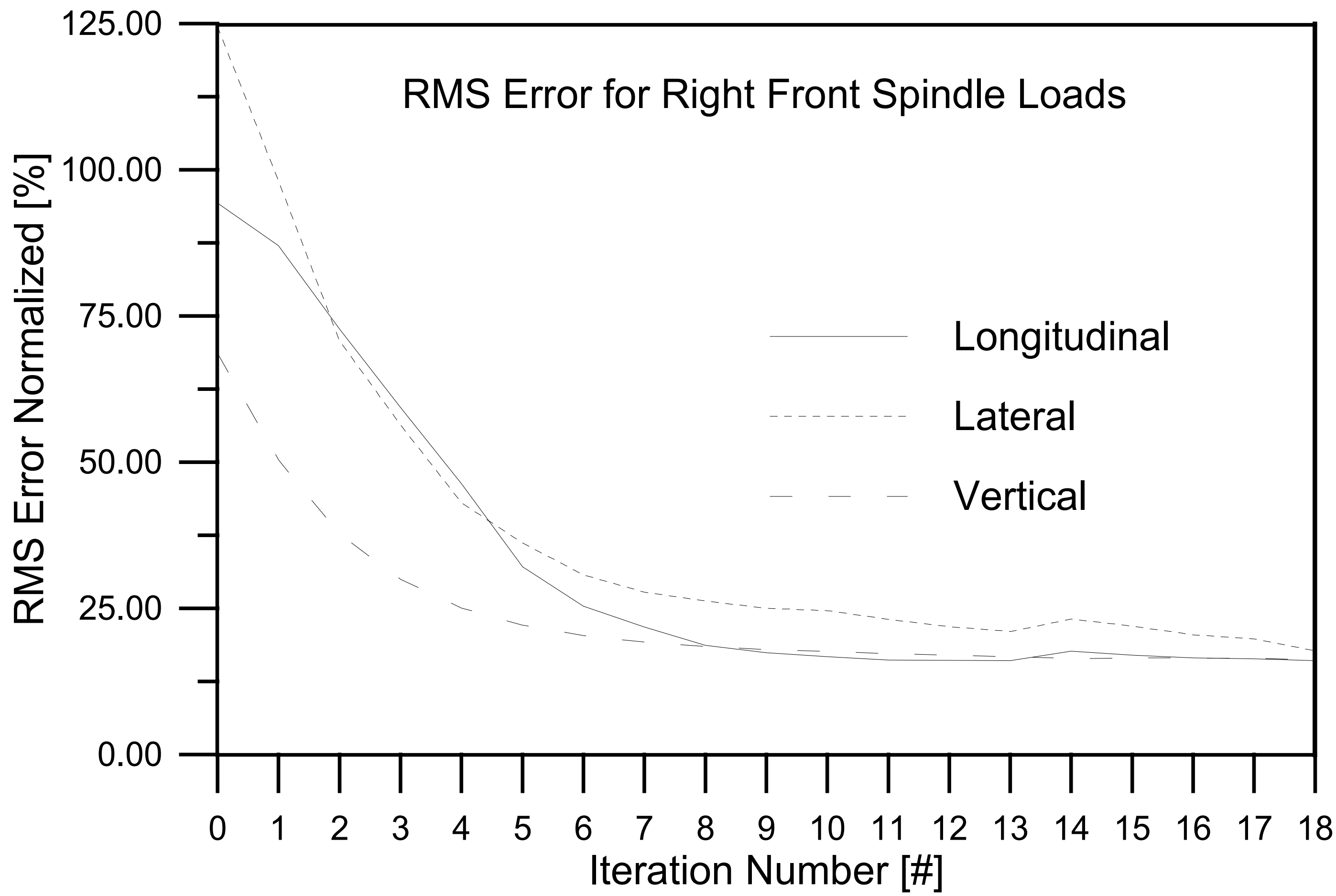
- Belgian block surface was considered
- Drive channels: actuator displacements
- Response channels: spindle loads
- Control Band: 0.5 to 50 Hertz
- 18 iteration were conducted
- Turbo tool was used



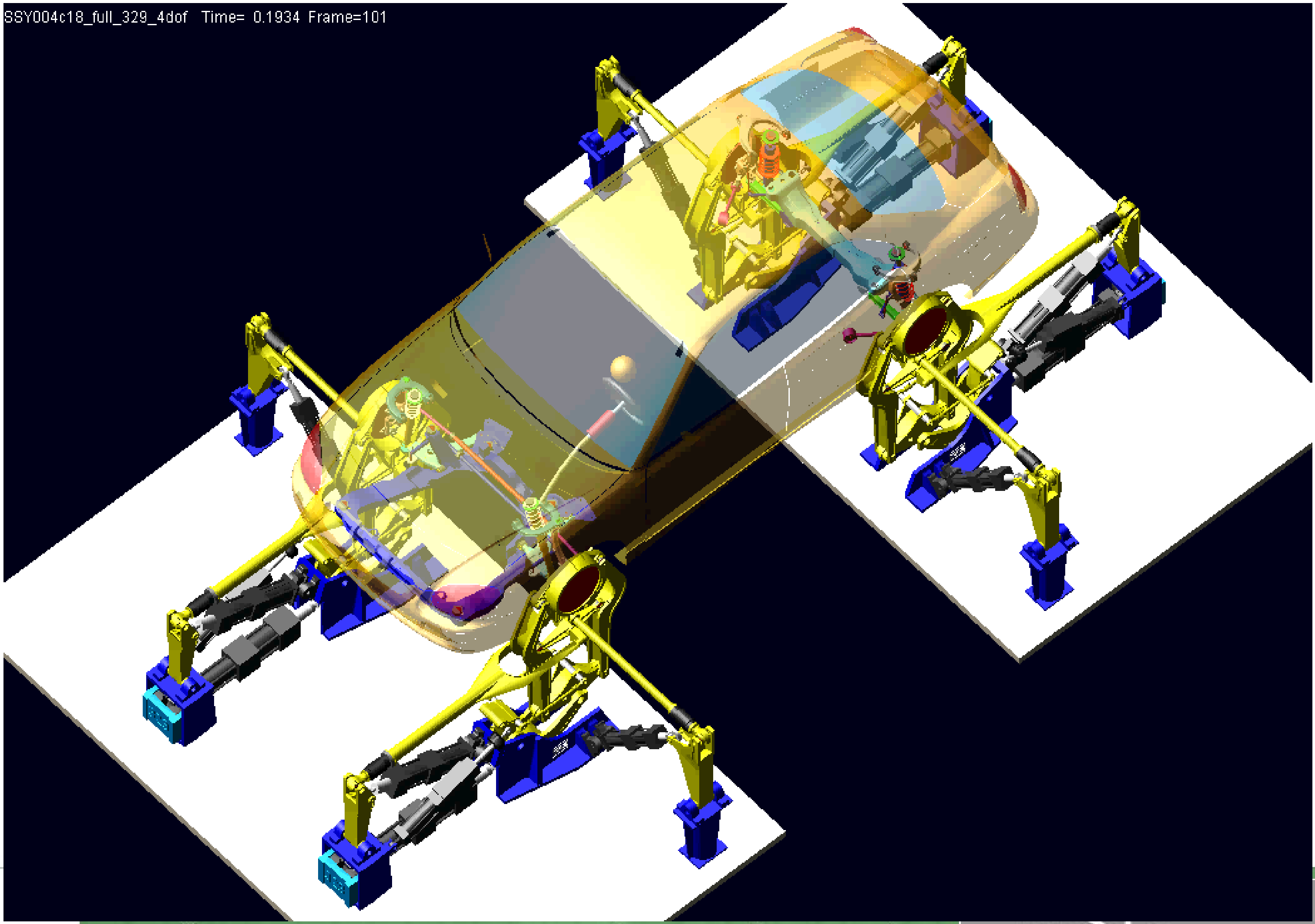
Frequency Response Function



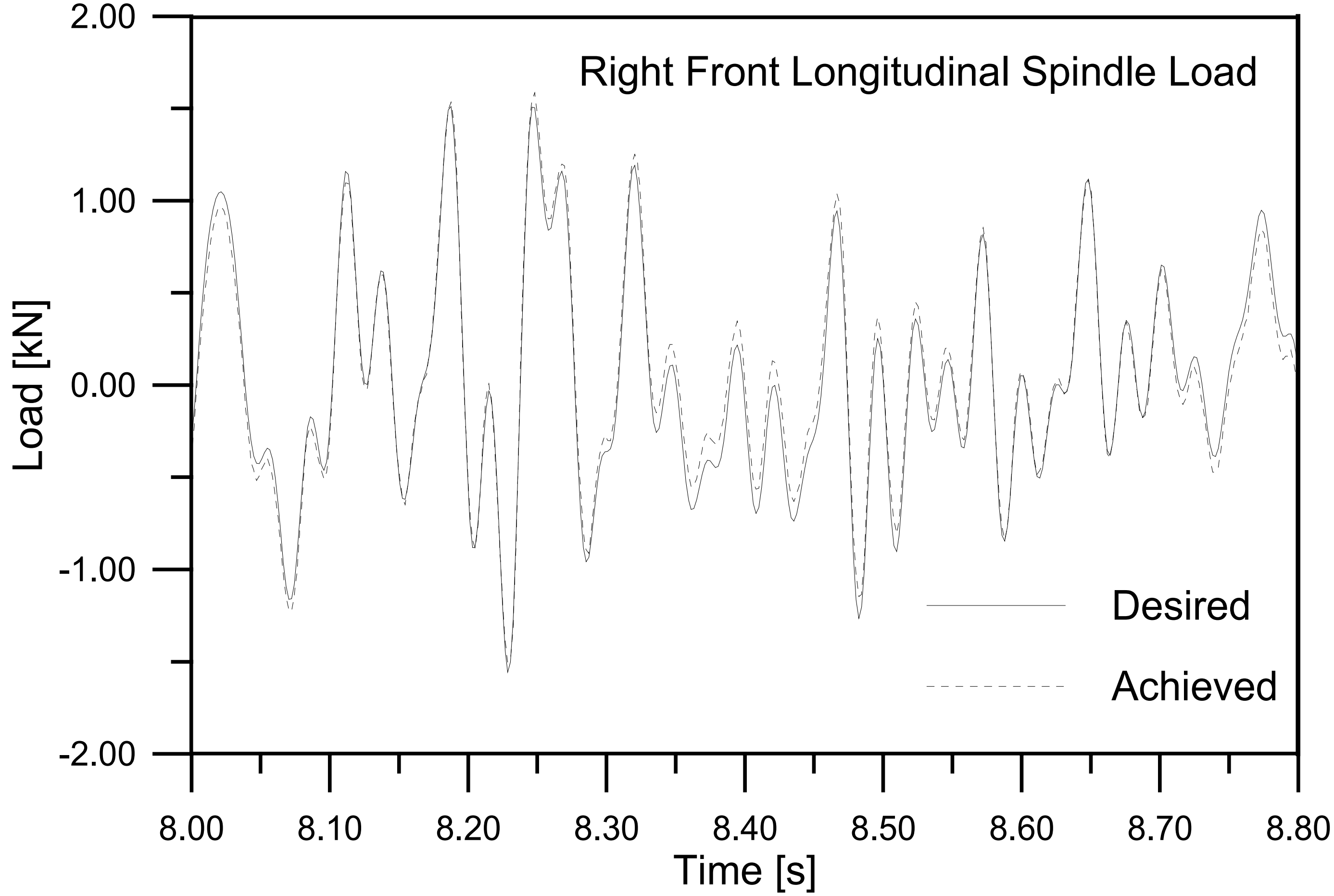
RMS Plot of the Iteration



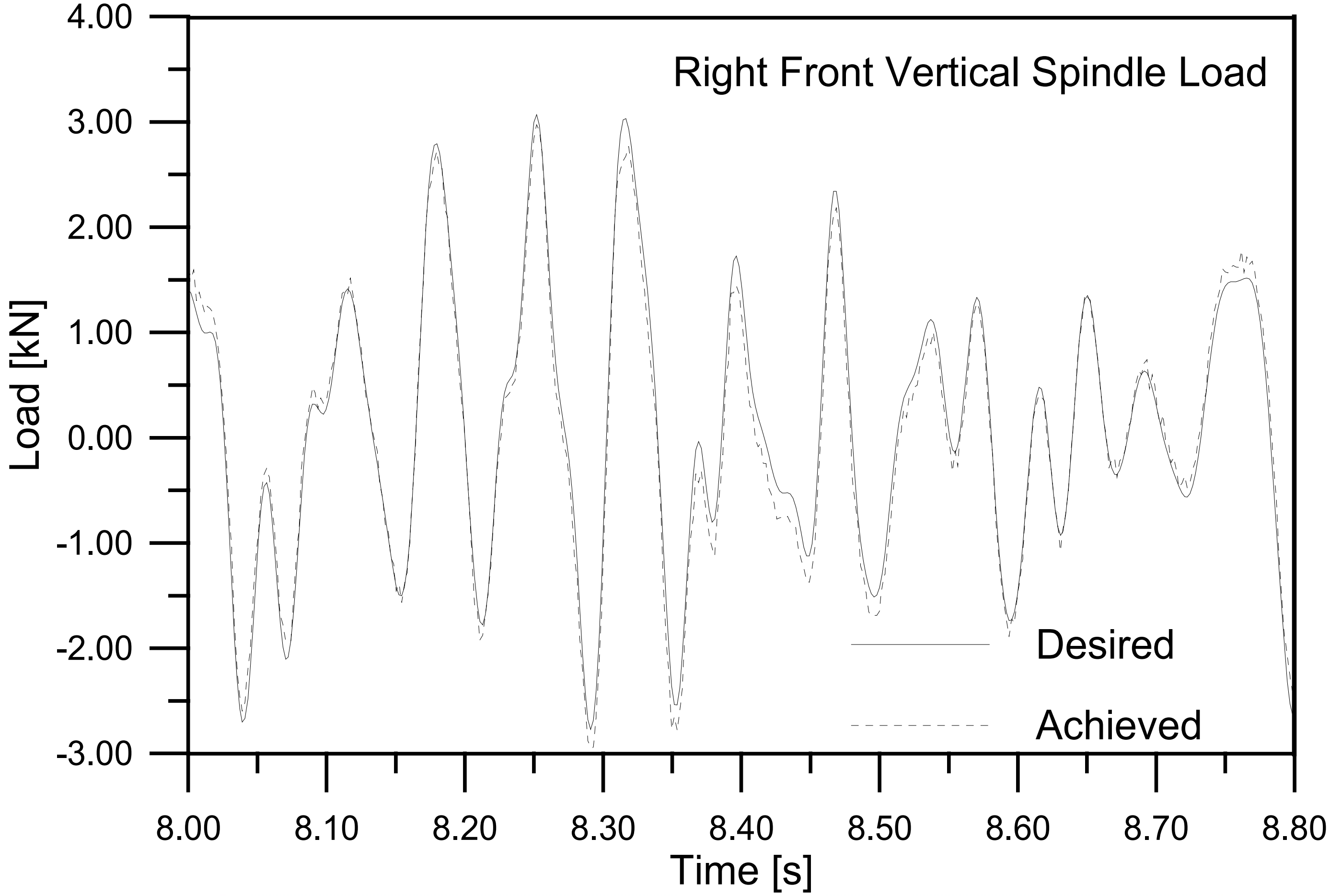
Virtual Test Animation



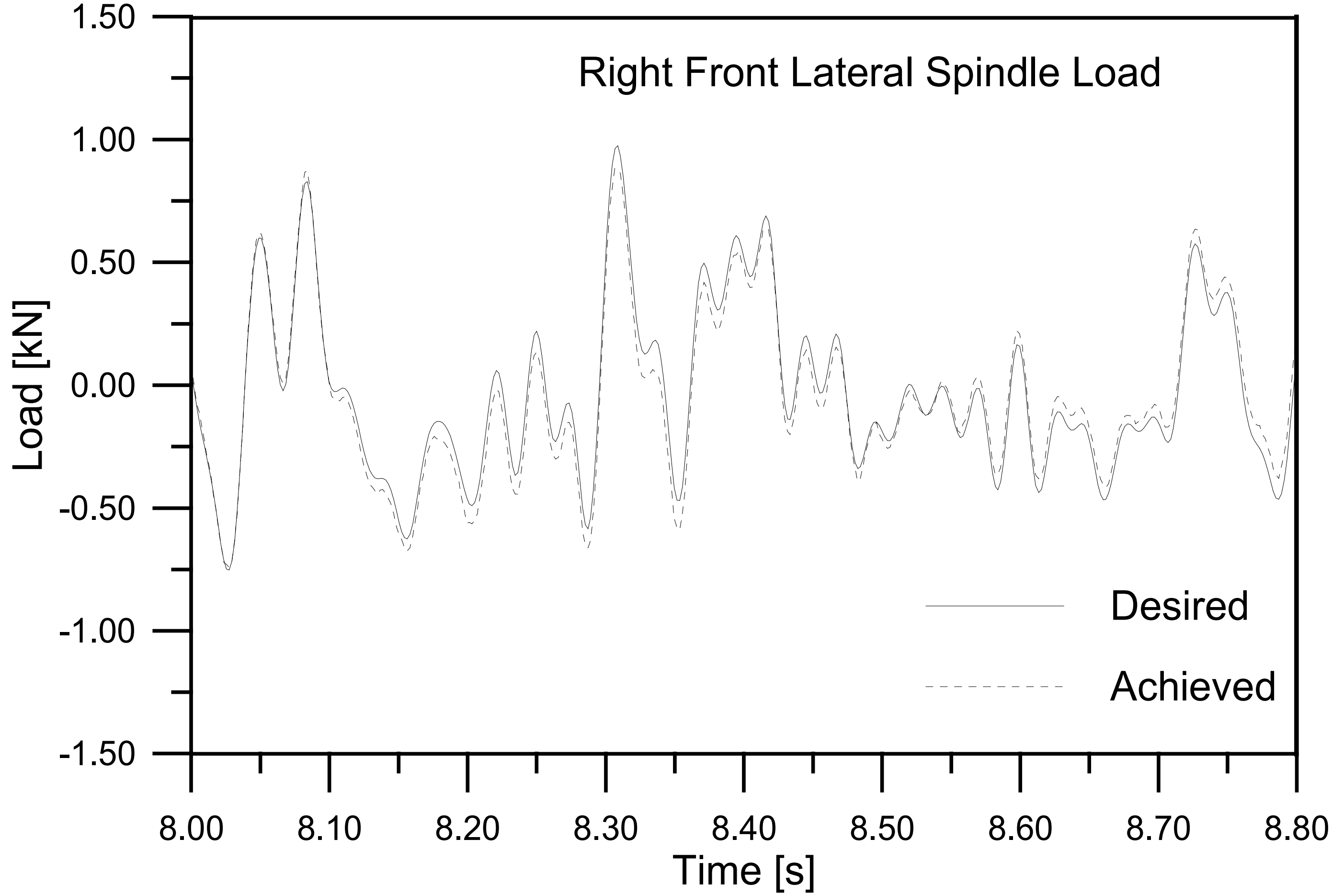
Iteration Result



Iteration Result



Iteration Result



RMS Error

	RMS Error %
Left Front Vertical Spindle Load	9.4
Right Front Vertical Spindle Load	15.7
Left Rear Vertical Spindle Load	13.0
Right Rear Vertical Spindle Load	8.0

Percentage of RMS error between lab measured and VTL predicted vertical spindle load and acceleration signals

Iteration Result

	Fatigue Life of desired loads	Fatigue Life of achieved loads	Ratio between desired and achieved
Longitudinal	1020	923	0.94
Lateral	1040	1180	1.13
Vertical	985	638	0.65

Iteration Result

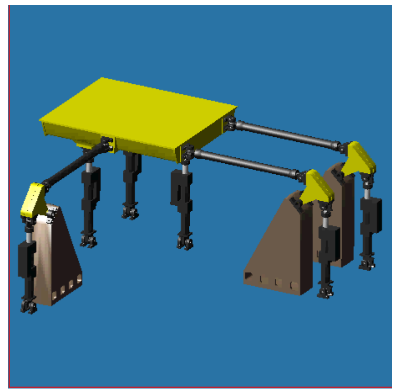
- **RMS error for all SWIFT load channels are below 30% with most of the channels below 20%.**
- **Time history plots show excellent match between desired and achieved spindle load.**
- **The differences between the fatigue lives of desired and achieved spindle loads are all within 50 %.**

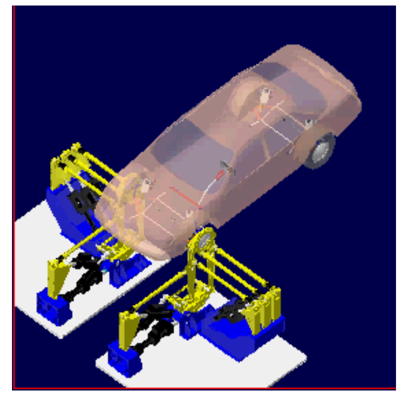
Conclusion: 329 VTL has RPC iteration capability

VTL Applications

Durability

- **329 Road Simulators**
- **MAST Systems**
- **4 and 7 Post Systems**





NVH

- **4 Post Systems**

Handling

- **Dynamic K&C**