Simulation of freight train during braking operation using SIMPACK

Politecnico di Torino
Dipartimento di Meccanica
N. Bosso, A. Gugliotta, A. Somà
Introduction

• This activity has been made in a research project together with SAB-WABCO S.P.A (Piossaco, Torino).
• SAB-WABCO has realized a full-scale hardware simulator of the braking system of an entire train long up to 2 km.
• The simulator includes all the pneumatic and control device up to the braking cylinders.
• In this context, has been individuated the necessity to link the braking simulator with a virtual simulator to obtain the dynamic response of the train.
Objectives

• Aim of the work was to realize a real-time virtual simulator of a long train to be integrated with the hardware simulator of the braking system (Hardware in the loop).

• Results expected from the virtual simulator were: the braking distance, the hook effort and some indications for the risk of derailment.
Method

• The virtual train simulator has been realized using analytical simplified models.

• SIMPACK has been used to realize more complex models (limited to few vehicles train) in order to develop and validate the simplified models, and evaluate the effect of approximations.
Real-Time

Hardware Braking Simulator

Pressure Brake cylinders

Virtual Train Simulator

Results:
Velocity Position Hook effort
Y/Q ratio dQ/Q ratio

Off-line

Validation

SIMPACK: Simulated Braking Manoeuvre

SIMPACK: Detailed Model 7 Vehicles train

p

SIMPACK: Detailed Model 7 Vehicles train

p
Model

• In order to simulate different train configurations, a series of models of common freight vehicles have been created.
• The models are divided in two typology: bogie vehicles and 2-axle vehicles.
• The various vehicles have been connected using different models of buffers/drawn gear.
Vehicles Typology

2-Axle Vehicles

Bogie Vehicles

Primary Suspension

Secondary Suspension

Spherical Joint

Body Frame (B)

Wheelset (W1,W2)

Wheelset (W1,W2, W3,W4)

Bogie Frame (TC1,TC2)
Simulations

- The vehicles have been composed in trains with different configurations and assembled on different track.
- Simulation are performed both at constant speed than during a braking maneuver.
- A set of critical parameter are analyzed on each analysis: Y/Q, dQ/Q, Y Forces, Longitudinal Effort, Vehicle kinematics.
<table>
<thead>
<tr>
<th>Without Braking</th>
<th>During Braking</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Forza Trazione/resp</strong></td>
<td><strong>Forza Trazione/resp</strong></td>
</tr>
<tr>
<td><strong>Applied force</strong></td>
<td><strong>Applied force</strong></td>
</tr>
<tr>
<td>Date: 02-12-14</td>
<td>Date: 02-12-14</td>
</tr>
</tbody>
</table>

- **Buffers Effort**
- **Without Braking**
- **During Braking**
Y Forces

SIMPACK

Simplified Model

Andamento della forza laterale sul binario

Forza Y asse 1
Forza Y asse 2
Forza Y asse 3
Forza Y asse 4
Forza Y asse 5
Forza Y asse 6

0 5 10 15 20 25 30 35 40 45 50
tempo [s]

0 1
Ascissa curvilinea [km]
**Y/Q RATIO**

**SIMPACK**

**Simplified Model**

[Graphs showing Y/Q ratio over time for different cases]
Relevant conclusions

• Results obtained using SIMPACK, demonstrate that during braking operations the risk of derailment in curved track is increased.

• Considering a wide range of freight vehicles it was possible to develop a simplified (real-time) code, to obtain a first-level indication of derailment risk during braking.
Other Research Activities

• Enhancements to the discrete track flexibility model
• Model validation using a Roller-Rig
Discrete Track Flexibility

- In the following will be described an easy method to enhance the SIMPACK model of discrete flexible track.
- The model allow to introduce a lateral flexibility between the sleeper and each rail.
- This flexibility can be expressed as function of the position along the track.
- Possible application is the simulation of a track with damage in the rail-sleeper connections.
Discrete Track Flexibility

Basic SIMPACK Model

(*) Additional Elements: 1 for each wheelset
F_L, F_R = Force elements

Left Rail (*)
Right Rail (*)

Prism Joint (*)
Discrete Track Flexibility

• Force elements are defined by expression (1 expression for each additional rail element).
• The stiffness can be changed as function of the track position using an input function (different for the right and left side).

express.str ($X_{r1r}$) =
'IFCTN(JOINTST($J_W1,1$),$I_{Yrstiff}$)*
JOINTST($J_R1R,1$)'

16/21
Discrete Track Flexibility

As an example, 4 cases are considered:

- Constant stiffness (1,2)
- Localized low stiffness with short (3) and large extension (4)

<table>
<thead>
<tr>
<th>CASE</th>
<th>Ky (KN/m)</th>
<th>Ky2 (KN/m)</th>
<th>DS (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>450</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>200</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>450</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>450</td>
<td>5</td>
<td>75</td>
</tr>
</tbody>
</table>
Discrete Track Flexibility

**CASE 1**

**Lateral Wheelset Displacement**

![Graph showing Lateral Wheelset Displacement for Case 1](image)

**CASE 2**

**Lateral Wheelset Displacement**

![Graph showing Lateral Wheelset Displacement for Case 2](image)
Discrete Track Flexibility

CASE 3

CASE 4
Ongoing activity

Model validation using a Roller-Rig

Roller-Rig realized at Politecnico di Torino
• A new 1:5 scale roller-rig has been developed and built at Politecnico di Torino.

• The Roller is designed in order to carry on tests both on a single suspended wheelset then on a railway bogie with wheelbase in the range 1.8 – 3.5 m.

• Current activity is to validate a numerical model of a passenger train using the roller-rig.