Railway Dynamics Studies
at CITEF with SI MPACK
Introduction to CITEF

UPM – Universidad Politécnica de Madrid

ETSII – Escuela Técnica Superior de Ingenieros Industriales

CITEF – Centro de Investigación en Tecnologías Ferroviarias

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SIMPACK modelling group (3 people)

 cuốn Prof. Dr. Carlos Vera (director)

cancelled Berta Suárez (project director)

cancelled Jenny Paulin (project engineer)

cancelled Pablo Rodríguez (project engineer)
Projects

Railway dynamics in SIMPACK

- Pantograph models
- Catenary models
- **Coupled model: pantograph - catenary**
- Rolling stock
- Student projects

Future projects

- Switch modelling
- Railway track stiffness transition
Aerial conductor rails

Conductor rail
- main application in Metro systems
- replaces conventional overhead lines in tunnels
- 2 materials: aluminium (rail) & copper (contact wire)
Conductor rail as an elastic body

SIMPACK MODEL: Conductor rail (includes supports)
- modelled as an elastic body in a FEM program
- supports are included in the FEM model
- modes up to 30 Hz are included in FEMBS
- tracks with lengths >300 m modelled

Supports that carry the conductor rail every 10 m are modelled in the FEM program and are not shown here.
SI MPACK MODEL: Pantograph

- three-dimensional model in SI MPACK
- conventional design with two conductor strips
MODELLING of pantograph

3-D CAD-drawings

including real values for:

- mass
- inertia moments
- geometry
Damping values were obtained by experiments to estimate:

- damping of pantograph’s head suspension
- friction loss in the joints

Two types of experiments were conducted:

- Experiment for determining damping of head suspension
- Experiment for determining friction loss in joints
Comparison of the results for head suspension damping

**Time domain**

![Time domain graph]

**Frequency domain**

![Frequency domain graph]
Pantograph – Additional forces

- Static force, \( F_{\text{static}} = 100 \text{ N} \)
- Aerodynamic force, \( F_{\text{aero}} = 10 \text{ N} \) \((for v>100 \text{ km/h})\)
Coupled SI MPACK model: CONDUCTOR RAIL & PANTOGRAPH

OBJECTIVES

- dynamic behaviour analysis
- calculation of contact forces that appear between contact strips and conductor rail (wear)

How do we model the contact between contact strips and conductor rail?

solution 1
simple contact model

solution 2
complex contact model
Solution 1: Simple contact model

- FE-18 “unilateral spring-damper” used for contact spring

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Moved point (moved marker) on the conductor rail

Contact spring (works only when contact)

Fixed point (marker) on contact strip
Solution 2: Complex contact model (introducing contact surfaces)

- MM-87 “surface/surface 3-D contact” used for moved points
- FE-18 “unilateral sping-damper” used for contact spring
Solution 2: Complex contact model (introducing contact surfaces)

How do we move the contact surface along the elastic contact wire?
Conductor rail: SPECIAL MOVED MARKER (USER ROUTINE)

- MM that moves along the elastic body (contact wire)
- MM allows use of several sections
- MM can be used in models with several pantographs
- MM essential for section overlapping
Conductor rail: SPECIAL MOVED MARKER

Example in SIMPACK: Section overlapping
Results: CONTACT FORCE GRAPH & STATISTICS

Introduction
Conductor Rail
Pantograph
Coupled Model
Rolling Stock
Student Projects

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Red: leading contact strip
Blue: trailing contact strip
Green: total contact force
PARAMETRIC VARIATION

- Running velocity
- Distance between supports

Assessing current collection quality

Contact Force [N]

- Mean
- Standard Deviation
- Statistical Maximum
- Statistical Minimum
- Actual Maximum
- Actual Minimum

Running Velocity Variation

10m 90km/h
10m 110km/h
10m 130km/h
12m 110km/h
14m 110km/h

standard deviation, \( \sigma \)
Future work

- Elastic pantograph head
- Wear on contact strips and contact wire
- Modelling a conventional catenary
- LOADS (data transfer SIMPACK – FEM)
Example for the model of a detailed motorized bogie

**CAD model**

**SIMPACK model**
Student projects

- Bogie over an elastic bridge
- Roller rig
- Passive and active steering
- Ergonomics of an urban coach
- Railway collision: implications on passengers
- Brake system of a freight car
- Detailed Model of an urban bogie
- Stability, comfort and derailment criteria
- Passive and active tilting
- Active suspensions
FIN...