DURABILITY ASSESSMENT: A VIRTUAL PROVING GROUND APPROACH

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Abstract The aim of the presented calculation is the assessment of the vehicle's durability performance under realistic loading conditions. Widely used static calculations only provide a rough overview of the behavior as loads and boundary conditions are largely idealized and abstract, while dynamic effects (e.g. vibrations on eigenfrequencies of different parts, damper forces) are completely excluded. Significant improvement can be achieved by such transient simulations where the loads are more realistic and the body dynamics are included.

However, the real life loading of a vehicle is largely unknown and thus it is hard to analyze. In the physical world, accelerated proving ground tests provide a good approximation of service life according to several decades of practice. They have a serious limitation: they can be utilized only after a prototype is constructed. However, they give a sound basis for simulations: virtual proving grounds can be constructed, where the vehicle concepts can be analyzed effectively in the earlier construction phases. The calculated results are directly related to those of the physical measurements, thus they may be easily validated.

Such proving ground tests exist for both on-road and off-road applications, including cars, coaches and military vehicles. It also means that relevant virtual proving grounds can be created accordingly for each vehicle category. It can effectively help the constructers in the early design phases and cut costs of the testing in these industries.

Our company has successfully utilized this method for different application areas. In the present paper the results of case studies are showcased, where such multi-body simulation is utilized to assess the durability performance of on-road and off-road vehicles based on the virtual proving ground approach. Besides the case studies, further possible development directions are identified and discussed. Also, the method is compared to durability assessments based on static load cases (e. g. acceleration fields or different forces acting on the vehicles).

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Slides of the related presentation can be found below.

In case of questions, do not hesitate to contact us!
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eCon Engineering

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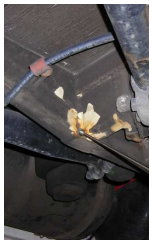
Durability - failure mode: Fatigue



Limiting factor of **durability** in case of welded structures: **fatigue fracture** by weld seams



Reason of fatigue



Reason of **fatigue fracture**:
loads from life-long **operation**

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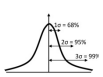
Problems of fatigue assessment

Reason of **fatigue fracture**:
loads from life-long **operation**

Failure:
stochastic



Load history:
random-like

Timeframe:
multiple years

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Experimental solution



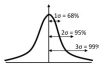
Proving Ground Tests

Statistical methods, prototype testing

Characteristic road segments

Accelerated testing

Failure: **stochastic**



Load history: **random-like**

Timeframe: **multiple years**

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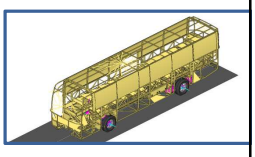
CAE solution



Proving Ground Tests

Virtual Proving Ground Test

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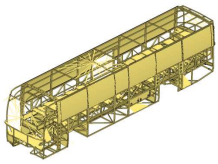
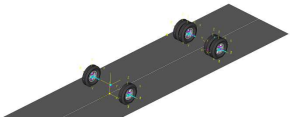
Parts of CAE model



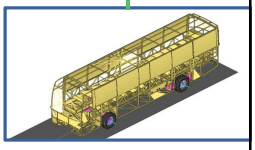


Frame structure
Linear FE flexible body

Suspension, drivetrain
Nonlinear with rigid bodies

Tyre and road
FTire

Virtual Proving Ground Test



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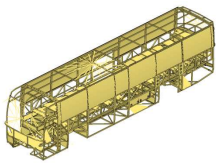
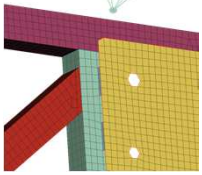
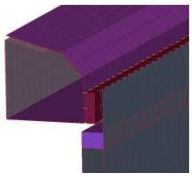
Frame structure



Linear FE model

Approx. 10x10 mm shell mesh size
Middle surface modelling
Welds modelled by connected mesh





Double glued glazing

Larger individual
point-like masses

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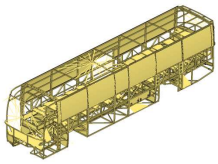
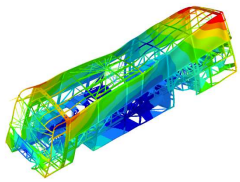
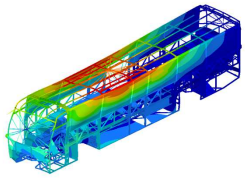
Frame structure







Flexible body: **C**omponent **M**ode **S**ynthesis

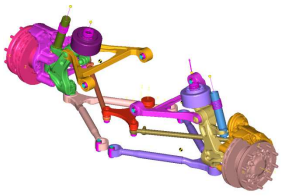
Dynamic effects included

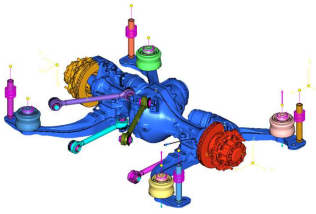
Different variants: different loads

Evaluated parts

300 modes - **~50 Hz**

Suspension

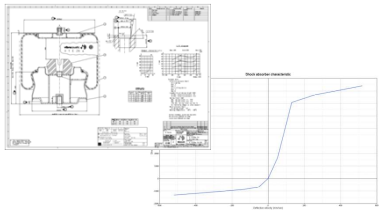




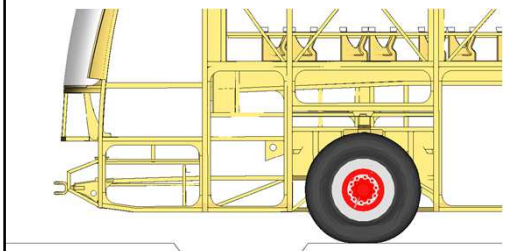
Rigid bodies, constraints

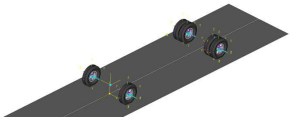
Nonlinear springs and dampers

Non-evaluated parts



Tyre, road





FTire

Co-simulation

Short wavelength road input

Road: **geometry** representation

Tyre: **measurement** or approximation

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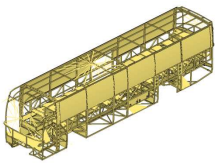
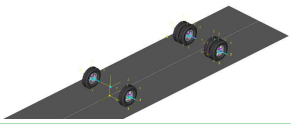
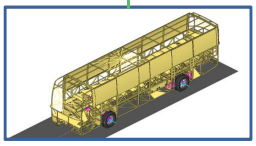
Results of simulation

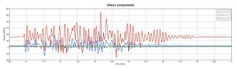




Frame structure Linear FE flexible body	**Suspension, drivetrain** Nonlinear with rigid bodies	**Tyre and road** FTire



Stress time history



Fatigue evaluation
Python script

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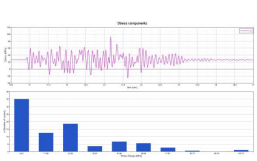
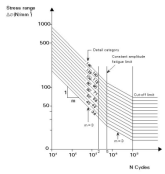
Parts of fatigue evaluation



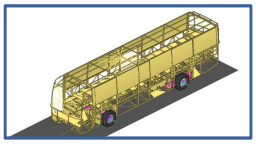


$$D = \sum d_i$$

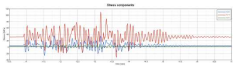
Processing transient results
Rainflow counting

Calculating partial damages
S-N curves - Eurocode

Total damage
Linear superposition, Miner's rule



Stress time history



Fatigue evaluation
Python script

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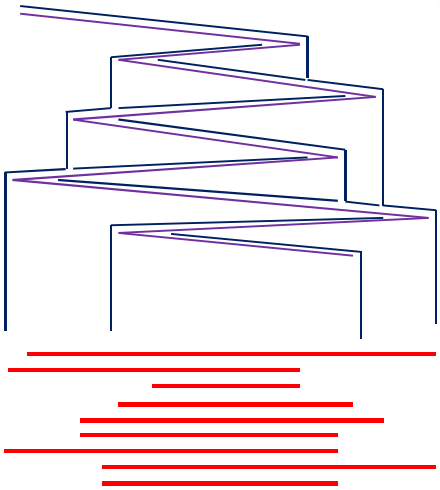
Rainflow counting

t

s

n_i

s_i



Histogram based on stress ranges

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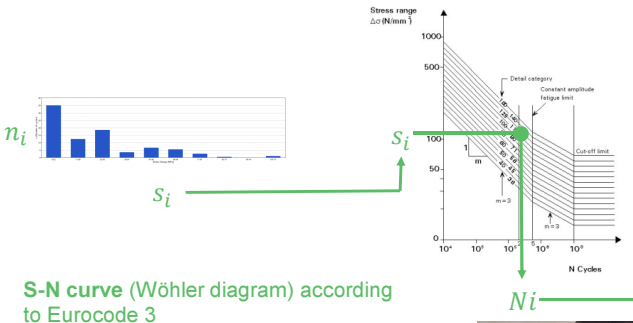
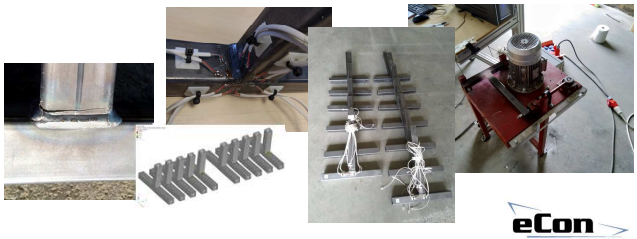
Partial damages



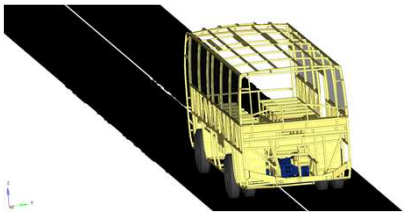
$$d_i = \frac{n_i}{N_i}$$

S-N curve (Wöhler diagram) according to Eurocode 3

Detail category based on measurements



Total damage



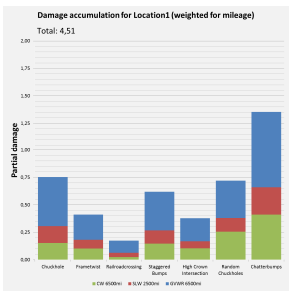
Animations to understand the **causes**

Miner's rule

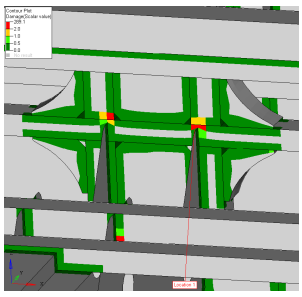
$$D = \sum d_i$$

Theoretical limit: 1

Detailed results for each critical weld

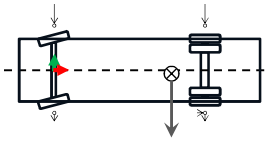


Overview for the whole structure



Comparison to alternative methods

Methods based on
static FE simulations



+ More **realistic** loads

+ **Dynamic effects** captured

- Computationally **more intensive**

- Less **experience** in results interpretation

Experimental method
(Physical Proving Ground)

+ (Much) **lower costs,** more **iterations**

+ Possible in **earlier design phase, quick feedback**

- **Regulatory** acceptance, validation

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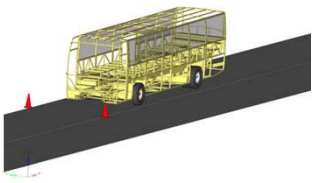
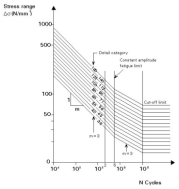
Further possibilities

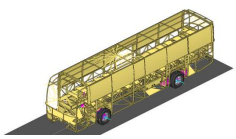
Dynamic manoeuvres
(controlled steering)





Fatigue calculation with other standard or method (e. g. industry/company specific methods)

Validation to measurements
(same structure, same track, …)



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Thank you for your kind attention!

Contact

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