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Simulation of railway track maintenance trains at MATISA

MultiBody Simulation User Group Meeting

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MATISA SINCE 1945

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Created in 1945 and, since then, MATISA is established in the area of Lausanne.

ISO 9001-2008 certified since 1996

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MATISA SWITZERLAND

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OFFICES:

Resources: approximately 180 employees
Area: 4’750 m² on 8 floors

WORKSHOP:

Resources: approximately 200 employees
Area: 33’730 m² / Workshop: 8’000 m²

PRESENTATION OF THE SOCIETY

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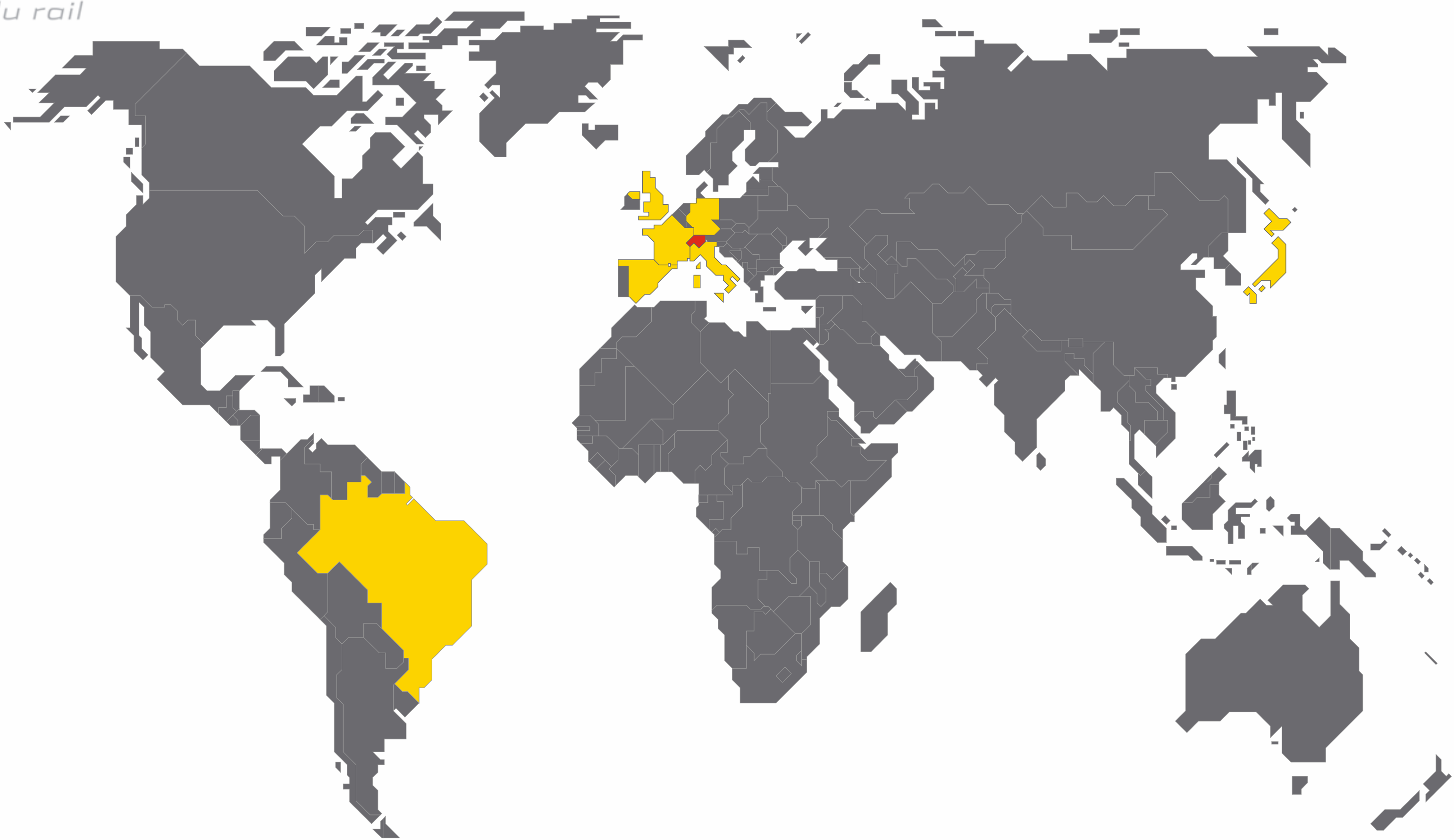
MATISA
European and
International…

Headquarter:
Switzerland

7 branches :
United Kingdom
France
Italy
Spain
Germany
Japan
Brazil



LARGE PRODUCTS RANGE

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TAMPING MACHINES

BALLAST REGULATORS

RENEWAL TRAINS

TRACK LAYING TRAINS

BALLAST CLEANERS

AUSCULTATION VEHICLES

TRANSPORT WAGONS

Working and Running Modes

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- MATISA vehicles run in 2 modes:
  - In working mode:
    - The vehicle runs at walking speed
  - In running mode:
    - MATISA vehicles travel on their own or are included in trains, running on railway networks to reach their working zones
    - Insertion in traffic, running at usual freight trains speed (around 100 km/h)
    - Thus this material is subjected to similar homologation standards as freight trains
    - A methodology was developed to include MultiBody Simulation with SIMPACK during the product development phase, with respect to the homologation scenarios.

Outline of the project

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Project Summary

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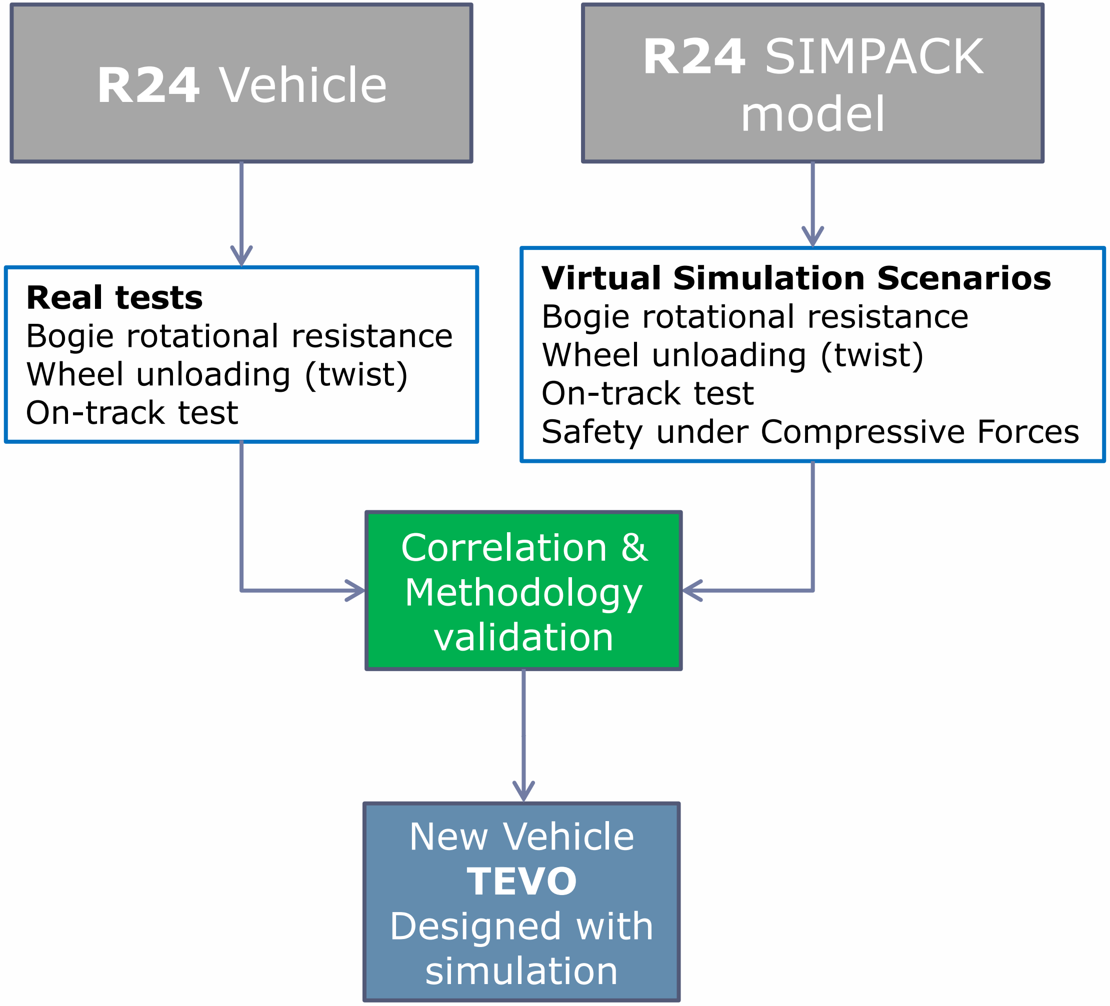
Development of SIMPACK methodology on an existing vehicle (R24) already certified.

Comparison between simulation and test results

Validation of the methodologies

Use of SIMPACK during the development phase of a new train: TEVO



R24 Ballast Regulator

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Ballast Regulator R24

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- Used to shape the ballast of existing railway track or after replacement of ballast in maintenance operations
- Consists of 1 wagon with 2 bogies and 1 trailer with a suspended wheelset:

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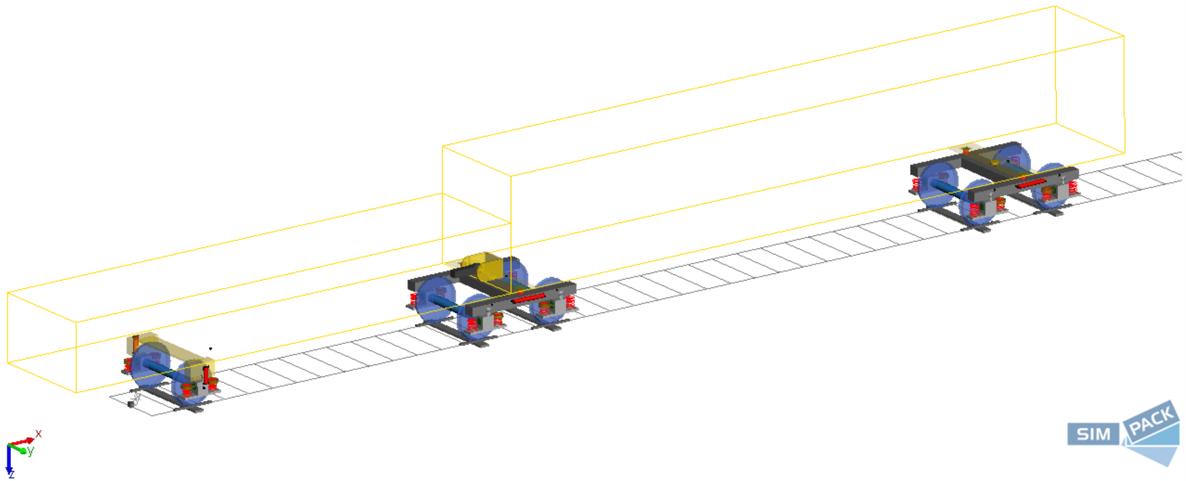
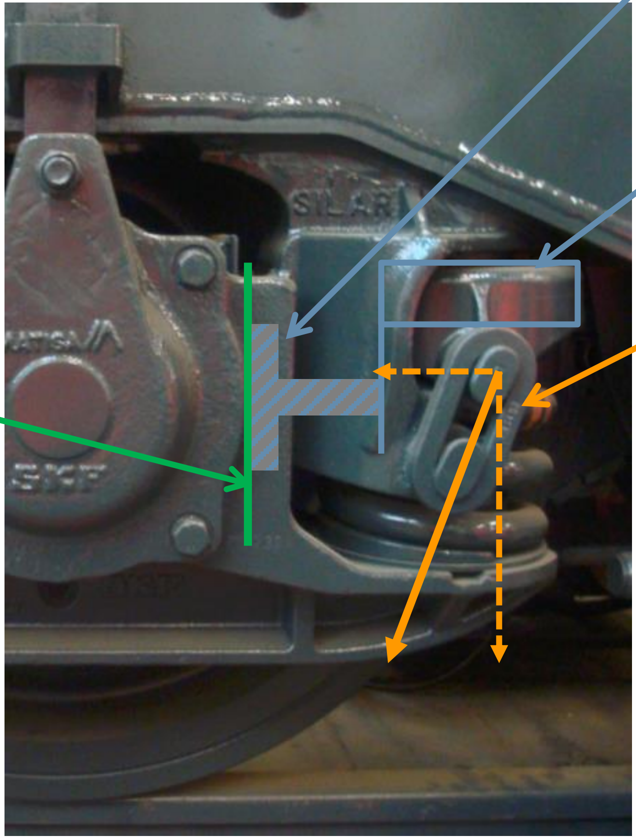
Ballast Regulator R24

- Bogie similar to the freight Y25 bogie
- Bogies can be trailer or motor bogies (hydraulic motors)
- Single wheelset suspension with similar elements as the bogie primary suspension, addition of a vertical damper



Ballast Regulator R24

- Suspensions:
  - Bogie Primary Suspension:
    - Nested coil springs and Lenoir link friction damper



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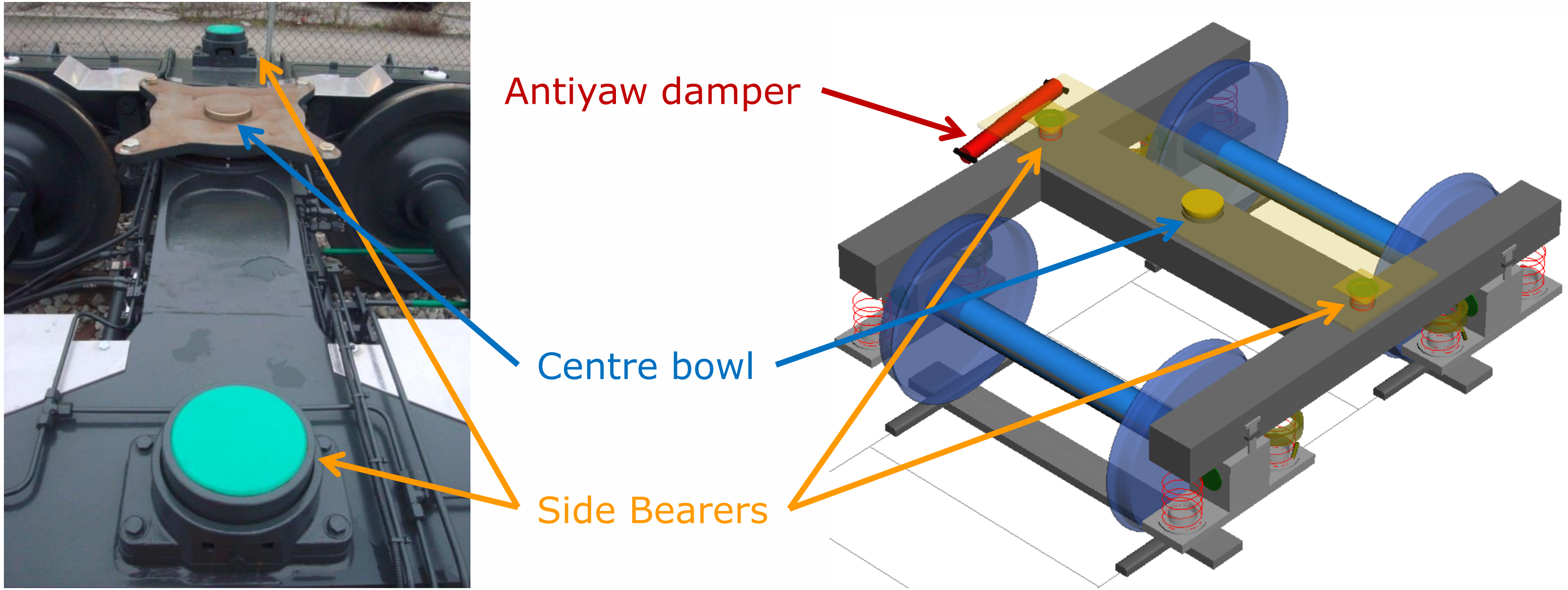
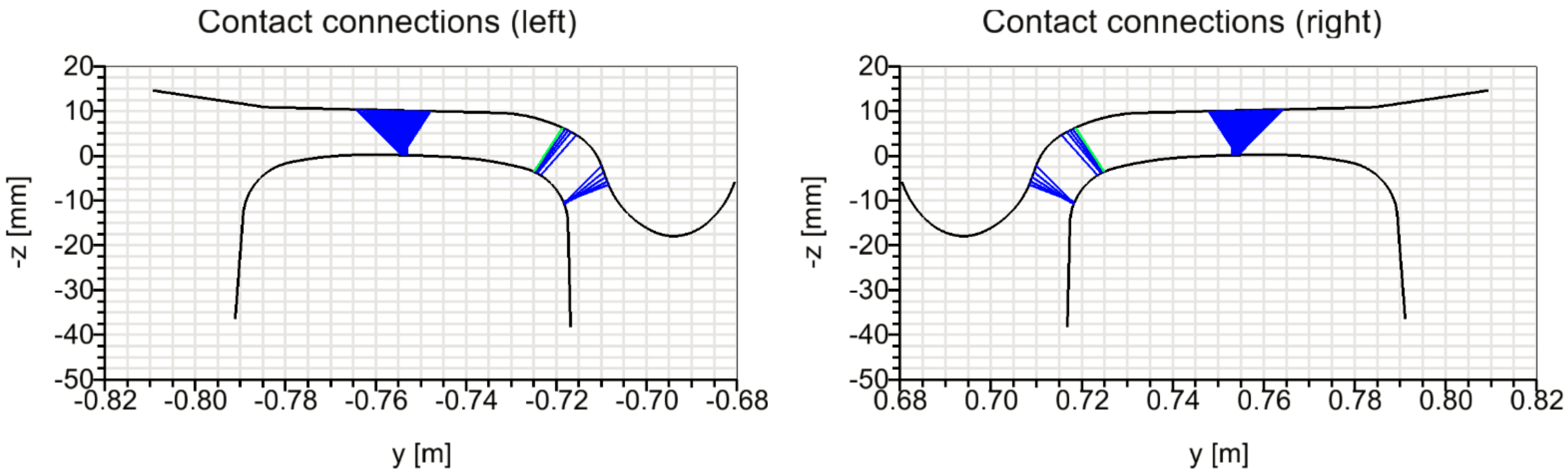
Ballast Regulator R24

- Suspensions:
  - Bogie Secondary Suspension:
    - Center bowl and side bearers
    - Anti-yaw damper (on one side) to improve stability



Ballast Regulator R24

- Wheel-Rail Contact:
  - Equivalent Elastic Contact from SIMPACK Rail
  - FASTSIM tangential force law
  - Wheel profile: Profile 1/40 from EN13715 standard
  - Rail profile: 60E1 rail, with rail cant 1:40 or 1:20.



R24
Correlation between test and simulation

Correlation Scenarios

- For the R24 vehicle, the following test vs. simulation correlations were performed:
  - Bogie rotational resistance (EN14363)
  - Wheel unloading (twist) (EN14363)
  - On-track test (EN14363)

- Additional « simulation-only » scenario was also performed, as no test data was available :
  - Running Safety under Compressive Forces (EN15839)

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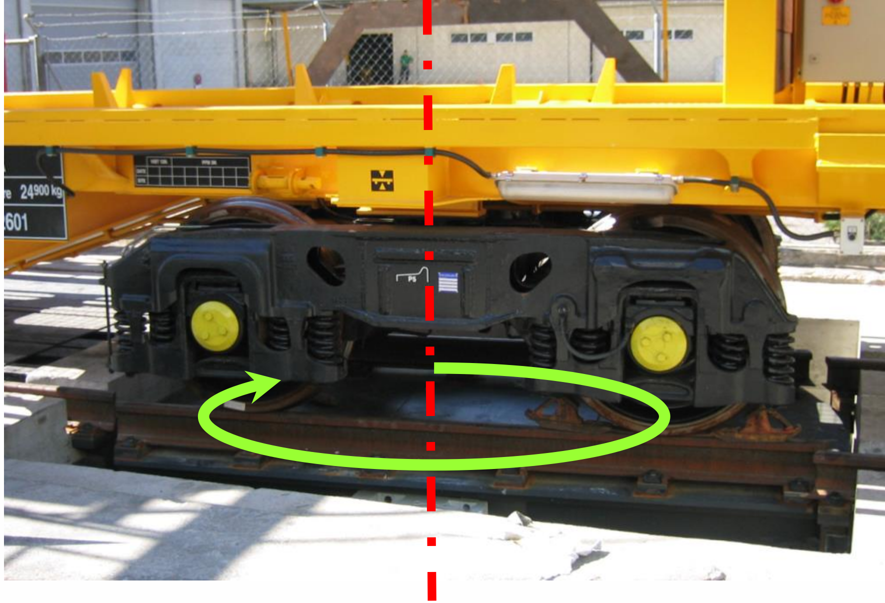
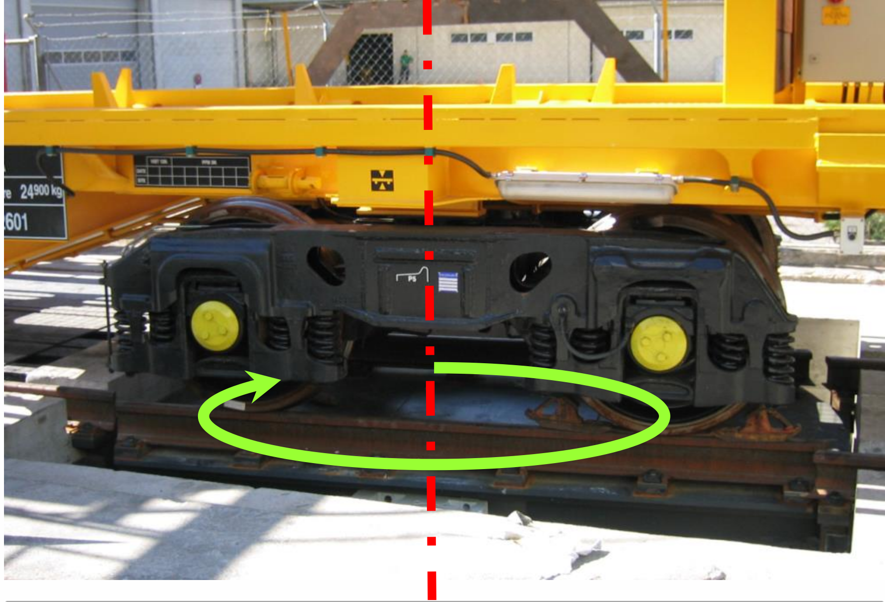
Bogie Rotational Resistance

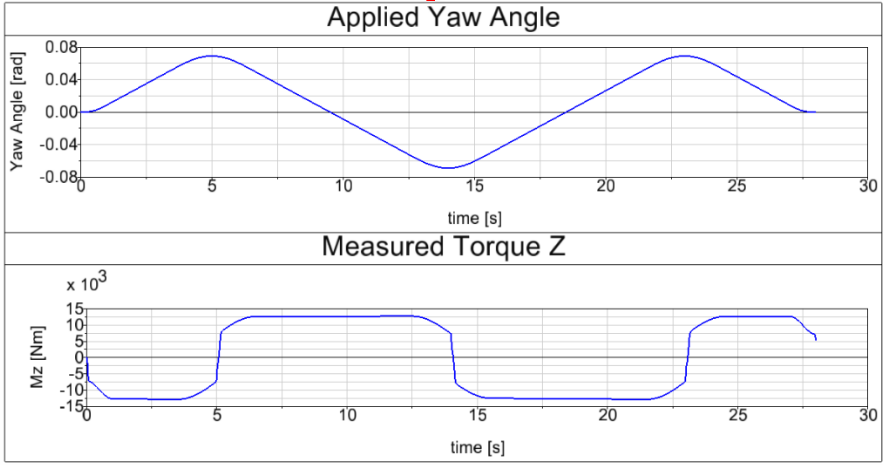
- Specified by EN14363 (section 4.4)
- The purpose of this test is to evaluate the **Bogie yaw rotational resistance** when a yaw angle is applied on the bogie at track level.
- It reflects the yaw torque generated when running through curves, switches and crosses, etc.



Bogie Rotational Resistance

- In practice, this test is realized on a specific test rig in our facilities.
- The test rig applies a « sawtooth like » angle cycle to the bogie.
- The yaw torque is measured on the test rig





Bogie Rotational Resistance

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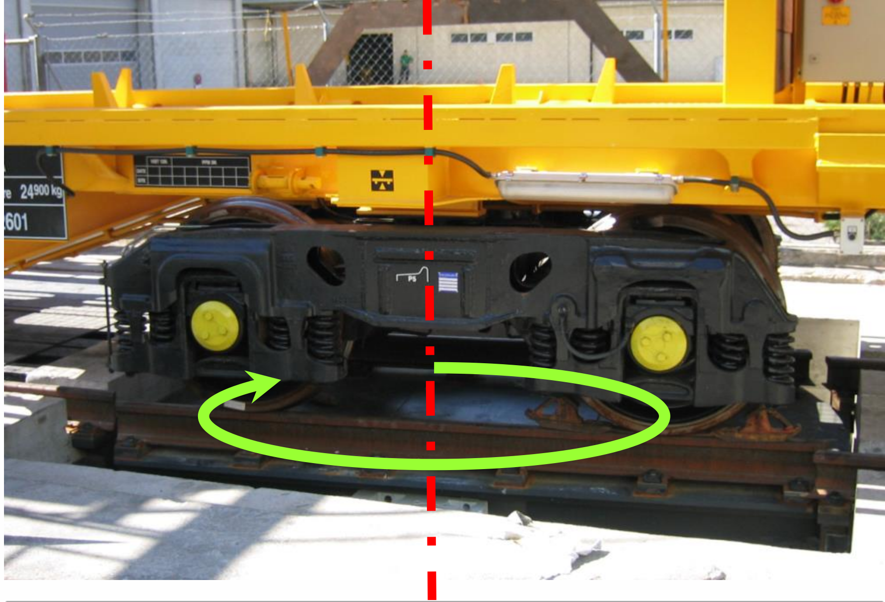
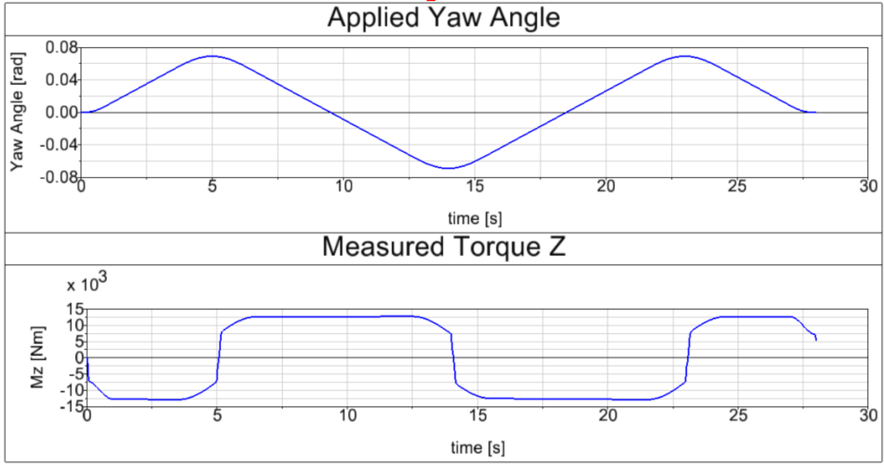
- The yaw torque measured on the test rig comes from two main sources:

1. Friction forces between bogie and chassis in the center bowl and on the side bearers

2. Viscous forces in the antiyaw damper.





Bogie Rotational Resistance

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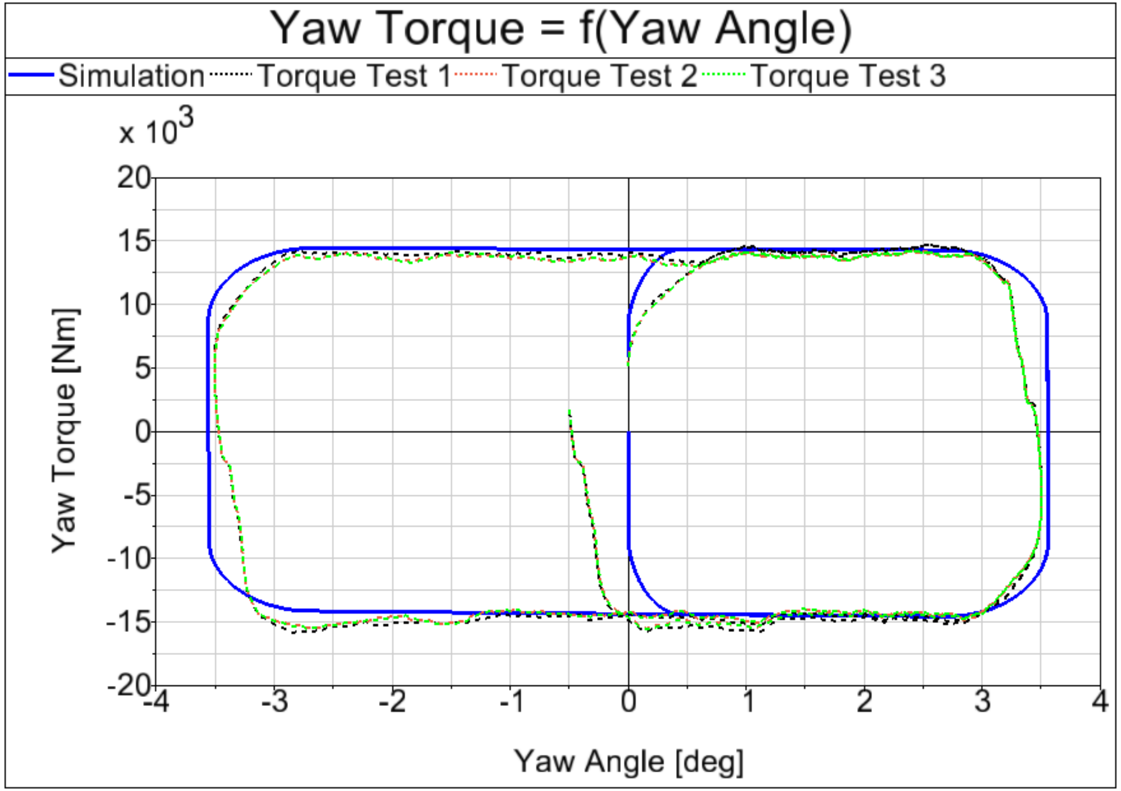
- Comparison of the yaw torque in simulation and measured in the tests:



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Wheel Unloading (twist test)

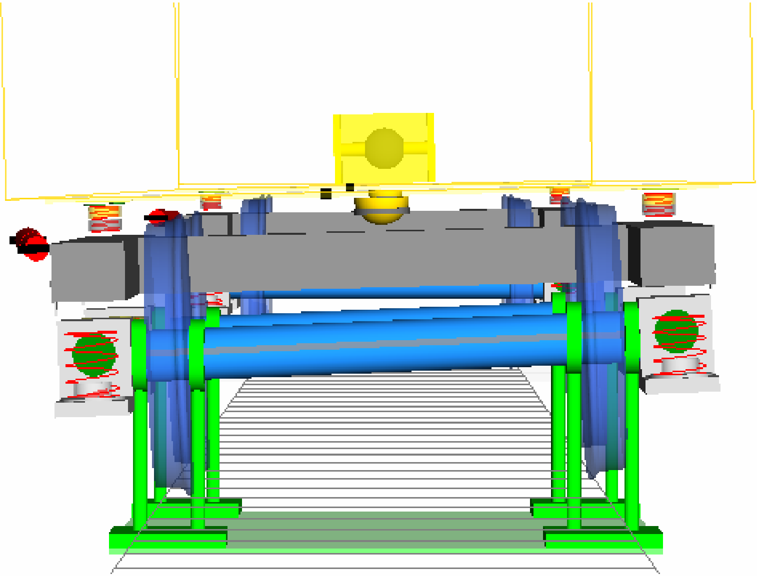
- Homologation scenario to ensure that railway vehicles can run safely on twisted tracks is described in the EN14363 standard

- Twist test specified by Method 2 of EN14363 is a combination of two different scenarios:
  1. Wheel unloading by twisting the bogie on a test rig
  2. Y force measured when running in a narrow curve at low speed (radius 150 m, no cant)

- In practice:
  - Wheel unloading measured on a specific test rig in our facilities
  - Y forces estimated analytically or by simulation

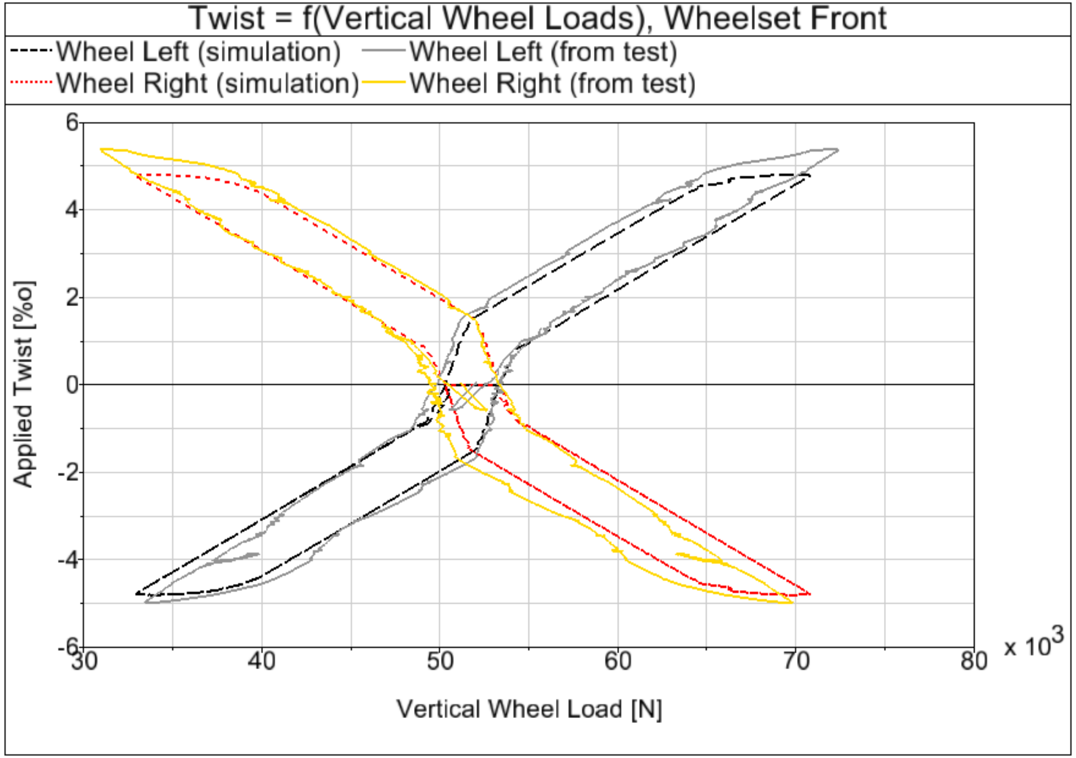
Wheel Unloading (twist test)

- Wheel unloading test rig
  - Hydraulic cylinders lift up or down the wheels of a bogie to apply a twist
  - Wheel loads are measured in the hydraulic cylinders
  - Twists heights to apply specified by EN14363 standard



Wheel Unloading (twist test)

- Wheel unloading (twist test)



On-track runs

- On-Track tests specified by the EN14363:
  - Running on real tracks to check the vehicle dynamic characteristics
  - Criteria regarding:
    - Track Loading (from wheel-rail forces)
    - Running Safety (from wheel-rail forces and accelerations on vehicle)
    - Ride quality (from accelerations on vehicle)

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On-track runs

- EN14363 recommends to run on complete tracks (several hundreds of km) and compile measurements according to the track sections

- To reduce the number of simulations, a subset of most severe track segments was identified, covering the whole range of straight and curved tracks on typical network:
  - Identification of several track segments
  - For each track segment, choice of a representative track section
  - Track sections for both forward and reverse directions

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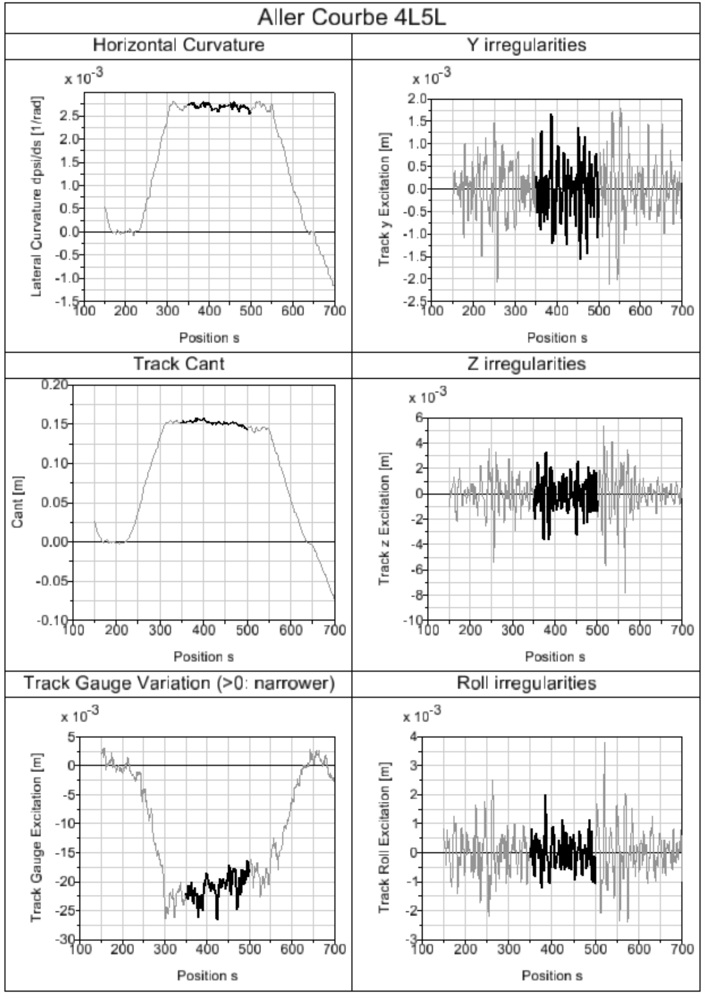
On-track runs

- Once the track sections are identified, the corresponding portions of measured track are imported in SIMPACK, for both:
  - Track design
  - Track irregularities



On-track runs

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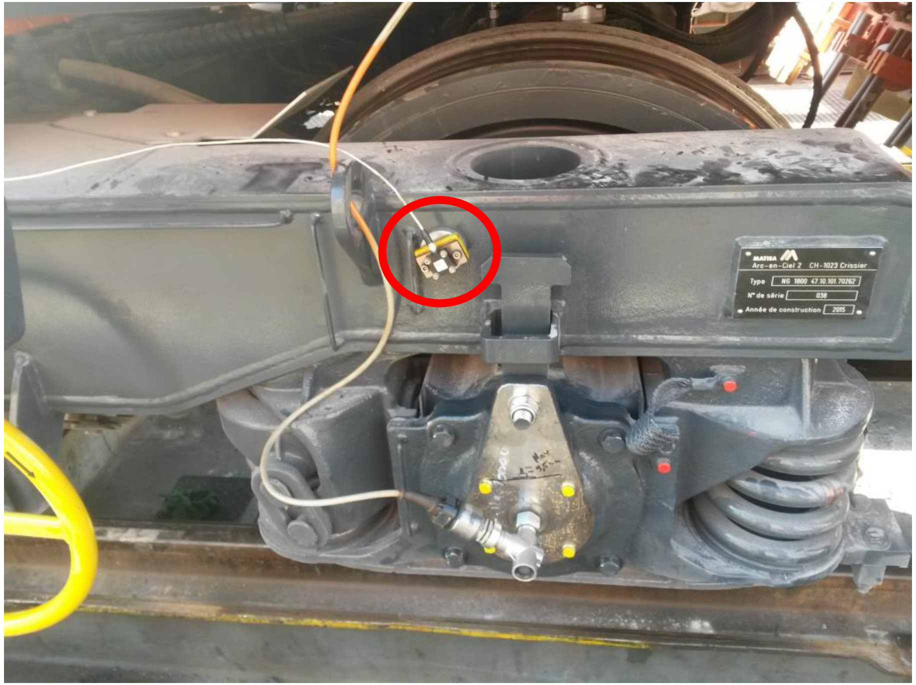
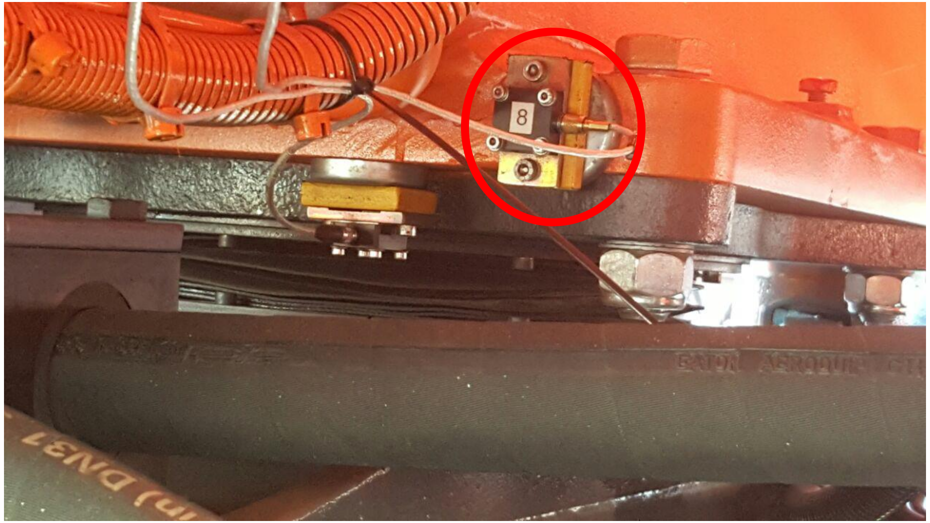
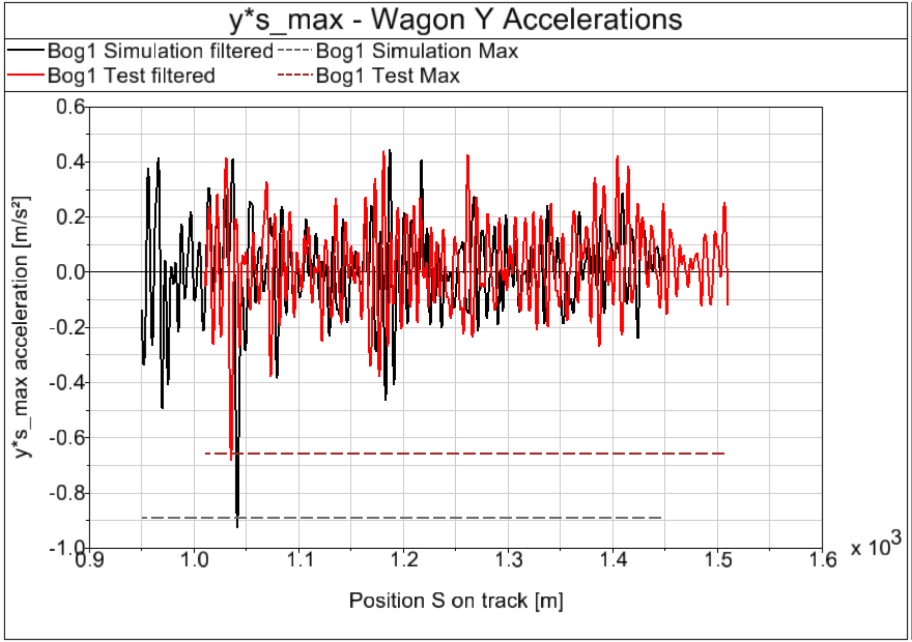
- Instrumentation with acceleration sensors on bogie frame and on the wagon's chassis

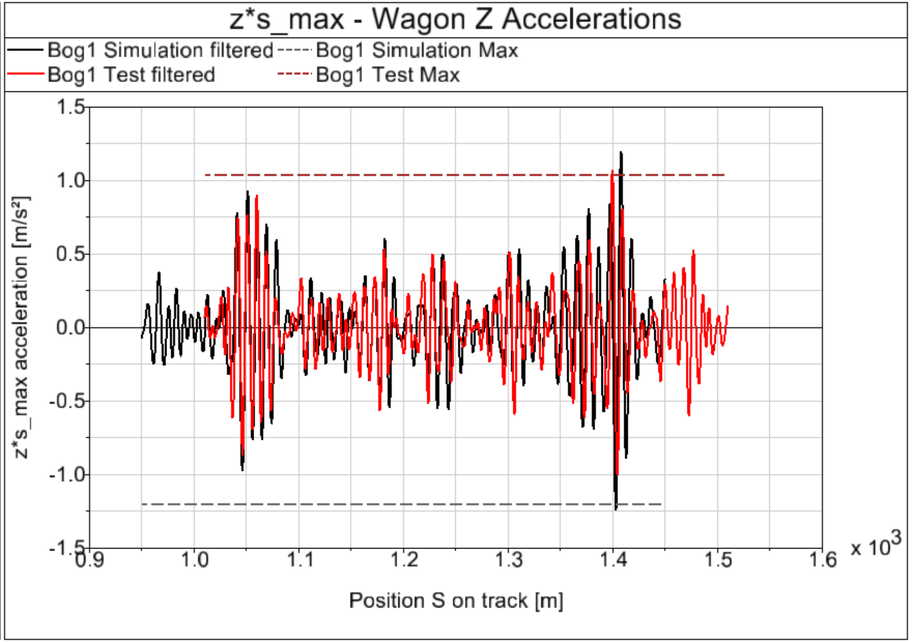




Simulation Scenarios with R24

- Comparison of sample acceleration signals





Why studying the compressive forces?

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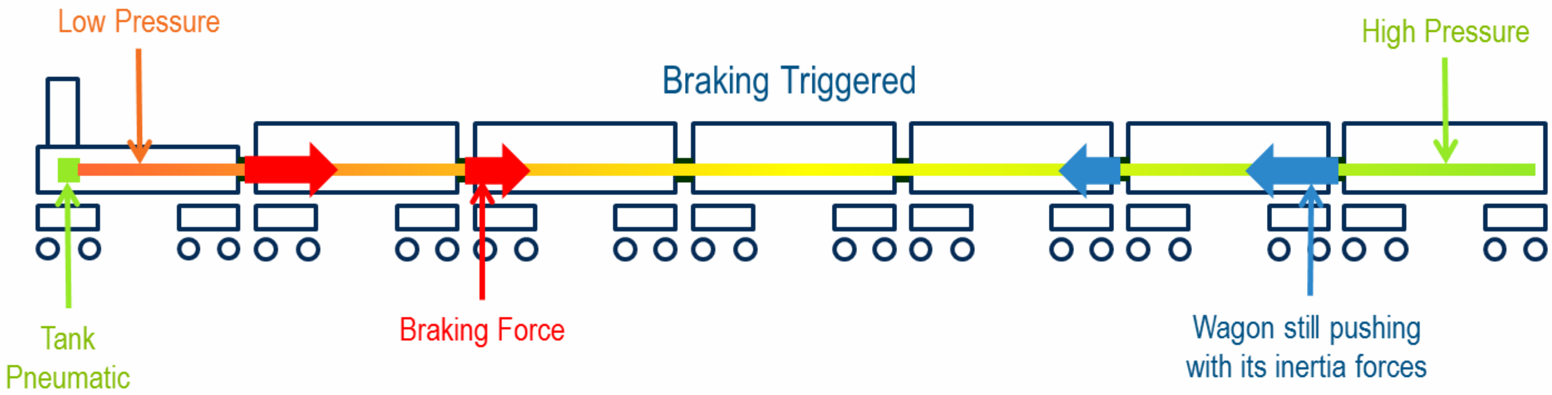
- Freight trains are usually braked using pneumatic systems
- Emergency braking **on very long trains** may take several seconds to propagate from one end to the other
- During this time, the train is subjected to high compressive forces: front side is braking while the rear is still pushing from its inertia
- These compression forces increase the risk of derailment when running in narrow curves



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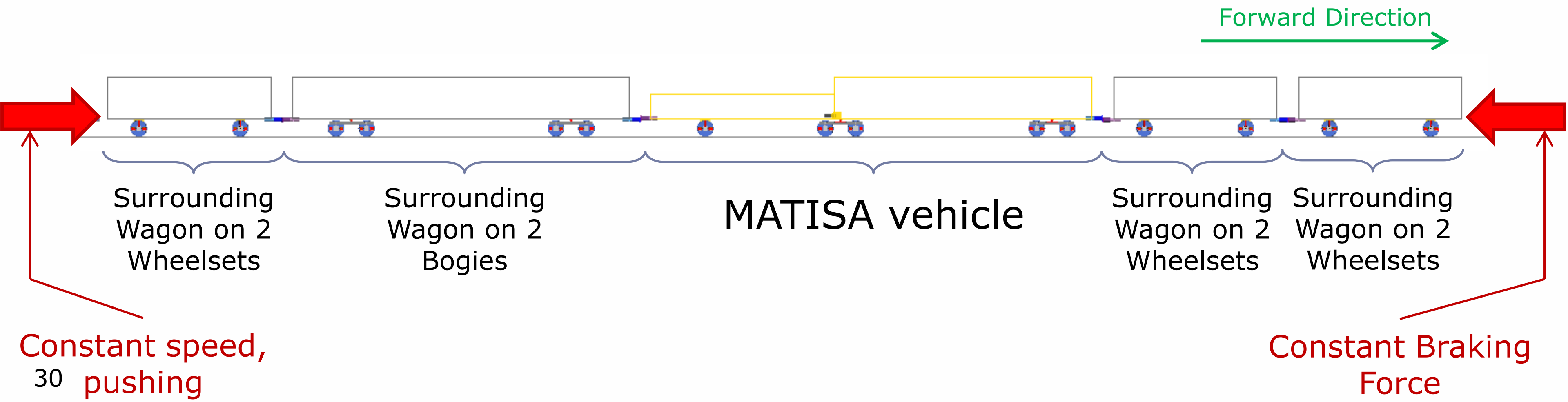
Safety under Compressive Forces

- EN15839 standard describes how the admissible compressible forces should be evaluated.
- The MATISA vehicle is surrounded by freight wagons, either short wagons on wheelsets or longer wagons on bogies.
- This train is submitted to high compressive forces: braking force in front and a locomotive pushing from the back at constant speed.



Safety under Compressive Forces

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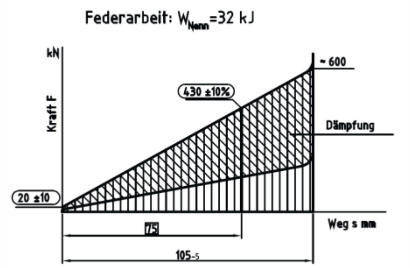
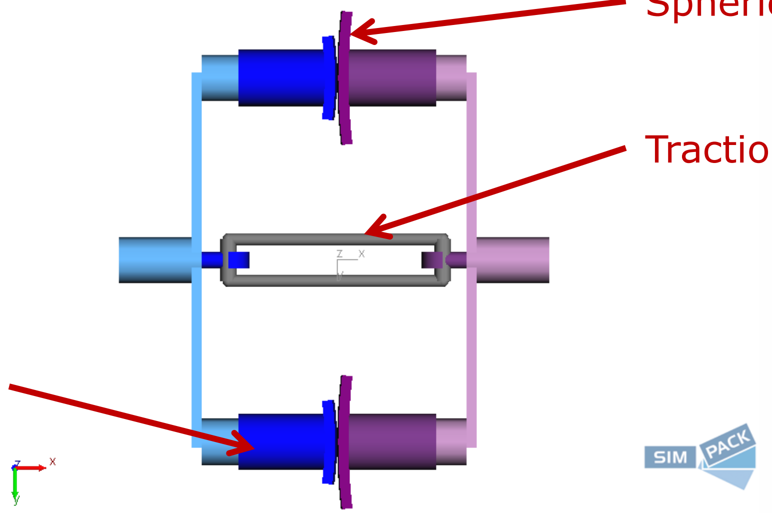
- Wagons are linked with spherical buffers (defined by EN15551 standard)





Safety under Compressive Forces

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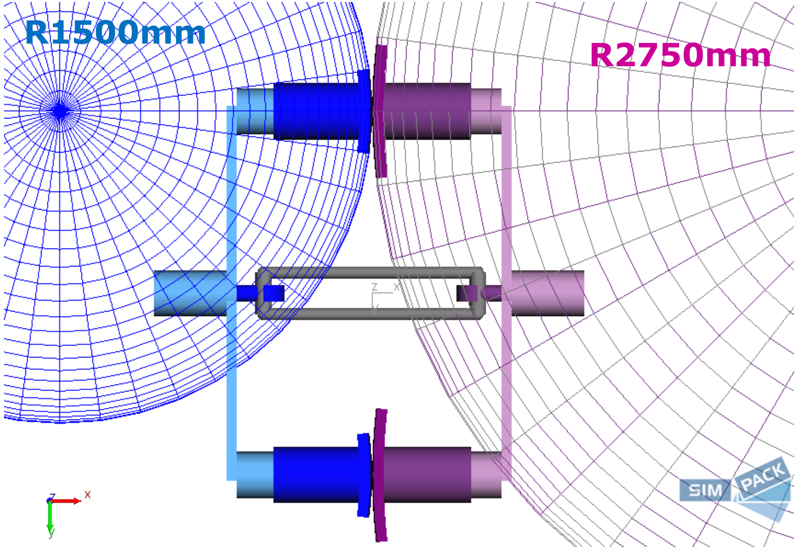

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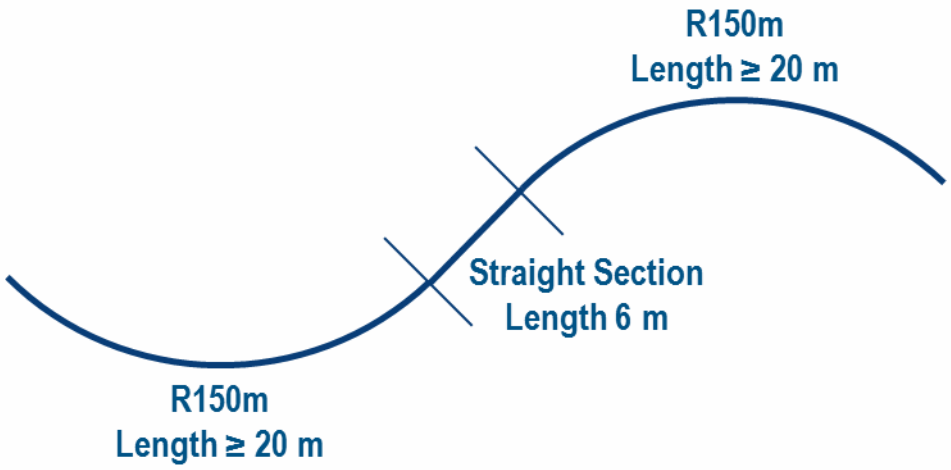
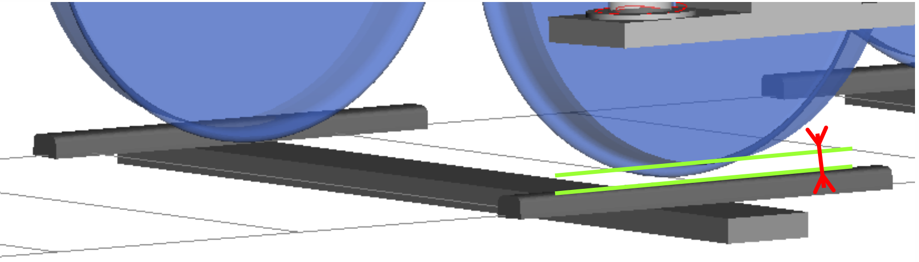
Safety under Compressive Forces

- This train runs at constant low speed (< 10 km/h) in narrow S-Curves with a short straight track transition.
- Several runs with several compressive forces

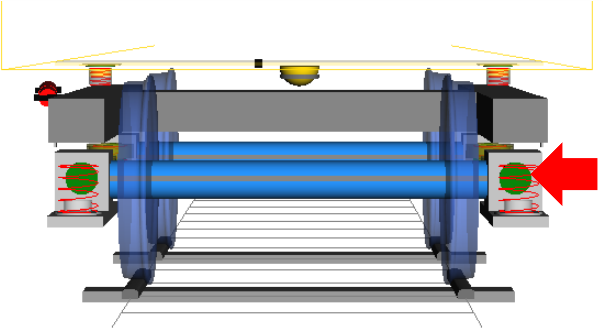


Safety under Compressive Forces

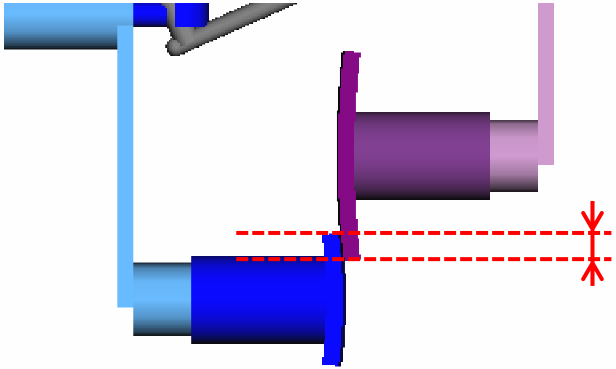
- Following criteria for evaluation of the maximum admissible compressive force
- Admissible Compressive Force is the highest force for which all criteria are fulfilled



Wheel raise dz_{ij} < 5 mm on steering wheels
Wheel raise dz_{ij} < 50 mm on non steering wheels



$H_{lim} < 25 + 0.6 * Q_0$



Buffer Lateral Overlapping > 25 mm

Safety under Compressive Forces

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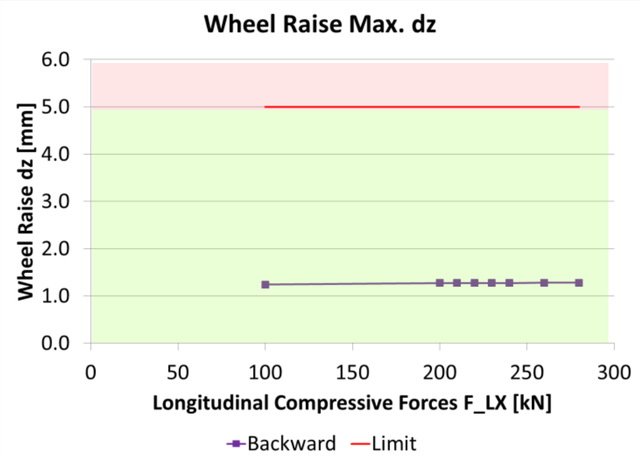
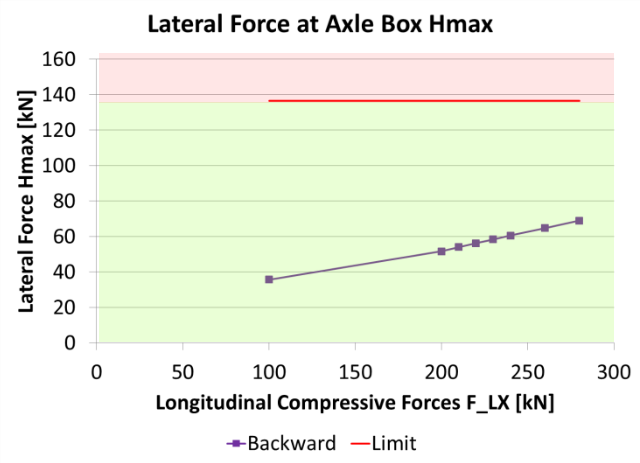
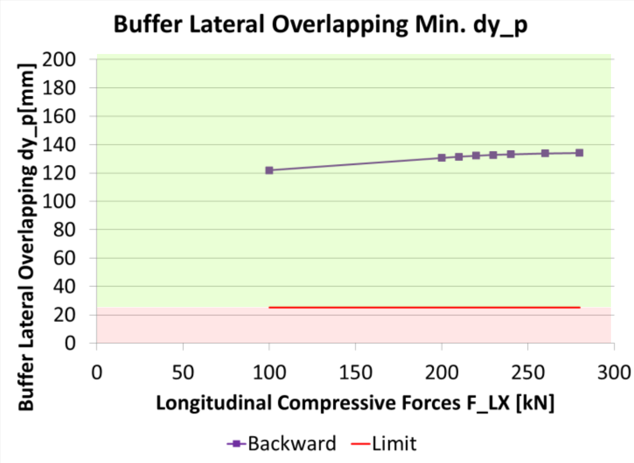
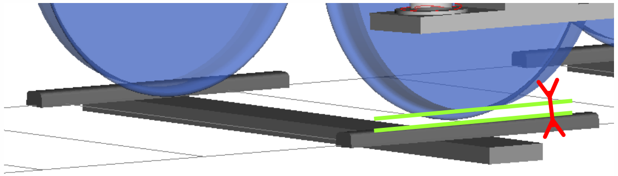
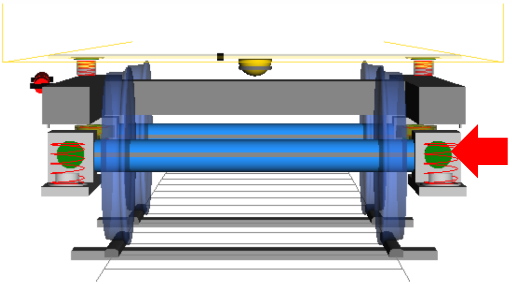
- Results

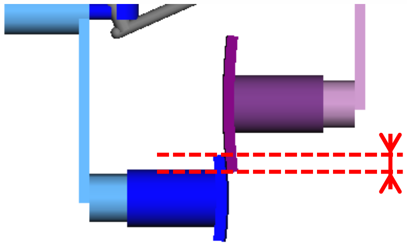












TEVO

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Simulations with a New Train: TEVO

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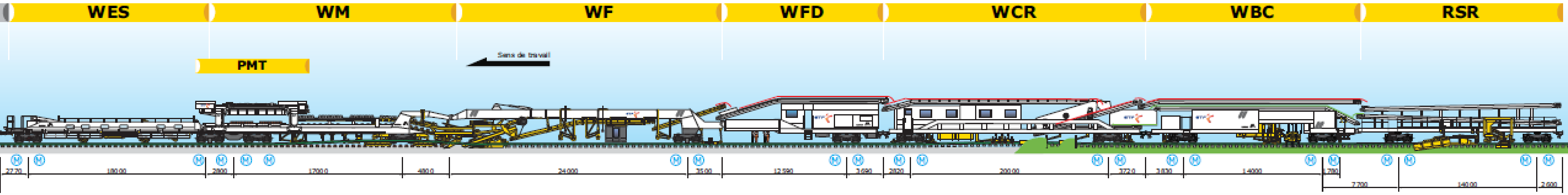
- From the R24 Ballast Regulator model, a new model of a complete track renewal train is set up: TEVO.
- TEVO is a maintenance train that removes track sleepers and ballast and replace them by new ones.
- It can replace track segments at once, to allow maintenance overnight while ensuring normal traffic in the day.



Simulations with a New Train: TEVO

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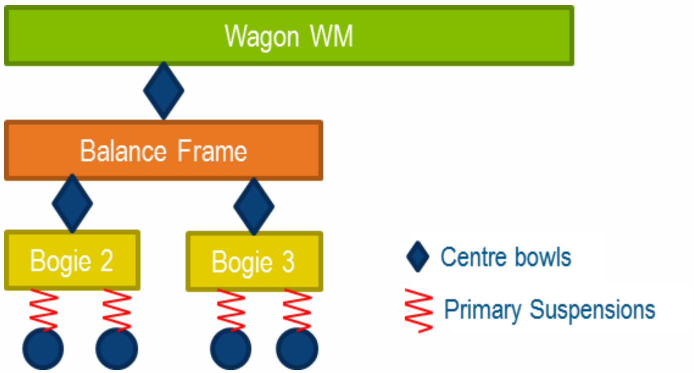
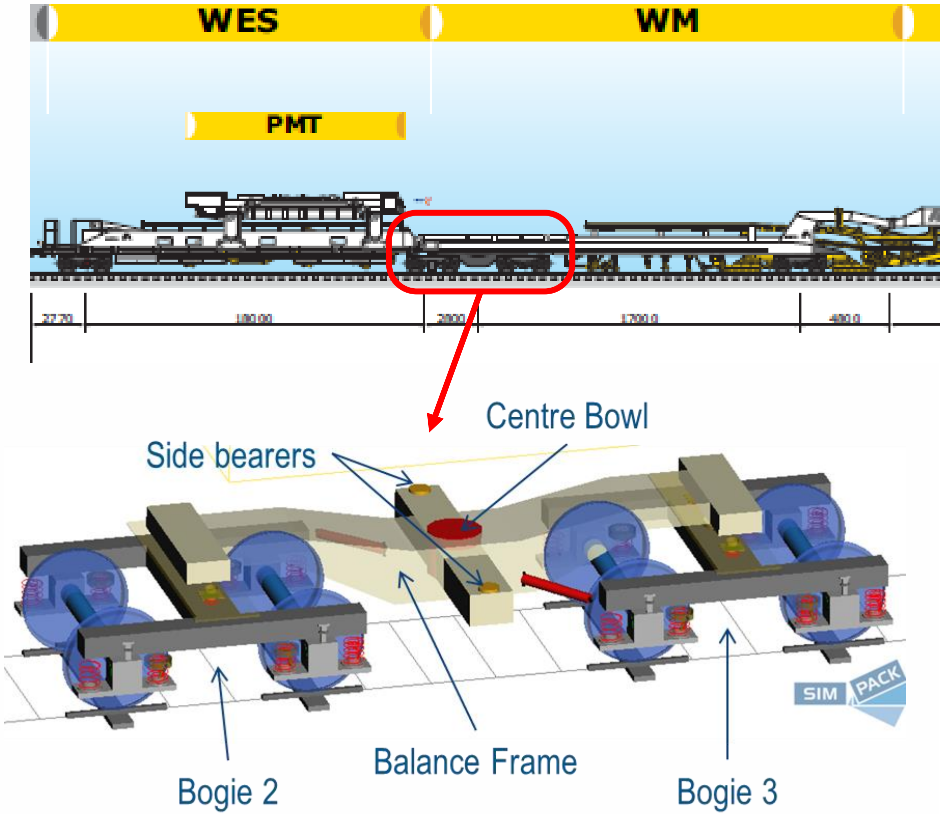
- TEVO specific architecture:
  - 3-stages suspension on bogies 2 and 3





Simulations with a New Train: TEVO

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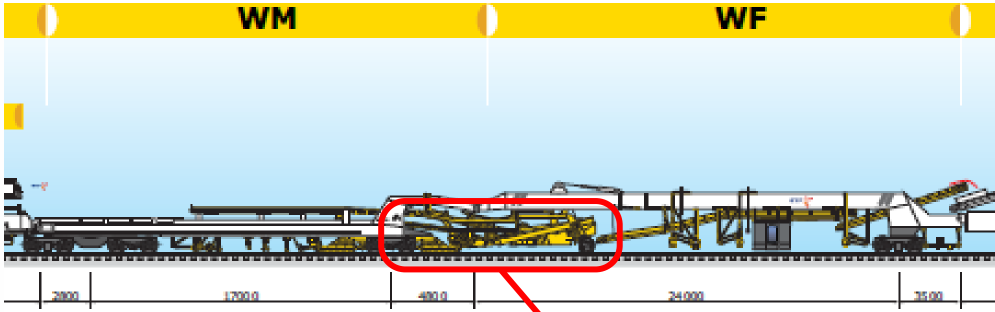
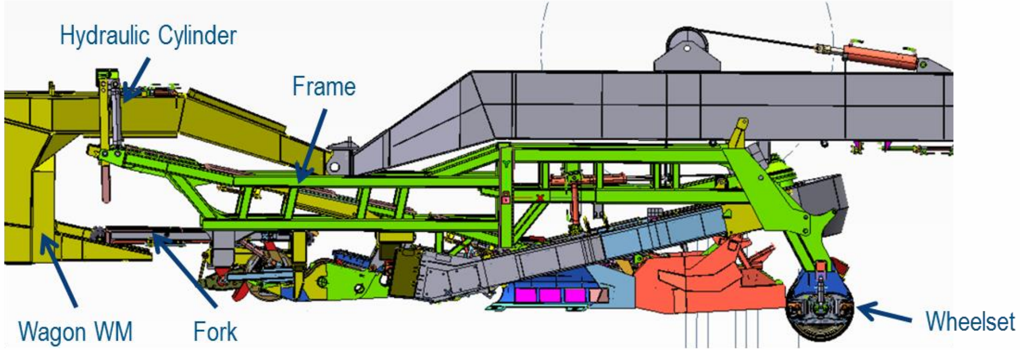
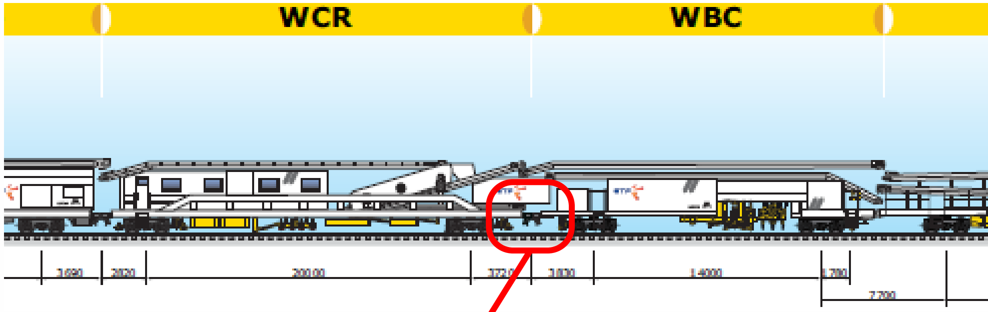
- TEVO specific architecture :
  - Working group: a chassis is suspended on Wagon WM on one end and on a suspended wheelset on the other end
  - Retractable wheelset in working zone

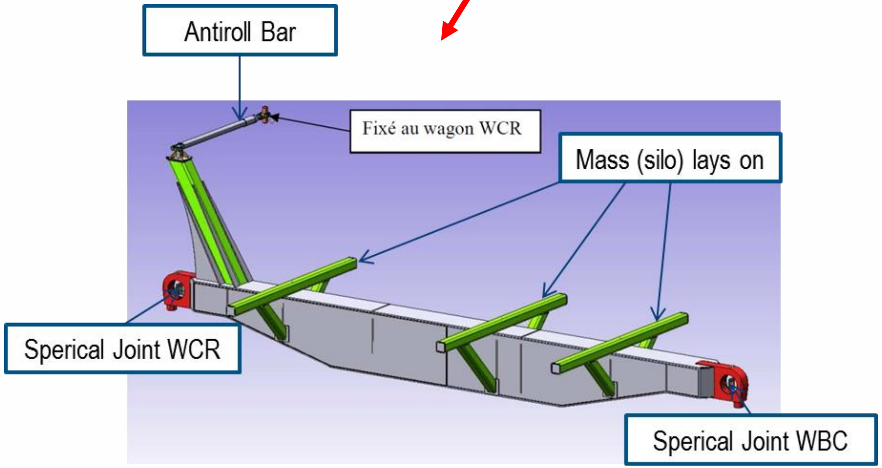




Simulations with a New Train: TEVO

- TEVO specific architecture :
  - Special link between wagons WCR and WBC
  - A mass (silo) lays on the drawbar





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Simulations with a New Train: TEVO

- Running the homologation scenarios by simulation during the product developement process helped identify critical issues before testing:

  - Choice of softer primary suspension springs to decrease maximum dynamic forces in on-track tests

  - Verification of the vehicle stability before running at normal speeds on real on-track tests

  - Elimination of twist tests on the wheel unloading test rig
    → direct cost reduction

Summary

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Summary

- MATISA vehicles are subjected to same homologation standards as freight trains

- They are very often customized or built in small series, thus almost unique

- A methodology was set up to include MultiBody simulations early in the product development phase:
  - Correlation with tests and validation of the methodologies on an existing vehicle (Ballast Regulator)
  - Model and simulations of a new railway track maintenance train (TEVO)

- SIMPACK simulations helped identify critical issues and improve the train design before manufacturing it

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THANK YOU FOR YOUR ATTENTION

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