NEW DEVELOPMENTS FOR TILTING TRAINS

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New Developments for tilting trains

A view of the prototype 3 kV EMU train ETR401

VT610 DMU for DB Railways

Goal of Pendolino project:
• to improve service speed on regional lines, with quite poor track quality,
• maintaining full safety and
• a comfort level compatible with then-offered one

Activity started in Italy around 1966, up to mid '70,
The first tilting unit (Y0160) was build and tested in early '70,
The first EMU in service, the ETR401 was delivered in 1975.
The series production of ETR450, entered in service in 1988.
The VT610 was delivered on early '90s

SLIDE 1 - The approach, the prototype, first application in Italy and Germany
The new bogie has been developed starting by 1991 and the ETR460 train is in service from 1994.

Bogie architecture basically unchanged in respect of Etr450/VT610:

New features: :
• tilting system totally underfloor
• body bolster simplified connection
• redesigned axlebox guide
• simplified bogie frame concept

Improved Traction concept and car body design:
• DC/AC traction power systems, designed for bi-current and three-current solutions.
• wider modular carbody, in large extrusions profiles
• pressure tightness, in two different options (pressure-sealed, pressurised)

SLIDE 2 - The Electro-Hydraulic Pendolino
The reference signal is measured through the acceleration of a non-tilting part of the vehicle (bogie frame). The gyroscope measures the roll angular velocity of the bogie frame. System starts to tilt following through the gyroscope the transition's geometry. After a short time, the accelerometer signal is added. On the cars following, the reference signal is basically the acceleration.

**SLIDE 3 - The Tilting command concept.**
The new bogie has been developed starting by 1991 and the ETR460 train is in service from 1994. Bogie architecture basically unchanged in respect of Etr450/VT610:

New features:

- tilting system totally underfloor
- body bolster simplified connection
- redesigned axlebox guide
- simplified bogie frame concept
- improved Traction concept and car body design:
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**SLIDE 4 - The Electro-Hydraulic Tilting Bogie**
New developments for tilting trains

<table>
<thead>
<tr>
<th>Roller mechanism and electro-mechanic actuator</th>
<th>Electro-mechanical bogie assembly</th>
<th>Electro-mechanical tilting actuator</th>
<th>Active Lateral Suspension in electro-mechanical tilting bogie</th>
</tr>
</thead>
</table>

Tilting mechanism: Roller link between the tilting bolster and the bogie frame.
Electromechanical Tilting Actuator: planetary roller spindle + brushless motor driven by Electric Power Unit.
Secondary suspension = single air-spring + two roll-bars.
Longitudinal traction link drives anti-yaw dampers.
No Active Lateral Suspension is required by swept envelope.
Active Lateral Suspension where very high levels of comfort are required
Pantograph is controlled vs. catenary by an active electromechanical servo-system (brushless motor + sliding frame)

SLIDE 5 - The Electro-Mechanic Tilting Bogie
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Kinematics of tilting and self-centring effect

Tilting systems is intrinsically self-centring in case of fault. During the tilting phase, centre of gravity is kept approximately at the same position. During the tilt rotation the reaction centre position guarantees the stability. No reaction is transmitted to bogie; therefore, effects to wheel/rail are negligible.

SLIDE 6- Self-centring effect.
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Train control system

Hydraulic tilting functional scheme

Electro-mechanical tilting functional scheme

SLIDE 7 - Tilting control system
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SLIDE 8 - Pendolino in the world
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SLIDE 9 - Developments - High Cant deficiency bogies, with EM actuators and tilting rods
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SLIDE 10 - Developments - TILTRONIX concept
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SLIDE 11 - Developments – Semi active lateral Suspension
**New developments for tilting trains**

<table>
<thead>
<tr>
<th>Frequency [Hz]</th>
<th>DAMPING COEFFICIENT [Ns/m]</th>
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<tr>
<td>0</td>
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<tr>
<td>5</td>
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<td>15</td>
<td>1.6</td>
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<td>20</td>
<td>1.2</td>
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</tbody>
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**SLIDE 12 - Developments** – Active Dampers

- **Active**
- **Hydraulic**