Simulation of railway track maintenance trains at MATISA

MultiBody Simulation User Group Meeting

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

ISO 9001-2008 certified since 1996
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

MATISA
European and International...

Headquarter:
Switzerland

7 branches:
United Kingdom
France
Italy
Spain
Germany
Japan
Brazil
LARGE PRODUCTS RANGE

- TAMPING MACHINES
- BALLAST REGULATORS
- RENEWAL TRAINS
- TRACK LAYING TRAINS
- BALLAST CLEANERS
- AUSCULTATION VEHICLES
- TRANSPORT WAGONS
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
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
Ballast Regulator R24

- 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:
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
Suspensions:
  Bogie Primary Suspension:
    Nested coil springs and Lenoir link friction damper
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.
Correlation between test and simulation
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)
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

- 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

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

**Yaw Torque = f(Yaw Angle)**

- Simulation
- Torque Test 1
- Torque Test 2
- Torque Test 3
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)
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
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

- 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?

- 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.
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

- Wagons are linked with spherical buffers (defined by EN15551 standard)
Safety under Compressive Forces

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

$H_{lim} < 25 + 0.6 \times Q_0$

Buffer Lateral Overlapping $> 25$ mm
Safety under Compressive Forces

Results
Simulations with a New Train: TEVO

- 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

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

![Diagram of TEVO train components](image)
Simulations with a New Train: TEVO

• **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
Simulations with a New Train: TEVO

- Running the homologation scenarios by simulation during the product development 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

- 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
THANK YOU FOR YOUR ATTENTION

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