FEMFAT LAB Virtual Iteration and Model Improvement

Otmar Gattringer

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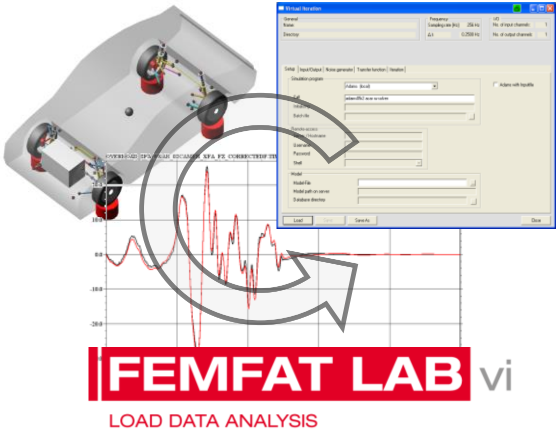
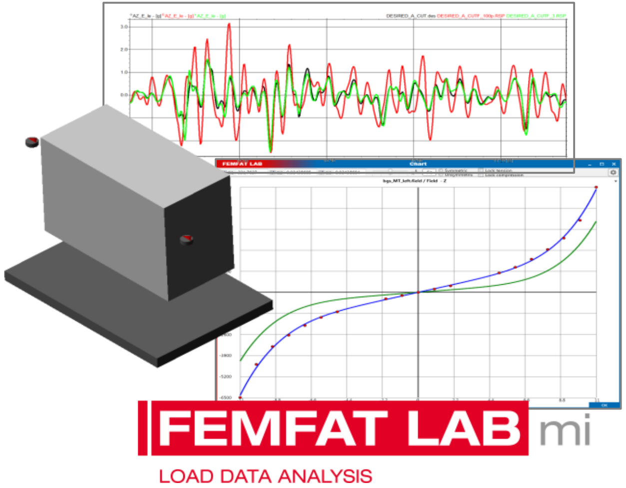
- Overview
- Motivation
- Full vehicle example
- Conclusion

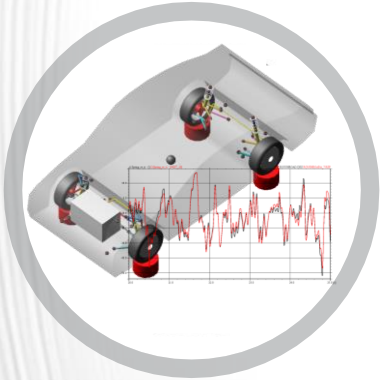




Overview

Modules

MAGNA



FEMFAT LAB vi

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Virtual iteration

- 3D ROAD

FEMFAT LAB mi

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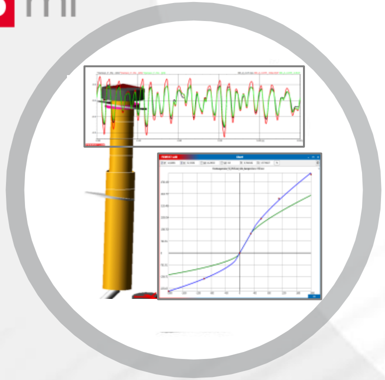
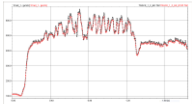
Model improvement



Interface to dynamic simulation



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time based analyzing tools

FEMFAT LAB frequency

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frequency based analyzing tools

FEMFAT LAB fatigue

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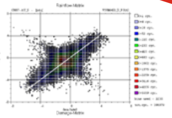
counting methods, damage analysis, data reduction, mixing tracks



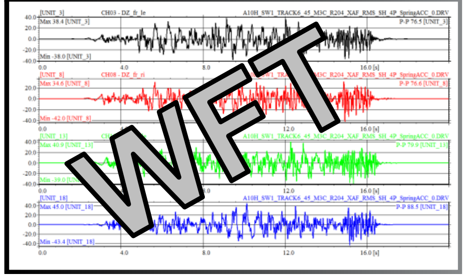
Load data analysis software

Motivation

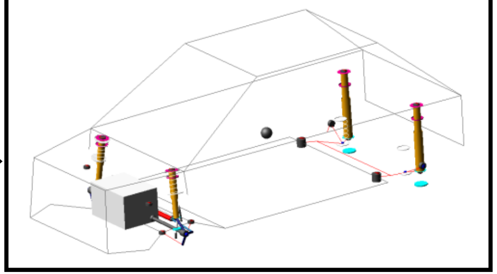
Motivation

Motivation illustrated by full vehicle simulation

Input

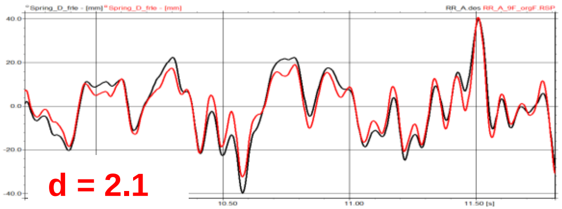


MBS

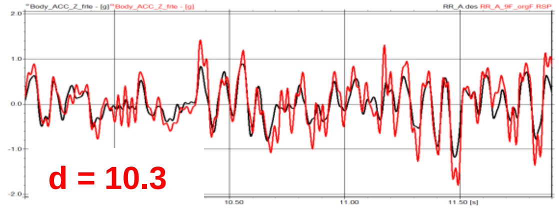


Output

Spring displacement front left



Body acceleration Z front left

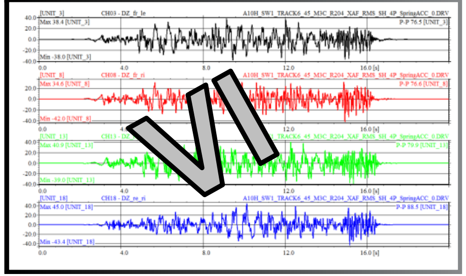


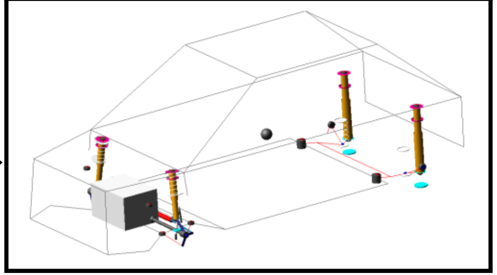
black…measurement / red…simulation

Motivation

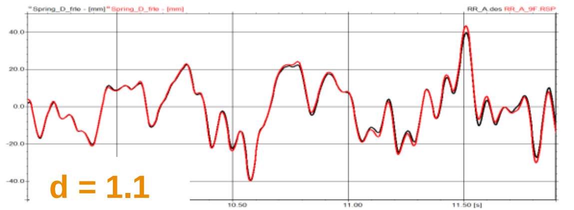
Motivation illustrated by full vehicle simulation

Input	MBS	Output

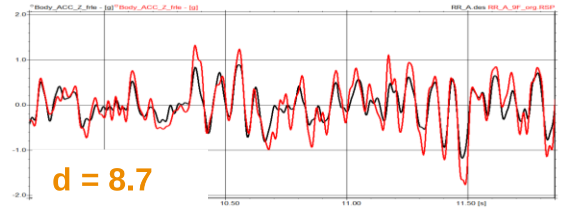




Spring displacement front left



Body acceleration Z front left

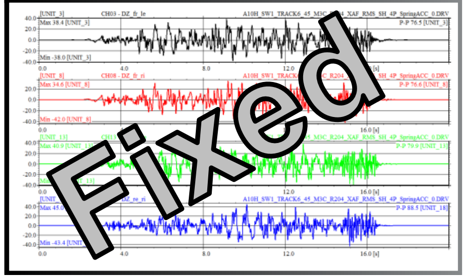


black…measurement / red…simulation

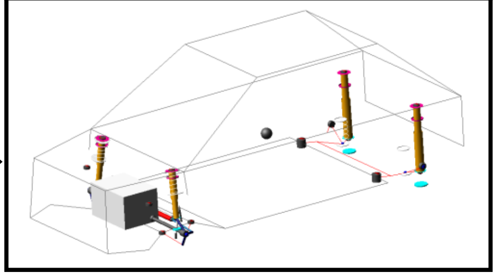
Motivation

Motivation illustrated by full vehicle simulation

Input



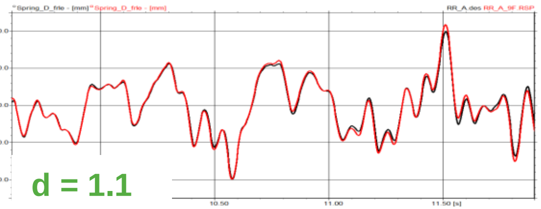
MBS



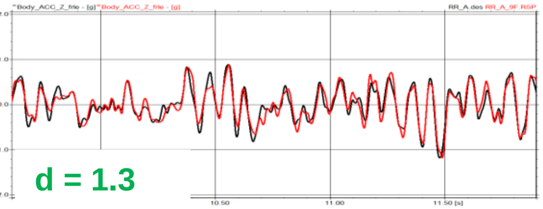
- Excitation fixed
- Trim model parameters to achieve better correlation in channels used for model check (e.g. body accelerations)

Output

Spring displacement front left



Body acceleration Z front left



black…measurement / red…simulation

Motivation

- MBS simulation results depend mainly on ***excitation*** and ***model accuracy***

- Excitation
  - Defined, e.g. stochastic road, standard load cases, …..
  - Measured, e.g. digital road, wheel forces (WFT), mount forces, …..
  - Iterated, e.g. by virtual iteration (displacements or forces)

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- Model accuracy
  - Parameters defined by user (CAD/CAE data, supplier values, measurements, experience, ….)
  - Some parameters can be also measured during road load data (RLD), e.g. damper characteristics
  - Model parameters can be modified manually depending on correlation of simulated and measured channels (manual model verification and trimming by additional checking signals is an important part of VI process)

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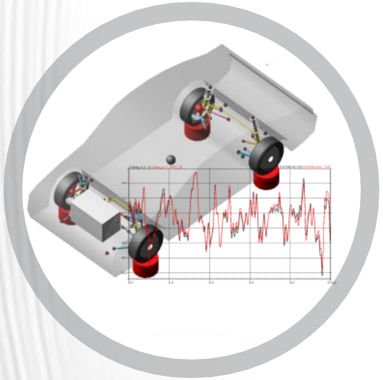
Modules



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Virtual iteration

- 3D ROAD

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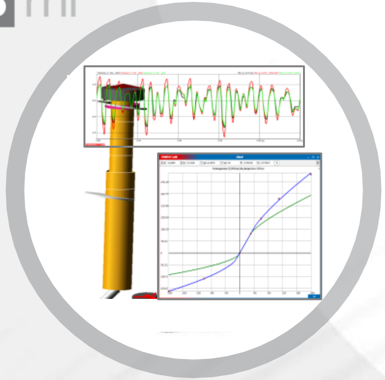
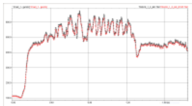
Model improvement



Interface to dynamic simulation



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time based analyzing tools

FEMFAT LAB frequency
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frequency based analyzing tools

FEMFAT LAB fatigue
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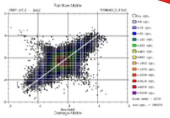
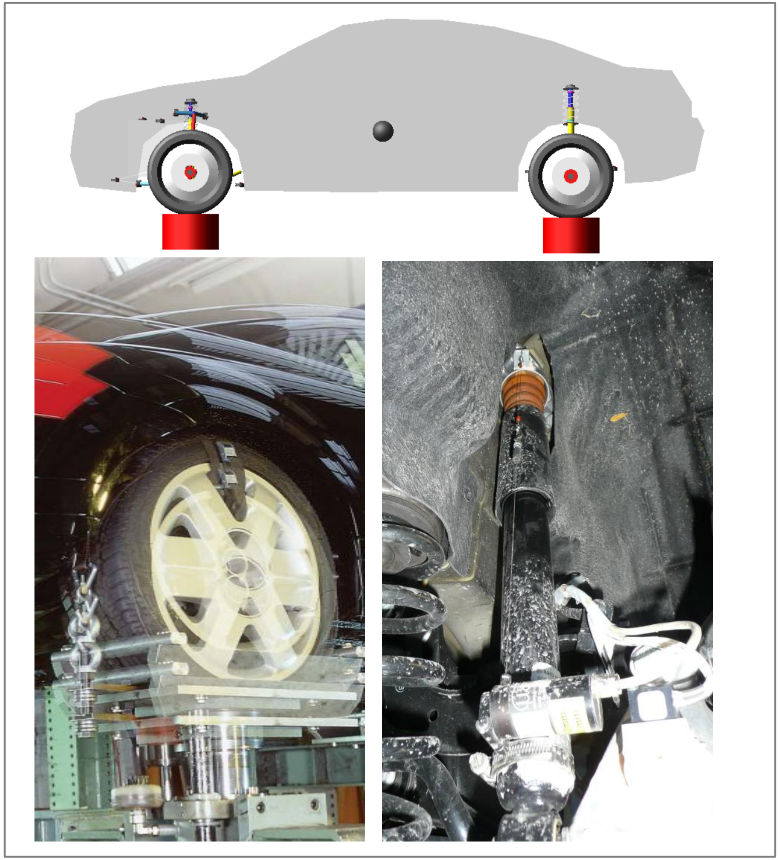
counting methods, damage analysis, data reduction, mixing tracks



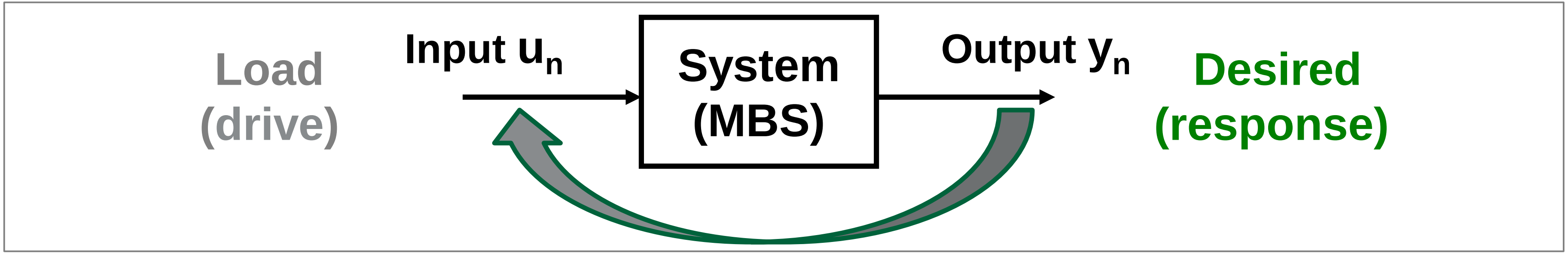
Load data analysis software

vi - introduction



- General approach
  - Generate external load based on internal, measured response
- Same approach as the iteration process in the laboratory (test bench)
- Excellent convergence between measurement and simulation
- Method is automated for
  - ADAMS
  - SIMPACK
  - MOTIONSOLVE
  - RECURDYN
  - VI - GRADE

vi - introduction



Inverse non-linear problem

find load for given response

Drive

High effort or not measureable

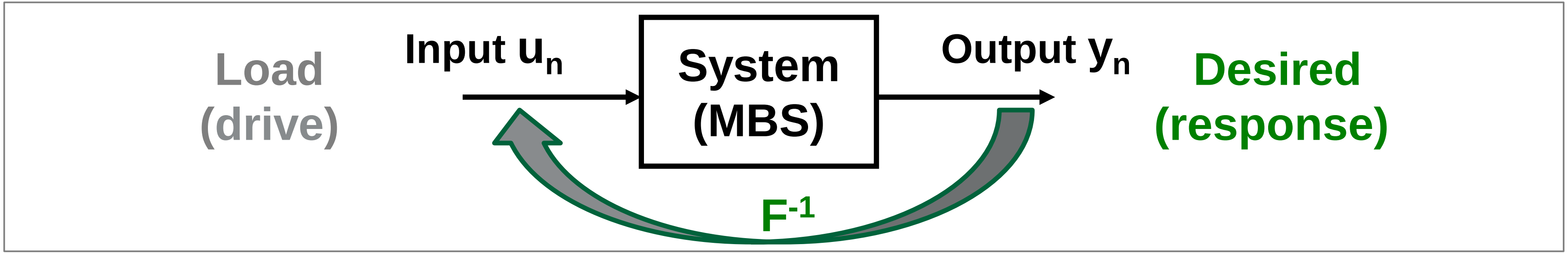
- Forces (external)
  - WFT
  - Load cell
  - Strain gauges
- Displacements (absolute)

Response

Often simply and cheaply measureable

- Accelerations
- Displacements (relative)
- Strains
- Forces (internal)

vi - introduction



Calculation of the transfer function (MBS):

$F(s) = y_0(s) / u_0(s)$ noise signal and its response

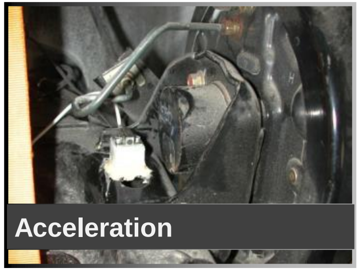
Calculation of first drive:

$u_1(s) = F^{-1}(s)\ y_{Desired}(s)$

Calculation of further iterations:

$u_{n+1}(s) = u_n(s) + F^{-1}(s)\ (y_{Desired}(s) - y_n(s))$

vi - measurement signals


Acceleration


Displacement


Strain – twist beam


Strain – ball joint

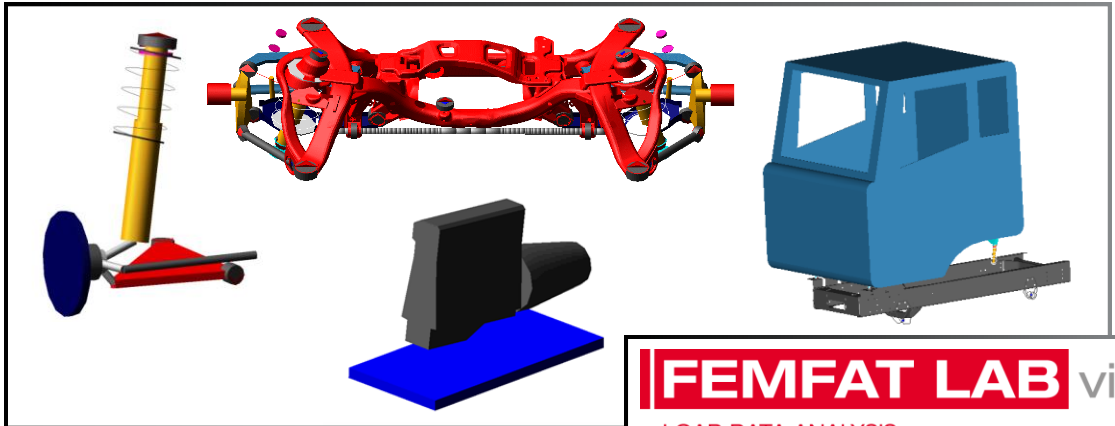

Load cell


Wheel force transducer

Typical responses

- Accelerations
  - 1-axial
  - 3-axial
- Displacements
  - Draw wire displacement sensor
- Frame torsion
- Strains (directly/calibrated to forces)
  - Axle
  - Ball joint
  - Link
  - Rod
  - Spring
  - Stabilizer
- Load cells
  - Mount
- Wheel force transducers

vi - examples



Subsystems

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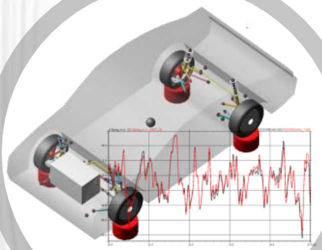
Examples

Test benches

Full vehicles

Modules



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Virtual iteration

- 3D ROAD

FEMFAT LAB mi
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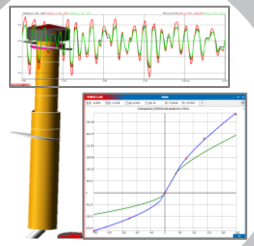
Model improvement



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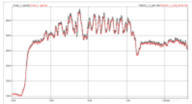

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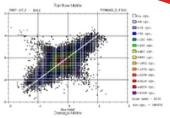


Load data analysis software

mi - introduction

- Automated model improvement:
  Manual trimming of an experienced engineer should be partially automated respectively supported (no absolute optimum because of feasible run-times)

- Model parameters improved based on RLD (channels for model check)
  - Mass, mass moment of inertia, center of gravity
  - Stiffness and damping, 1-axial, 3-axial, 6-axial

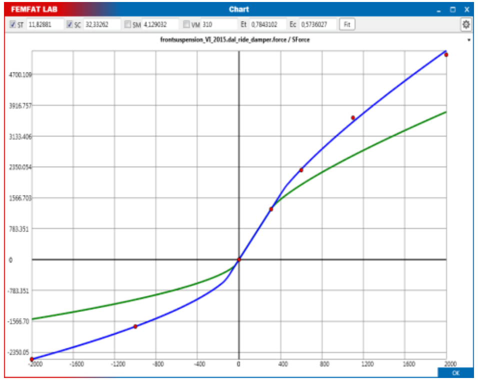
- Parameters must be defined and will be updated

- Excitation is well known (measured or computed by VI) and fixed during investigations

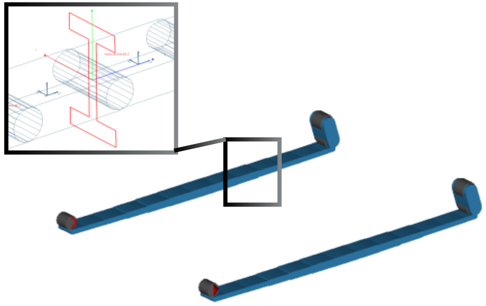
- A diagnose tool assists to identify the relevant parameters

mi - introduction

Supported model parameters which can be automatically improved

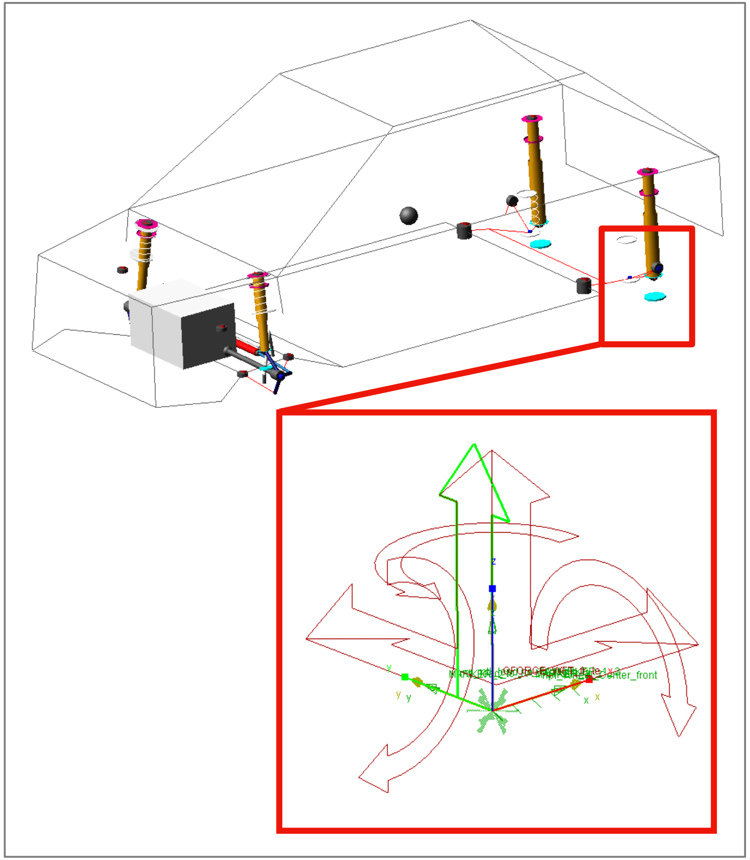


- Mass, center of gravity
- Mass moment of inertia
  - I_X or I_Y or I_Z
  - Common factor on I_X, I_Y and I_Z
- SFORCE, VFORCE, GFORCE, FIELD (bushing)
  - Stiffness by value or spline, translational or rotational
  - Damping by value or spline, translational or rotational
  - Common factor for all directions or directions separately
- BEAM
  - Planar moment of inertia
  - E and G modulus
- Definition of group (e.g. leaf spring)
- Clearance of bumpstop and reboundstop



Full vehicle example

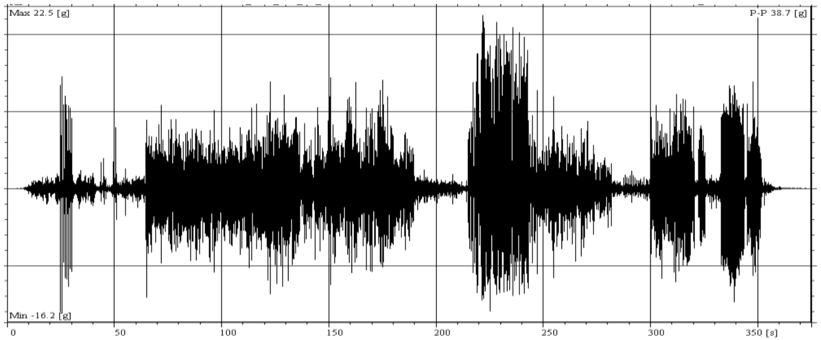
Full vehicle example



Model

- MSC.ADAMS/Car Model (rigid body)
- Input (load) computed by vi
  - 4-poster
    - Vertical displacement at wheel centers
    - Measured spring displacements and vertical wheel center accelerations should be reproduced
  - Measured signals at wheel center will be applied additionally
    - FX, FY, TX, TZ

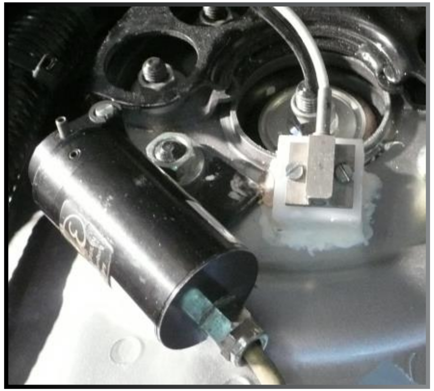
Full vehicle example



Measurement signals

- Spring displacements
- Damper forces
- Vertical wheel center accelerations
- Vertical body accelerations
- WFT signals

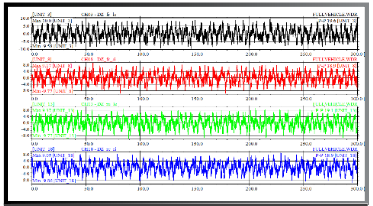


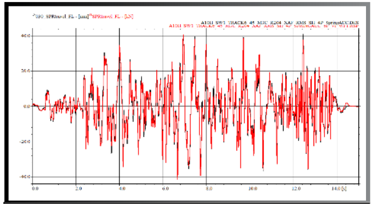

vi – virtual iteration

vi - full vehicle example

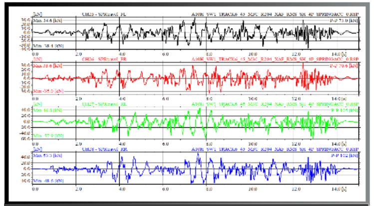
Iteration process



1. Noise

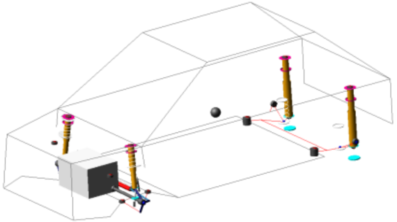


6. Response = desired

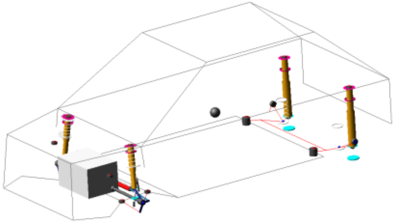


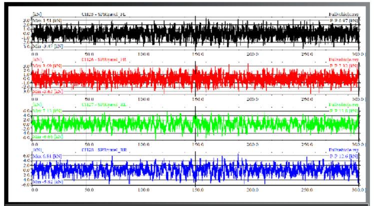
5. Response

$$u_{Noise} \Rightarrow y_{Noise}$$



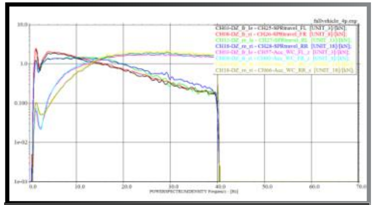
$$u_{n+1} = u_n + F^{-1} \left(y_{Desired} - y_n \right)$$





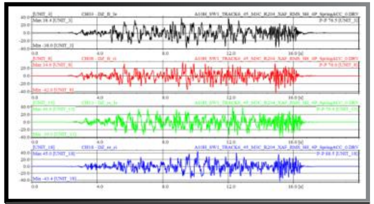
2. Response of noise

$$F = \frac{y_{Noise}}{u_{Noise}}$$



3. Transfer function

$$u_0 = F^{-1} y_{Desired}$$



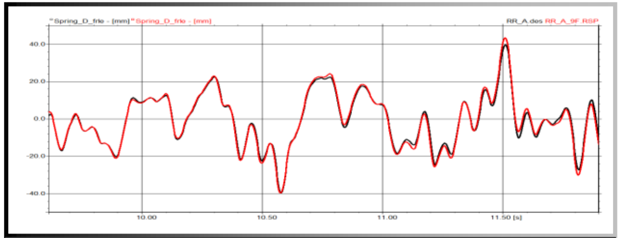
4. Drive signal

vi - full vehicle example

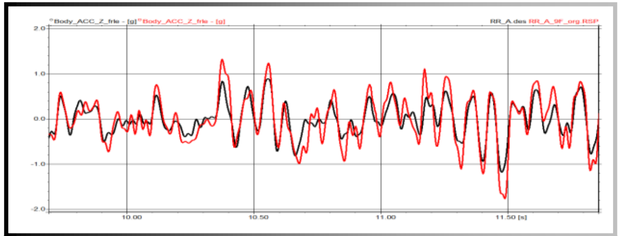
MAGNA

Results of 10th iterations, rough road maneuver - relative damage values (target is 1)

black…measurement / red…simulation



Spring displacement front left



Body acceleration Z front left

– Desired channels

- Spring front left:	1.14	- ACC WC front left:	0.68
- Spring front right:	1.07	- ACC WC front right:	0.76
- Spring rear left:	1.06	- ACC WC rear left:	1.12
- Spring rear right:	1.02	- ACC WC rear right:	1.09

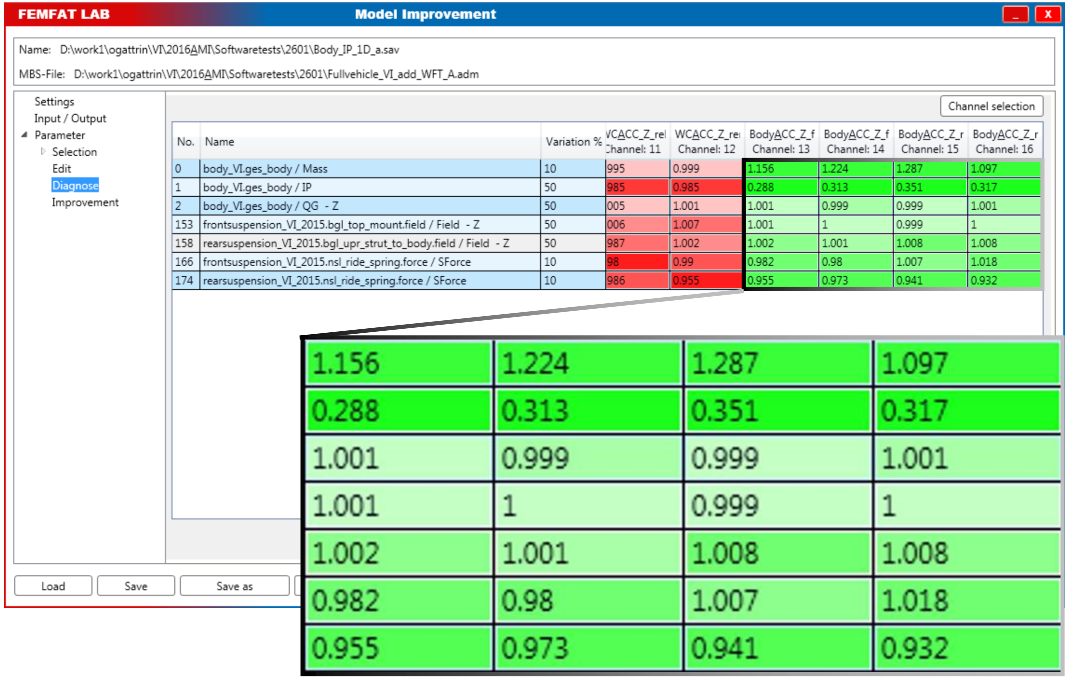
– Channels for model check - body accelerations are inaccurate

- Damper force front left:	0.82	- ACC body front left:	8.34
- Damper force front right:	0.81	- ACC body front right:	8.74
- Damper force rear left:	1.10	- ACC body rear left:	4.18
- Damper force rear right:	1.20	- ACC body rear right:	5.97

⇨ Model should be improved to achieve better correlation in body accelerations

mi - model improvement

mi - full vehicle example



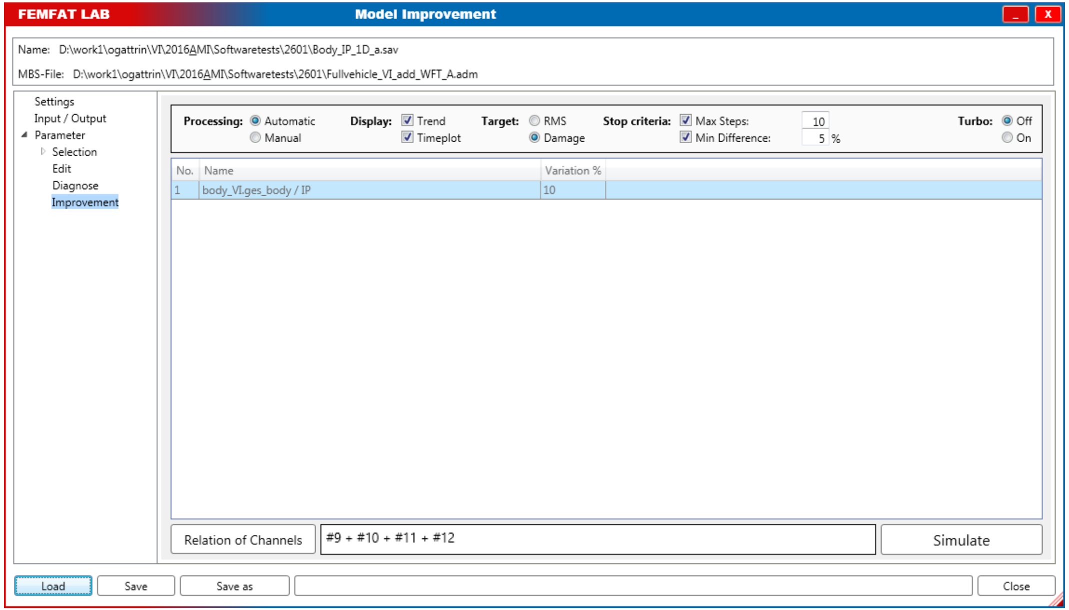
No.	Name	Variation %	WCACC_Z_rel Channel: 11	WCACC_Z_rel Channel: 12	BodyACC_Z_f Channel: 13	BodyACC_Z_f Channel: 14	BodyACC_Z_r Channel: 15	BodyACC_Z_r Channel: 16
0	body_VI.ges_body / Mass	10	995	0.999	1.156	1.224	1.287	1.097
1	body_VI.ges_body / IP	50	985	0.985	0.288	0.313	0.351	0.317
2	body_VI.ges_body / QG - Z	50	005	1.001	1.001	0.999	0.999	1.001
153	frontsuspension_VI_2015.bgl_top_mount.field / Field - Z	50	006	1.007	1.001	1	0.999	1
158	rearsuspension_VI_2015.bgl_upr_strut_to_body.field / Field - Z	50	987	1.002	1.002	1.001	1.008	1.008
166	frontsuspension_VI_2015.nsl_ride_spring.force / SForce	10	98	0.99	0.982	0.98	1.007	1.018
174	rearsuspension_VI_2015.nsl_ride_spring.force / SForce	10	986	0.955	0.955	0.973	0.941	0.932

Diagnose

- Last drive of virtual iteration is used
- Different reasonable parameters are selected
- Each parameter is varied and the results compared to unvaried model
- Table shows influence of variation of each parameter to the different channels
- High variation from one indicates that parameter has useful potential

Mass moment of inertia has most effect on body accelerations

mi - full vehicle example



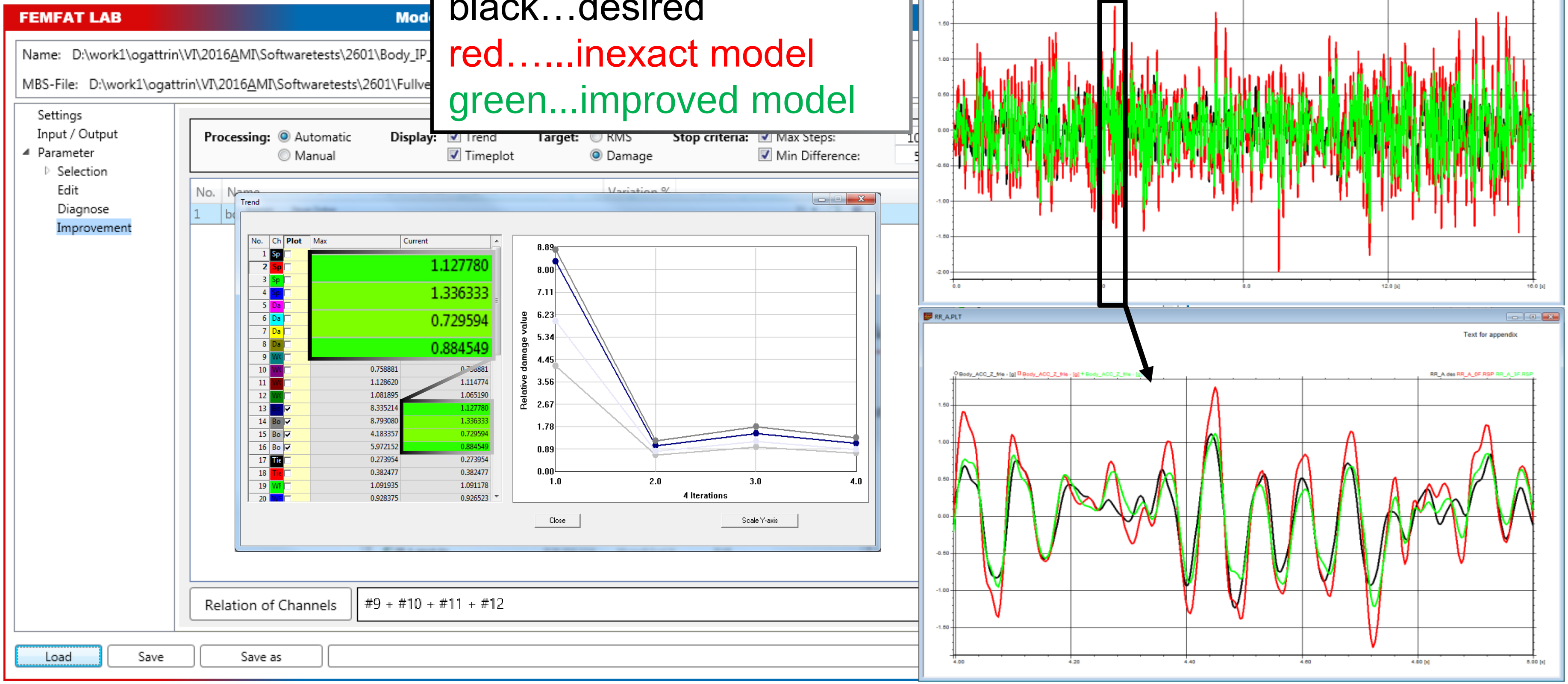
Improvement

- Mass moment of inertia should be optimized to get a better correlation in body accelerations
- Target:
  Sum of relative damage values of body accelerations should be optimized
- Stop criteria:
  Change between two consecutive steps is smaller than 5%

mi - full vehicle example

Results

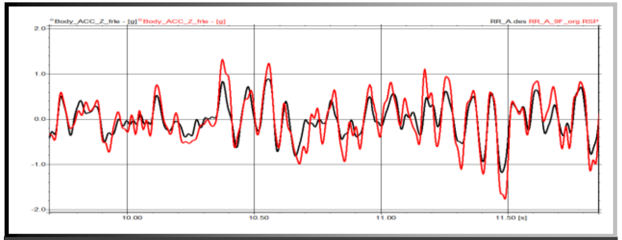
Time plot
black…desired
red……inexact model
green...improved model



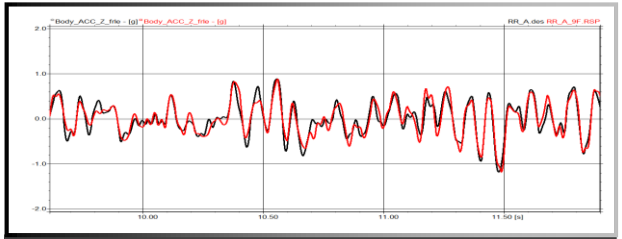
mi - full vehicle example

Results

- Improved mass moment of inertia leads to better correlation in body acceleration



Body acceleration Z front left - start



Body acceleration Z front left - improved

black…measurement
red…simulation

- ACC body front left:	8.34	- ACC body front left:	1.12
- ACC body front right:	8.74	- ACC body front right:	1.34
- ACC body rear left:	4.18	- ACC body rear left:	0.73
- ACC body rear right:	5.97	- ACC body rear right:	0.88

- 9 ADAMS simulations were required in total

Conclusion

Conclusion

- FEMFAT Lab combines simulation and measurement
- Virtual iteration
  - Powerful method for load data generation
  - Excellent convergence between measurement and simulation
  - Efficient method to generate absolute displacements (e.g. tire patch, frame movement for add on parts like cab, tank, engine, exhaust systems)
  - Efficient parameter studies and transfer to similar vehicles (invariant load)
- Model improvement
  - mi supports to improve the model quality
  - Worse defined parameter can be identified with suitable measurement channels
- Full vehicle example shows capability of the methods