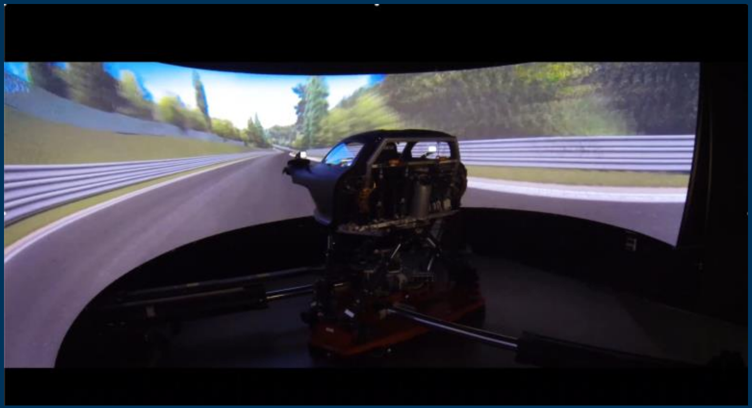
HBM Prenscia Technology Day

Virtual Seminar Series



Vehicle Test Simulation and WFT Loads Simulation

Presented by Mr. David Ewbank
Technical Director
VI-grade

Session #3: **Vehicle Testing & Simulation**

Vehicle Test Simulation and WFT Loads Simulation

Abstract

Vehicle design for durability is a long-established discipline, affecting all aspects of vehicle engineering. However, despite well proven techniques and processes, the loads used for component and system design are measured on a mule or even a competitor vehicle at the beginning of a vehicle programme and may not be revisited until well into an advanced prototype stage. At this stage, any durability concerns due to the use of approximated load cases can be difficult to implement due to costly tooling updates.

This presentation demonstrates the use of advanced simulation methods to investigate the variability of a vehicle design on the wheel loads and to produce a set of load cases which are robust and encompass the loads that could be achieved considering all possible tuning variations. As well as using robot driver technology this process can be extended to introduce the human element through the use of VI-grades advanced driving simulators with a human driver to study the impact of human variability of predicted wheel forces.

About the presenter, Mr. David Ewbank

David Ewbank started his career at MIRA where he started out in road load data measurement and objective vehicle dynamics testing using analogue tape recorders and mainframe computers to digitize the data. His career progressed into computer simulation of durability and vehicle dynamics with MDI Adams Version 8, later moving to MDI and then MSC Software to focus on multi-body dynamics simulation as a Consultant. David is now in his 15th year working for VI-grade as a Technical Specialist with a particular expertise in real time simulation and driving simulators as well as being the VI-Certified Technical Manager.

Prediction of robust virtual WFT loads data using VI-CarRealTime and VI-grade Driving Simulator Technology

David Ewbank

TIME TO MARKET

DEVELOP
IN LESS TIME

DEVELOPMENT COSTS

LESS PROTOTYPES AND
TESTING

COMPLEX SYSTEMS INTEGRATION

COLLABORATIVE DEVELOPMENT
PLATFORM AMONG THE INDUSTRY

VEHICLE DEVELOPMENT CHALLENGES TODAY

COMPLEX SYSTEMS INTEGRATION

VEHICLE MODEL

A detailed vehicle model with all its subsystems and components.

ROAD MODEL

Detailed and realistic road model, reproducing the exact test conditions.

DRIVER MODEL

An advanced virtual driver model to reproduce any open-loop and closed-loop maneuver.

FASTER – CHEAPER – SAFER INNOVATION

LESS TIME

LESS COST

LESS RISKS

MOVING FROM PROTOTYPES TESTING TO VIRTUAL DEVELOPMENT

Typical Process for Durability

WFT data fixed through design process
- Not representative of latest design
- What impact do design changes have on wheel forces?

RLD Measurement (mule/competitor vehicle)

CAE Design

Fatigue Analysis

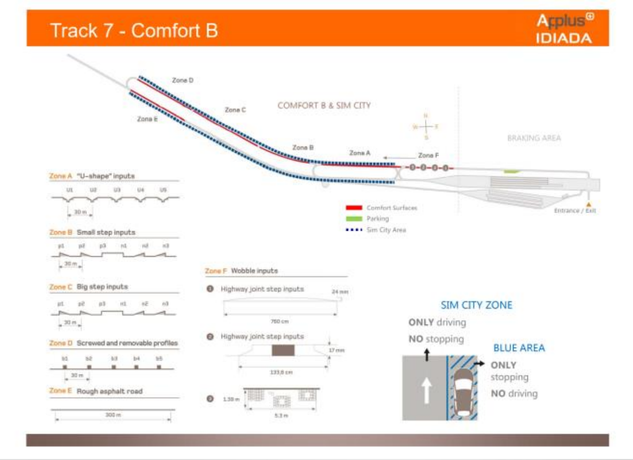
Post Processing and analysis

Design Process

RLD Measurement
- Costly
- Time consuming
- No access to representative vehicle
- Mule vehicle ballasted to target weight

VI-CarRealTime Vehicle Model

- Applus+ IDIADA Comfort Road Surfaces
- Accurate faster-than-real-time simulations
- Laser scanned road surfaces
- Complex tyre models (Ftire, MFSwift and CDTire supported)
- Versatile VI-CarRealTime Investigation mode

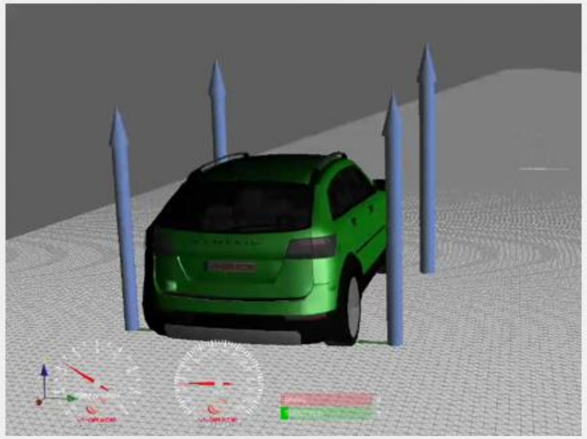


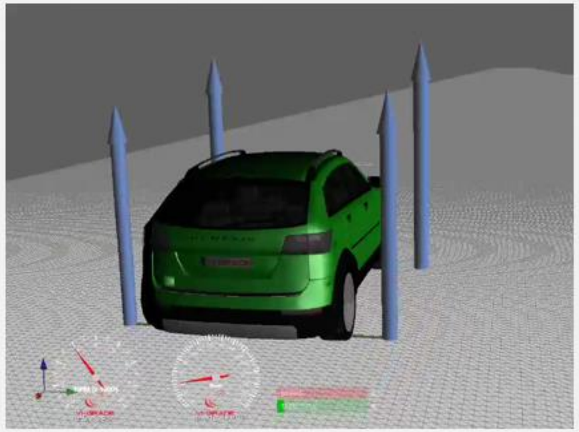
Primary Ride
- Long wave pitches
- Test speed – 50 km/h

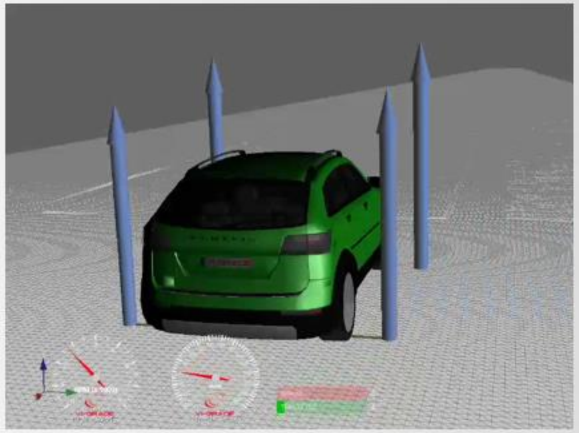
Inputs
- Various discrete inputs
- Test speed – 40 km/h

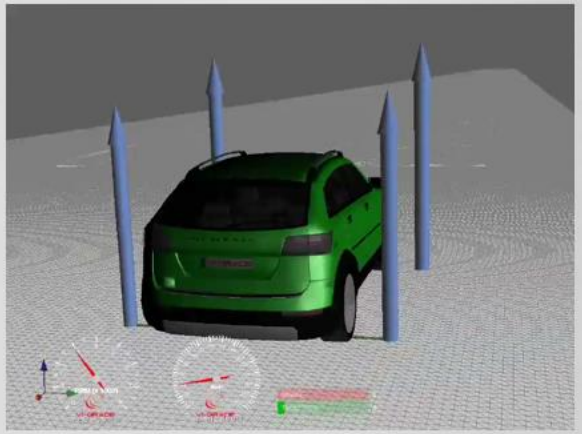
Badly Maintained Road
- Self explanatory
- Test speed – 60 km/h

Pave
- Classic durability road
- Test speed – 50 km/h









VI-CarRealTime Vehicle Model

- Correlated mid-sized SUV model

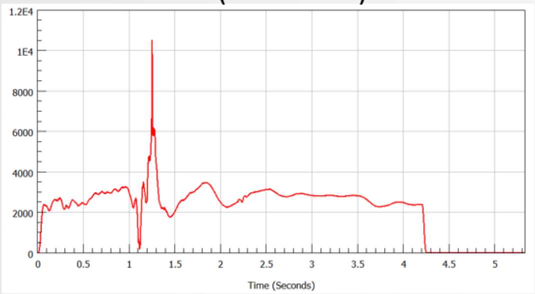
- Parameter sweeps
  - Unsprung mass
    - Front axle 71kg +/-20kg in 4 steps
    - Rear axle 58kg +/-20kg in 4 steps
  - Primary Spring
    - Front axle stiffness scaling 0.6 to 1.5 in 4 steps
    - Front axle stiffness scaling 0.6 to 1.5 in 4 steps
  - Ride damper
    - Front axle force scaling 0.5 to 2.0 in 4 steps
    - Rear axle force scaling 0.5 to 2.0 in 4 steps
  - Suspension bump stop clearance
    - Front axle -10mm to +20mm relative clearance in 4 steps
    - Rear axle -10mm to +20mm relative clearance in 4 steps

Potential Damage - Introduction

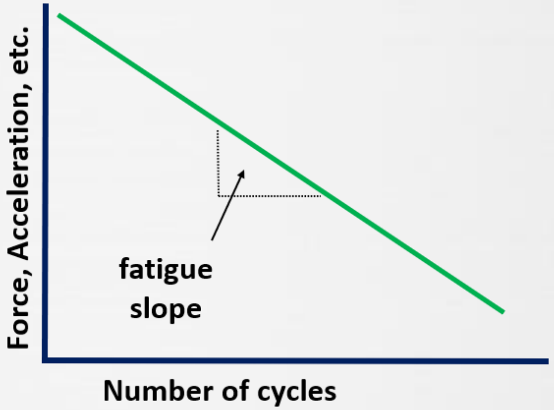
nCode

- Provides a simple way to compare time series using fatigue damage principles
- Can be used with any time series to give a relative A:B damage comparison
- Uses Rainflow cycle counting to identify fatigue cycles
- Uses a single slope stress-life curve and linear Miners' Rule cumulative damage
- …but <u>does not</u> predict absolute fatigue life

Pot-Hole (6 seconds)



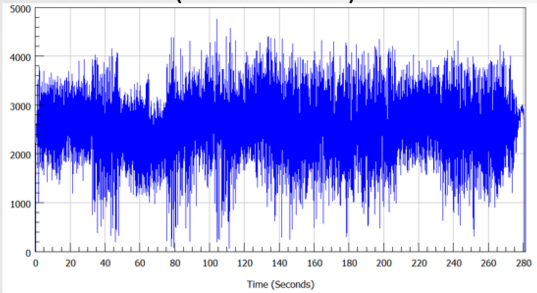
Parameter	Maximum	Minimum	Cycles	Damage	Ratio
WFT – Vertical - Force (N)	10500	0	4	1200	0.12



Pot-Hole Potential Damage → **Potential Damage Ratio A:B**

Pave Potential Damage → **Potential Damage Ratio B:A**

Pave (280 seconds)

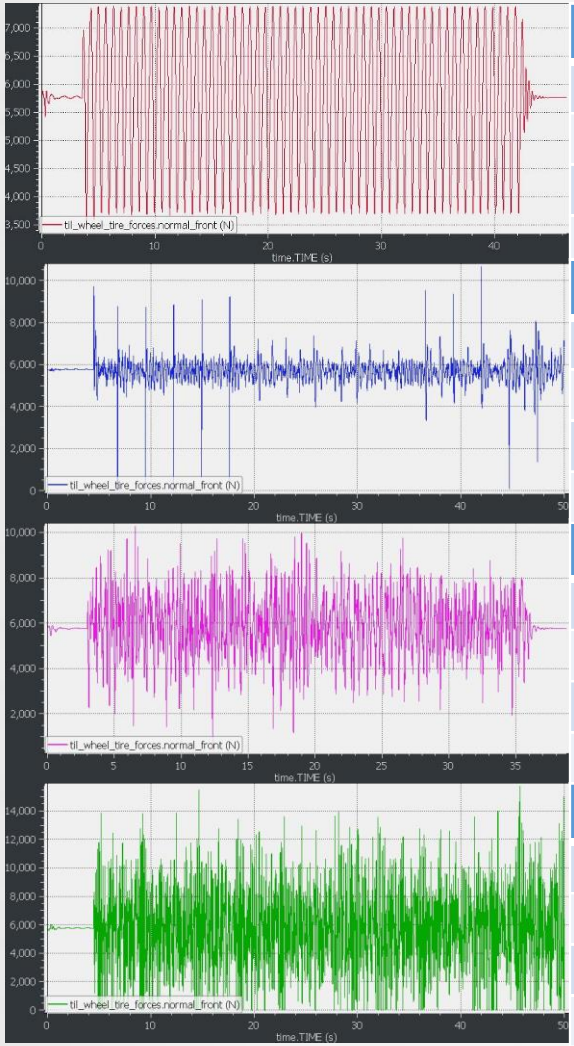


Parameter	Maximum	Minimum	Cycles	Damage	Ratio
WFT – Vertical - Force (N)	4760	0	1430	10000	8.33

(Generic results used for example)

Primary results

Front Left Wheel normal force (N) Time History



Primary ride

Parameter	Minimum	Maximum	Cycles	Potential Damage	Normalized Ratio
FL Tyre Normal Force	3397	7386	61	2902	2.83
FR Tyre Normal Force	3561	7626	60	2967	2.90
RL Tyre Normal Force	3026	6142	61	1024	1.00
RR Tyre Normal Force	3147	6327	60	1115	1.09

Inputs

Parameter	Minimum	Maximum	Cycles	Potential Damage	Ratio
FL Tyre Normal Force	0	1.07E+04	50	6154	6.0
FR Tyre Normal Force	0	1.14E+04	44	6907	6.7
RL Tyre Normal Force	0	1.01E+04	61	5312	5.2
RR Tyre Normal Force	0	1.10E+04	44	6165	6.0

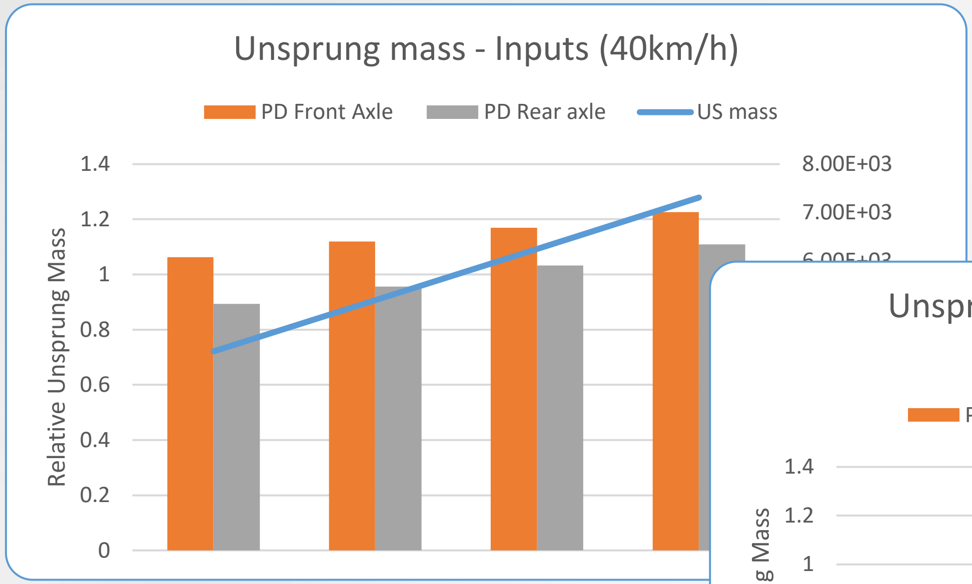
BMR

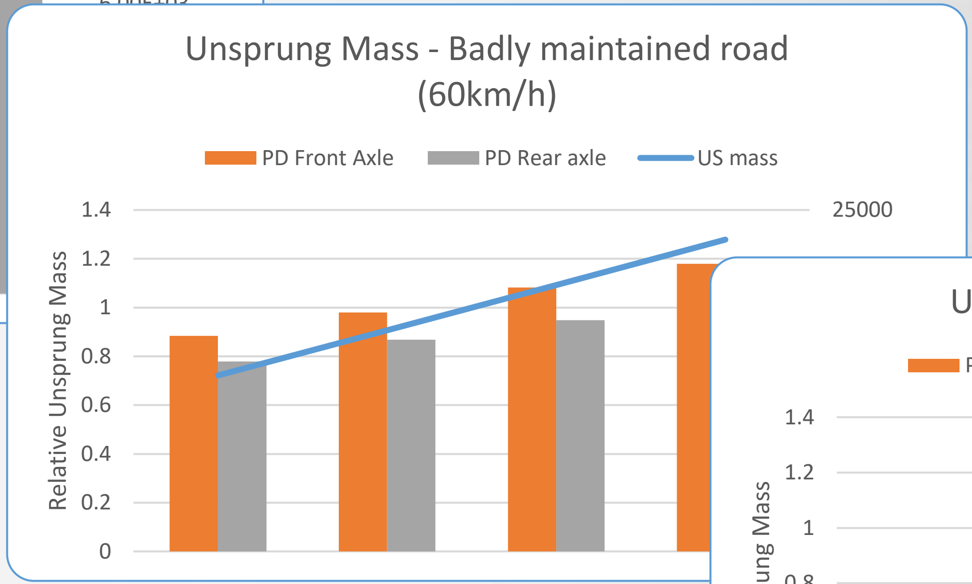
Parameter	Minimum	Maximum	Cycles	Potential Damage	Ratio
FL Tyre Normal Force	388.6	1.03E+04	171	1.62E+04	15.8
FR Tyre Normal Force	0	1.13E+04	134	1.05E+04	10.3
RL Tyre Normal Force	0	9438	192	2.08E+04	20.3
RR Tyre Normal Force	0	9197	164	1.15E+04	11.2

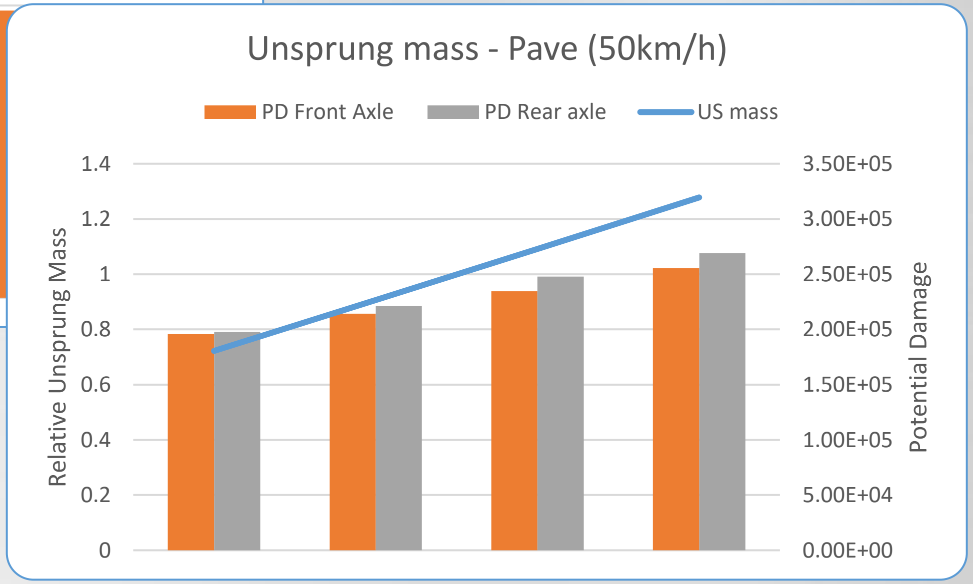
Pave

Parameter	Minimum	Maximum	Cycles	Potential Damage	Ratio
FL Tyre Normal Force	0	1.57E+04	465	2.48E+05	242
FR Tyre Normal Force	0	2.03E+04	393	2.02E+05	197
RL Tyre Normal Force	0	1.65E+04	570	2.55E+05	249
RR Tyre Normal Force	0	1.65E+04	541	2.13E+05	208

Unsprung mass

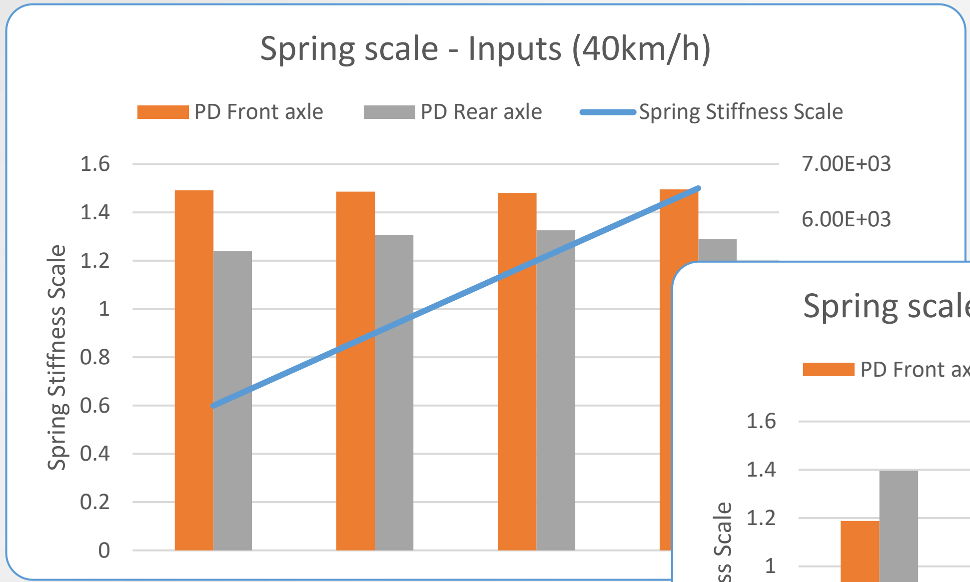


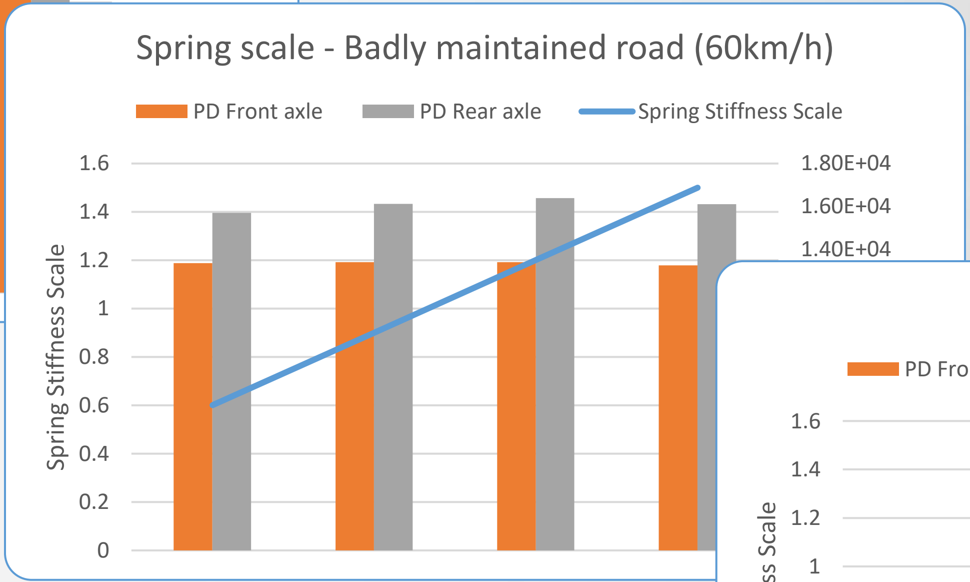


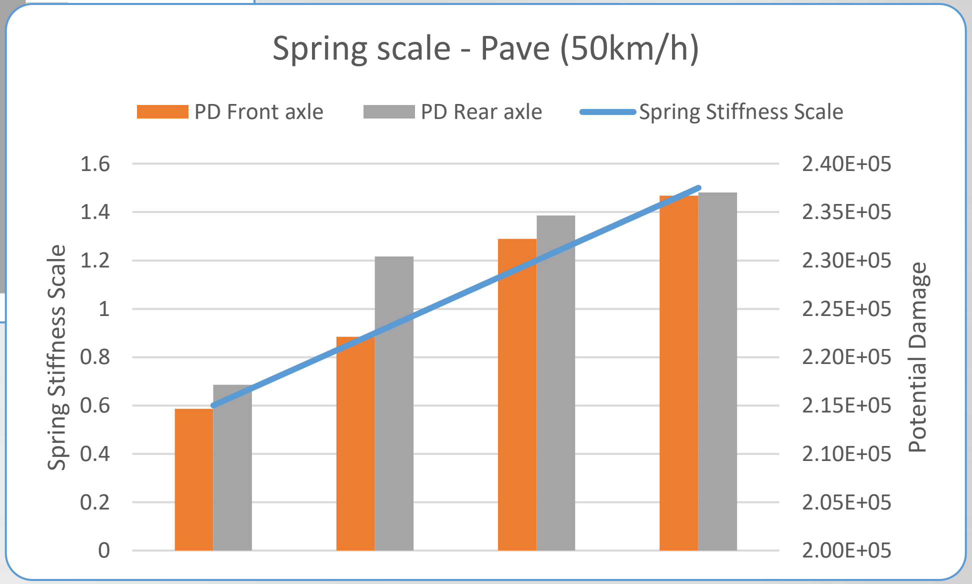


↑ Unsprung mass = Potential damage ↑

Spring rate scaling

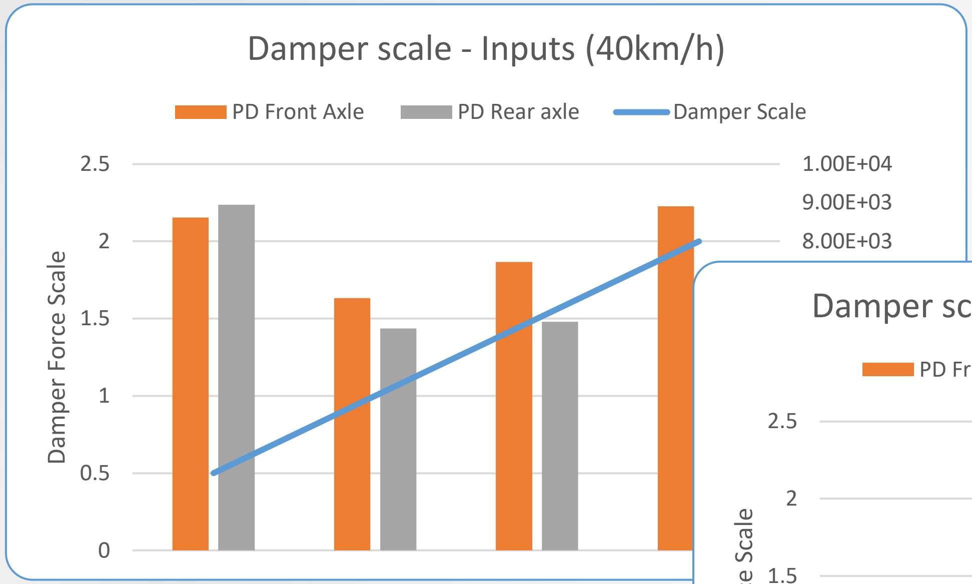


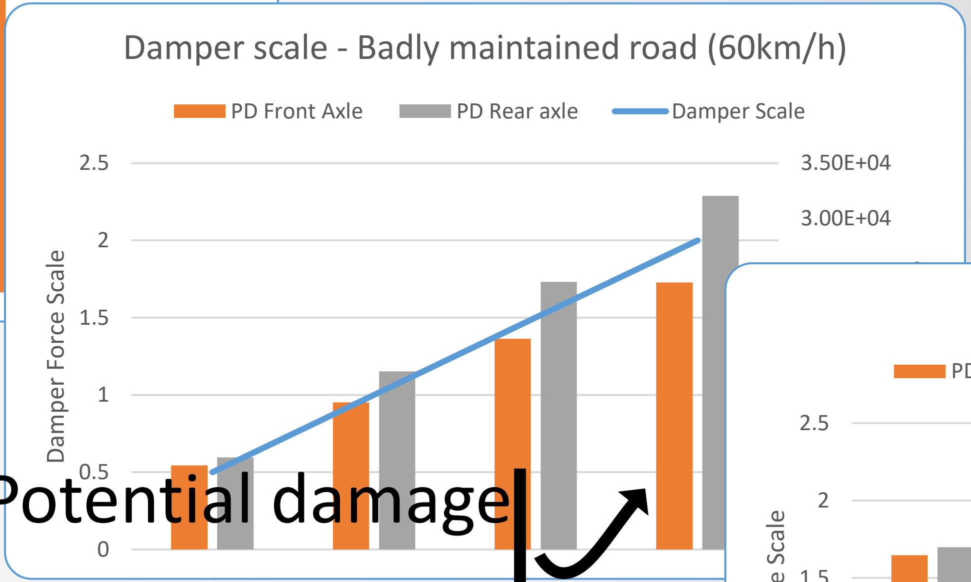


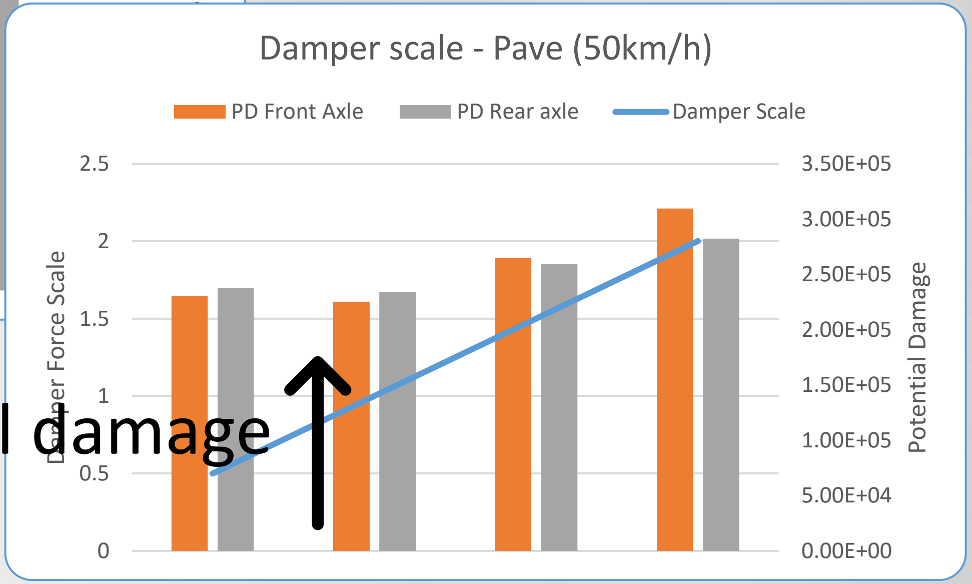


↑ Spring stiffness = Potential damage ↑
(on pave only)

Damper rate scaling





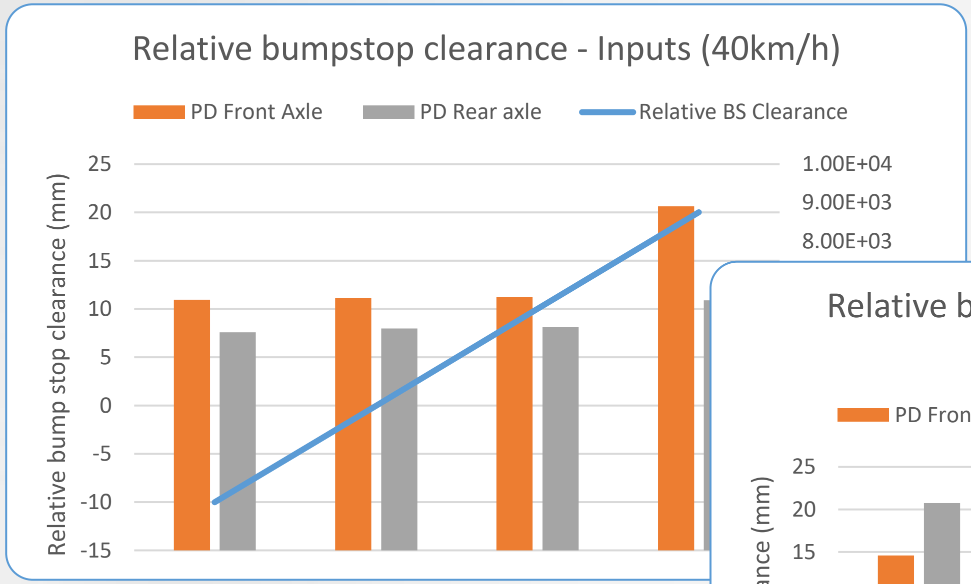


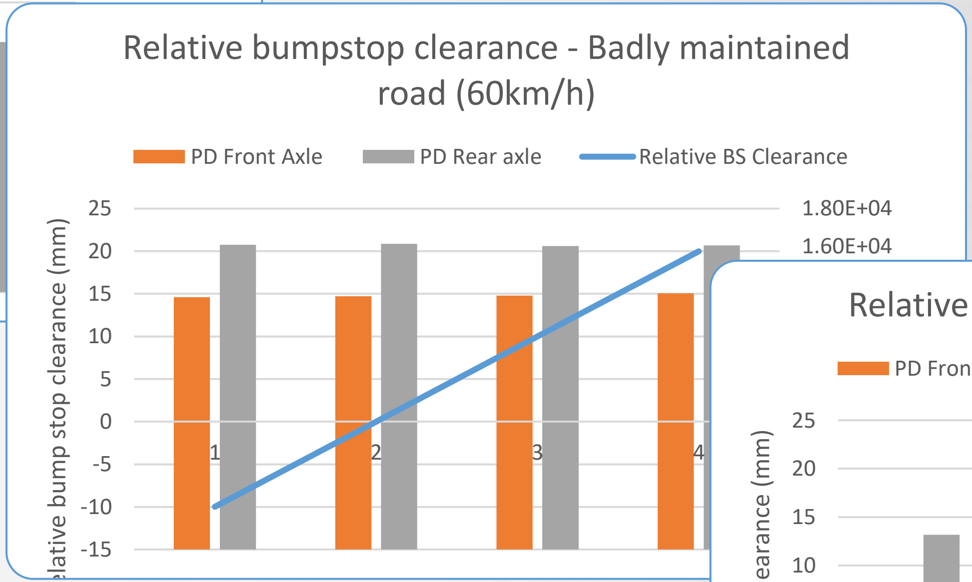
↑ Damper rate scale = Potential damage ↗

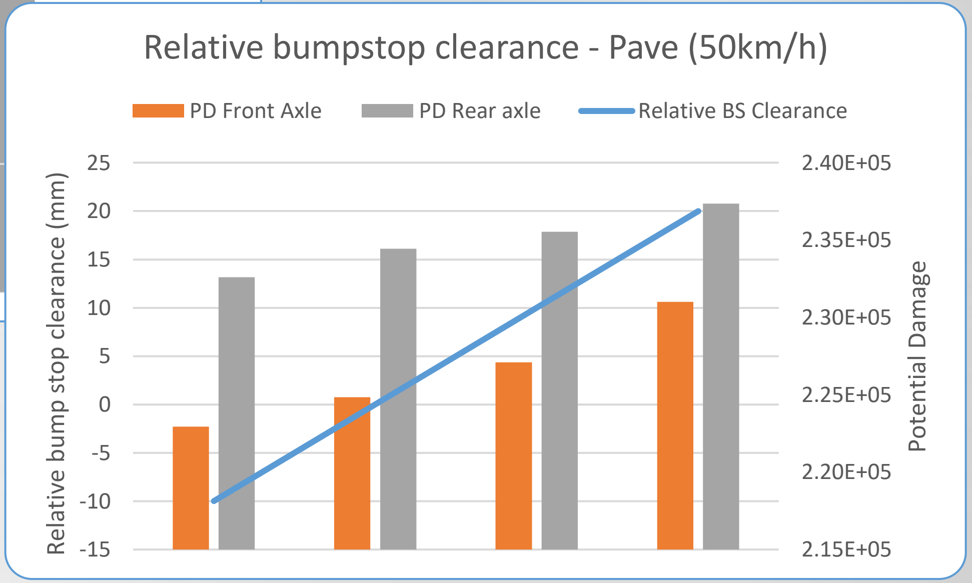
↑ Damper rate scale = Potential damage ↑

(Badly maintained road)

Bump stop clearance





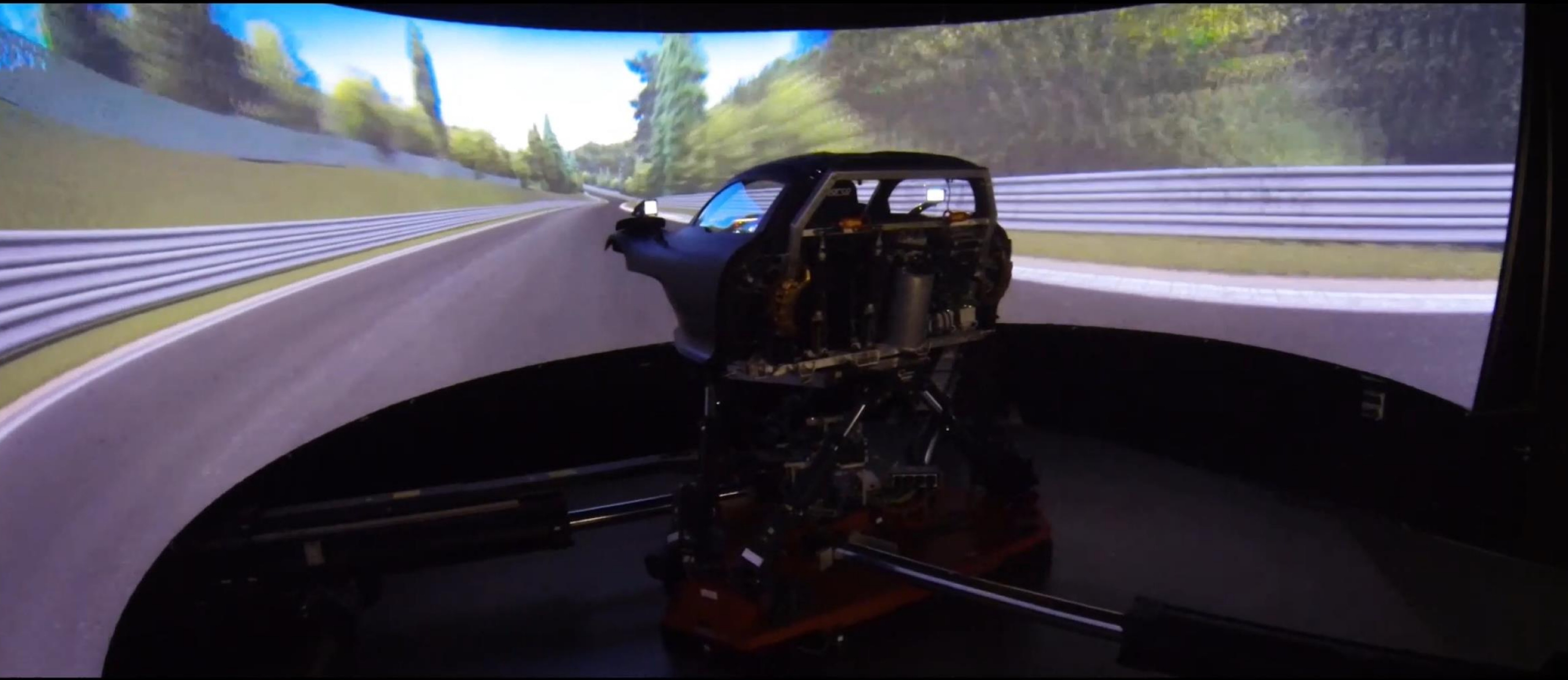


No significant trends to highlight

Key points

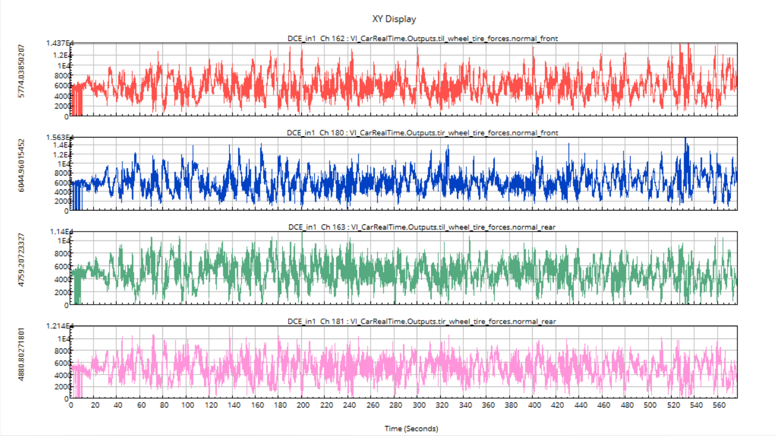
- Using VI-CarRealTime Investigation mode to run DOE's can generate a lot of data
- nCode from HBM Prenscia is an ideal tool for sorting through the data, calculating Potential Damage as well as other statistics and useful information in an automated process
- Easily identify trends in data
- Identify the design parameters which are likely to have the most significance when considering vWFT loads
- Demonstrates a process to thoroughly review the measured wheel forces at the beginning of a design programme and study the likely impact of design changes on component loads

- However, so far we have ignored one crucial part:



Driver Variability

- How key is driver-driver variability on potential damage?
- Two human drivers using a stretch of Italian country road, given task of driving enthusiastically, but not recklessly.



Driver 1

Parameter	Minimum	Maximum	Cycles	Potential Damage	Normalized Ratio
FL Tyre Normal Force	0	1.44e4	1.437e4	8.89e4	1.75
FR Tyre Normal Force	0	1.56e4	1.563e4	9.11e4	1.80
RL Tyre Normal Force	0	1.14e4	1.140e4	6.99e4	1.38
RR Tyre Normal Force	0	1.21e4	1.214e4	6.42e4	1.27

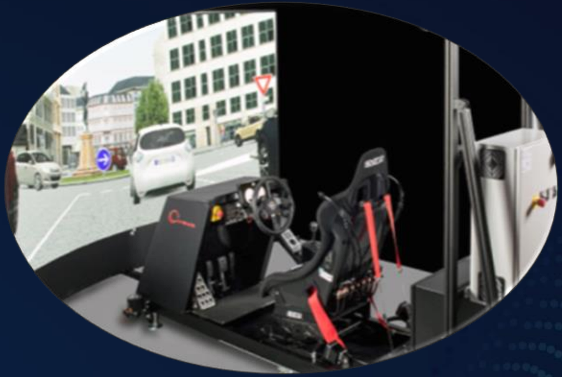
Driver 2

Parameter	Minimum	Maximum	Cycles	Potential Damage	Normalized Ratio
FL Tyre Normal Force	0	1.43e4	1.432e4	7.22e4	1.42
FR Tyre Normal Force	0	1.63e4	1.628e4	6.93e4	1.37
RL Tyre Normal Force	0	1.11e4	1.106e4	5.54e4	1.09
RR Tyre Normal Force	0	1.06e4	1.061e4	5.07e4	1

The Driver can provide a significant variable

- VI-grade Driving Simulator Technology can help you asses how much

DESKTOP STATIC



COMPACT STATIC

FULL SCALE STATIC

SMALL DYNAMIC

MID-SIZE DYNAMIC

FULL SCALE DYNAMIC

BRIDGING THE GAP BETWEEN TESTING AND SIMULATION

TO HELP CUSTOMERS ACHIEVE VIRTUAL PRODUCT SIGN-OFF

CONCEPT

OFF-LINE

SIMULATED

ON-LINE

REAL/SIMULATED

IN-VEHICLE

REAL

SIGN-OFF

BREAKING THE RULES OF THE AUTOMOTIVE DEVELOPMENT PROCESS

Thankyou – Any Questions?

David Ewbank
UK Technical Director
david.ewbank@vi-grade.com
+44 (0) 7966 140324

www.vi-grade.com

Q&A

- Eduardo Calixto (ECC, Germany)
  - Can we use such a model for verification and validation of Safety functions and Functions requirements?
    - *I think this would depend on the specific safety functions and function requirements that you refer to. Certainly the VI-CarRealTime model is used increasingly as a base to test, develop and validate ADAS and other safety functions.*
  - Is this kind of simulation acceptable by authorities?
    - *CAE Simulation is increasingly being accepted by authorities to validate vehicle derivatives for crash performance where the base vehicle passes physical tests.I am not aware of any particular safety standards for durability, but considering the huge range of scenarios that are feasible for inclusion in ADAS and AV testing and sign off, the only practical (and safe) way to consider them all is through simulation and driving simulator based testing.*
  - Can I use your model to simulate other stressors such as temperature humidity , voltage applied for electronic equipment in the car?
    - *It is feasible to include sub models which could consider temperature and other environmental effects on the model. Already tyre models exist which consider the effects of use on temperature and hence pressure on tyre performance as well as tyre wear performance. Virtual models for vehicle control systems can also include variability of supply voltage etc on the actual performance of the control outputs. So while the base VI-CarRealTime model may not directly include these effects, it is a highly extensible model platform open to user enhancements.*

Q&A

- Prashant Khapane (JLR)
  - You mentioned a correlated model, was it the BiW correlated or vehicle model correlated with Physical RLD?
    - *In this example the vehicle dynamics model was correlated against measured kinematics and compliance data as well as for dynamic handling and ride comfort tests, measured on the physical vehicle. However, further work to correlate the virtual wheel force transducer loads against actual measured WFT loads for the real vehicle was not done.*

- Halil Zınar DÜZGÜN (TOGG, Turkey)
  - For the potential damage glyph,what is the threshold for SNslope and intercept? We say it's 'potential damage' but some how we are really into the parameters, especially slope. Is it really important or if we comparing two data is it not so critical? What is your comments? Thanks?
    - *This used an SN slope of -3 and an intercept of 1000. The intercept is irrelevant for normalised or ratio results as this drops out of the equations. The slope is important. The slope changes the damage weighting between large and small cycles. The steeper the slope the more a high range cycle is damage weighted (a higher damage value) when compared with a low range cycle. The shallower the slope the less a high range cycle is damage weighted when compared with a low range cycle.*

- Ata TOKER (TOGG, Turkey)
  - Did you specify vehicle speed profile to different drivers? - It can change potential damage a lot apart from the driving style?
    - *To add to this, it is quite possible to specify a tighter speed control for the human drivers to follow, however in this case the intention was to demonstrate the variability that can be seen by giving drivers a similar brief, but not to follow a precise speed profile.*

Q&A

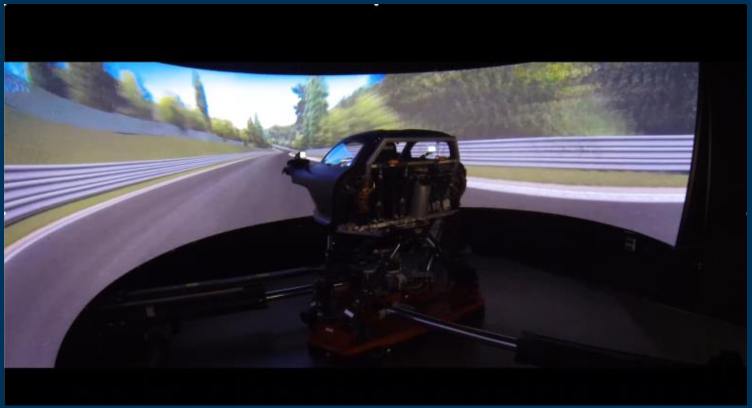
- Jamie Shenton (JCB, UK)
  - If we are comparing the graphs to compare each surface, why are the speeds different also?
    - *The test speeds chosen in this case were the recommended test speeds for each surface as defined by Applus+ IDIADA.*

- Saket Sharma (Aston Martin, UK)
  - How could the ideal virtual model be scaled for variability of the real world. Is it better to run multiple DOEs or would using statistical distribution be a better approach?
    - *I think there is scope to use both approaches. Considering the DOE based approach does enable a quite specific understanding of the impact of which design parameters (whether in isolation or as part of a more complex parameter interaction sensitivity study) have a direct influence of the potential damage caused. Taking a more statistical approach is unlikely to uncover such detailed understanding of any design interactions.*

- David Blanchard (Horiba MIRA)
  - Do the tyres model well for durability loads?
    - *There are many different types of tyre models, some for pure vehicle handling, some for ride and other, more complex models are becoming increasingly accurate for durability prediction. Clearly the requirements are quite different, but certainly FTire and CDTire are both able to deal with the highly non-linear tyre behaviour during durability events. Both are also capable of running in real time for use on driving simulators with some simplification of the effective mesh resolution.*

HBM Prenscia Technology Day

Virtual Seminar Series



Vehicle Test Simulation and WFT Loads Simulation

Presented by Mr. David Ewbank
Technical Director
VI-grade

Session #3: **Vehicle Testing & Simulation**