“Modular vehicle concept – modular model design – reliable calculation chain”

Dynamic analysis of the Avenio® platform with multi-body simulation (MBS)
Structure

- Presentation of Avenio® tram platform
- Tasks of the Light Rail dynamics group (bids, load generation, vehicle certification at public authorities, etc.)
- Modeling at LR EN – past and present (Combino® -> Avenio®)
- Present modeling (modules for car bodies, articulations, bogies)
- Automated simulation in batch run
- Automated and interface-optimized postprocessing (tool chains)
Avenio® - the 100% low-floor vehicle
Avenio® – a modular vehicle concept

- Low axle loads
- Extremely comfortable ride thanks to the torsionally flexible bogie connection (yawing)
- Optimum passenger flow due to a large number of double-leaf doors which are also provided at the ends of the vehicle

Length

- 18 m
- 27 m
- 36 m
- 45 m
- 54 m
- 63 m
- 72 m
Tasks of the Light Rail dynamics group at Siemens Mobility

- Bid processing (review of infrastructure, clarification of vehicle clearance gauge, etc.)
- Definition and calculation of design loads for car body strength
- Driving new and further developments (e.g. bogie components, articulations), influencing running performance and load level
- Accompanying vehicle certification (resistance against derailment, ride quality, running behaviour, etc.)
SIMPACK modeling at Light Rail

Complete model - “Modification Combino” 2005

- Finite number of vehicle variants which differ only in mass parameters, gauge and wheel-rail-profiles
- Divided car bodies for determining of the sectional loads
- End-to-end parameterization
- One input parameter file for all vehicle parameters, prepared as a document
- Total of seven complete models for the dynamic analysis during the COMBINO modification program
Modularity also in model – substructures for Avenio® development

Why substructures?

- Platform development calls for parallel processing of a number of models
- Quickly needed but modeling-intensive changes (such as the to running gear connection) requires a swift response

Aspects of building vehicle models from substructures:

- Only one substructure level possible => practical breakdown of the vehicle into subsystems is necessary
- Management of input parameters (local, global)
- Consideration of project-specific wheel-rail geometries
- Variable gauges (meter gauge / standard gauge)
5-section Avenio® vehicle

End module
Intermediate module
Intermediate module
Intermediate module
Front module

Motor bogie
Trailer bogie
Motor bogie
Trailer bogie
Motor bogie

Single articulation including pitch motion
Single articulation
Double articulation
Single articulation

Single articulation

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Modular submodels for Avenio®

Car bodies

Articulations

Bogies
Other modular submodels for Avenio®

- Traction control
- External influences (mass forces, wind forces) defined by U-vector
- Export of time series in binary format for postprocessing in Matlab (user element)
Basic 5-section Avenio® model

- Already contains the wheels and dummy bodies for connection to the bogie
- Project-specific wheel/rail profiles already set
- Bogie positions – and therefore car body positions as well – already defined
- Gauge (standard or meter gauge) already specified by means of logic variables
- Each submodel has its own parameter set which is based on the settings in the basic model and on a separate file with boundary conditions
- Grouping of the submodels via 0-DOF joints as well as via wiring of signal flow chains (force / control parameters)
Modular vehicle concept = Modular model structure

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Reliable tool chain
Avenio® platform load generation

Normative load cases (quasi-static)

Dynamic additional load cases
Tool chain in use – car body strength
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Tool chain in use – car body strength

Parallel simulation of entire vehicle platform with several computers

4 vehicles, around 50 maneuvers -> around 200 simulation jobs!

• Comprehensible definition of vehicle, track and boundary conditions in ONE list
• Distribution of simulation jobs across several processors

Fast simulation with optimal utilization of hardware and licenses!
Tool chain in use – car body strength

Postprocessing

- Analysis of critical moments for stress on the car body using appropriate reference values
- Provision of all forces, moments and accelerations acting on the car body
- Error check by checking $\sum \vec{F} = m \times \vec{a}$
- Output in ASCII file (ANSYS.mac compatible)
- Automatic provision of car body loads, no errors due to manual data transfer (coordinates transformation, etc.) from the MBS world into the FE world!
Tool chain in use – car body strength

FE analysis

- Determining of the structural loads
- Information on fatigue strength
Thank you very much for your attention!