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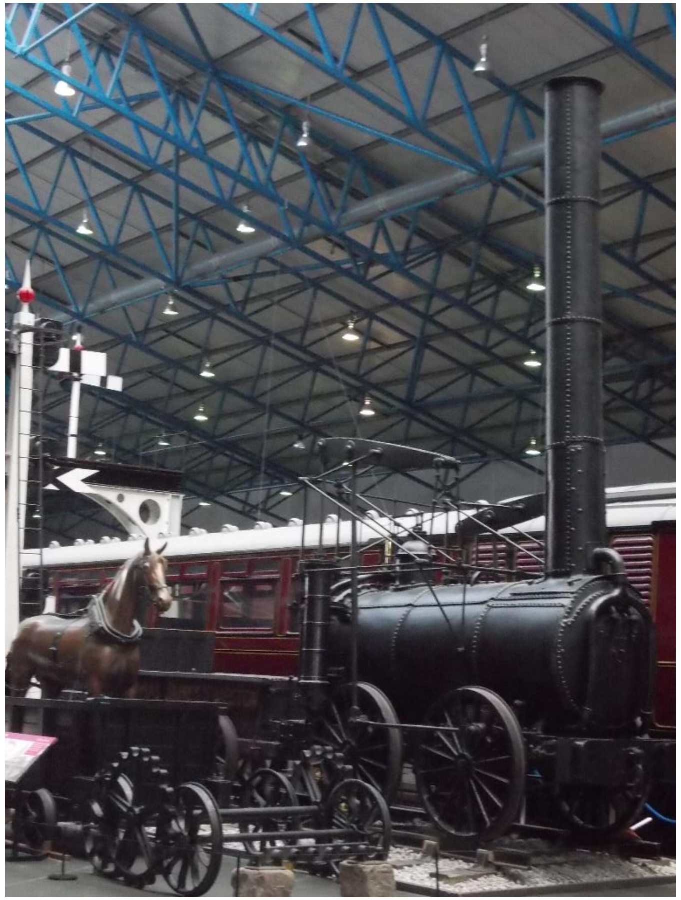
RESEARCH TOOLS APLICABLE IN DESIGNING OF HIGH-SPEED AND HIGH-POWER RAIL VEHICLES

Author: Ing. Vojtěch Dybala

Introduction

- Long history of the railway vehicles design (R. Trevithick – 1804; G. Stephenson – Locomotion 1 - 1825, Rocket - 1829)

Science Museum London – Rocket after „modernization“ in 1830



National Railway Museum York – ???

Introduction

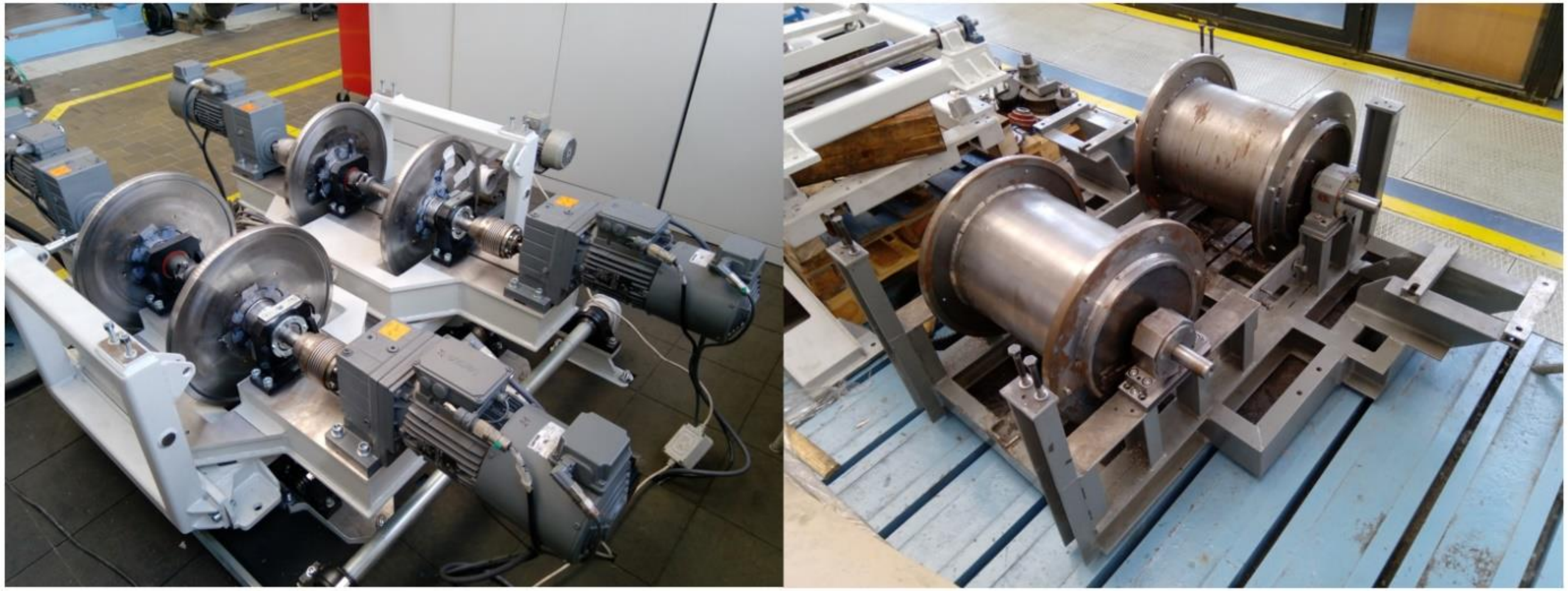
- 2nd half of 20th century – end of steam locomotives era (ČSD 1980) – new traction systems (diesel, diesel-electric, electric)
  - Increasing installed power and vehicle speed - R&D has been headed towards
    - Testing and measurement
      - Real vehicles on real tracks
      - **Roller rig testing in laboratories**
    - **Calculations and Simulations**

National Railway Museum York – Shinkansen Series 0

DB AG Munich – ICE 1

Roller rigs

- Consists of a frame, a propulsion system and **rollers** = rails substitution

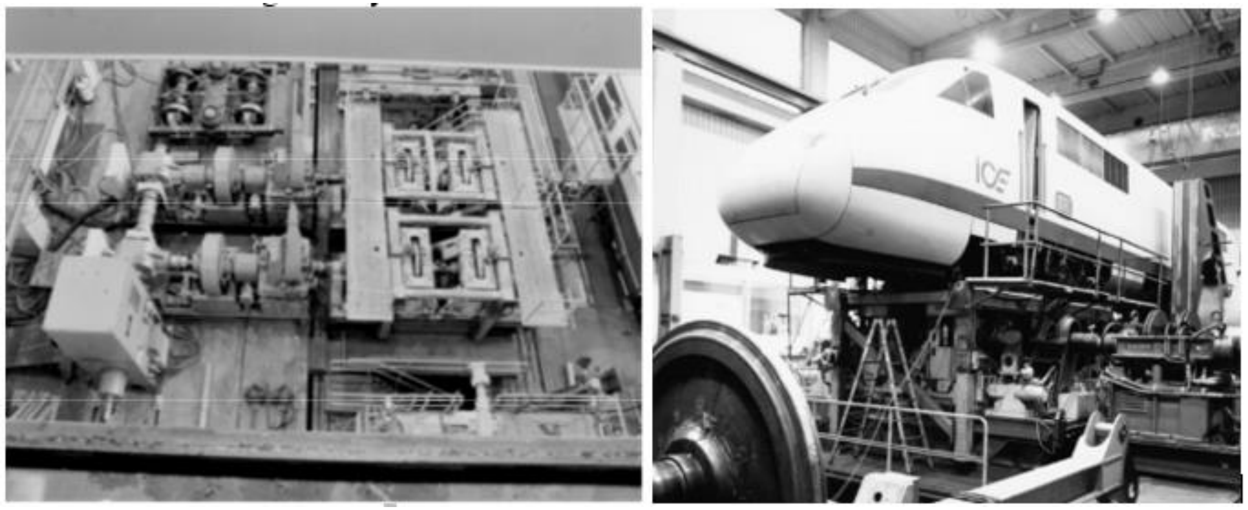


Roller rigs - Faculty of Mechanical Engineering at CTU in Prague

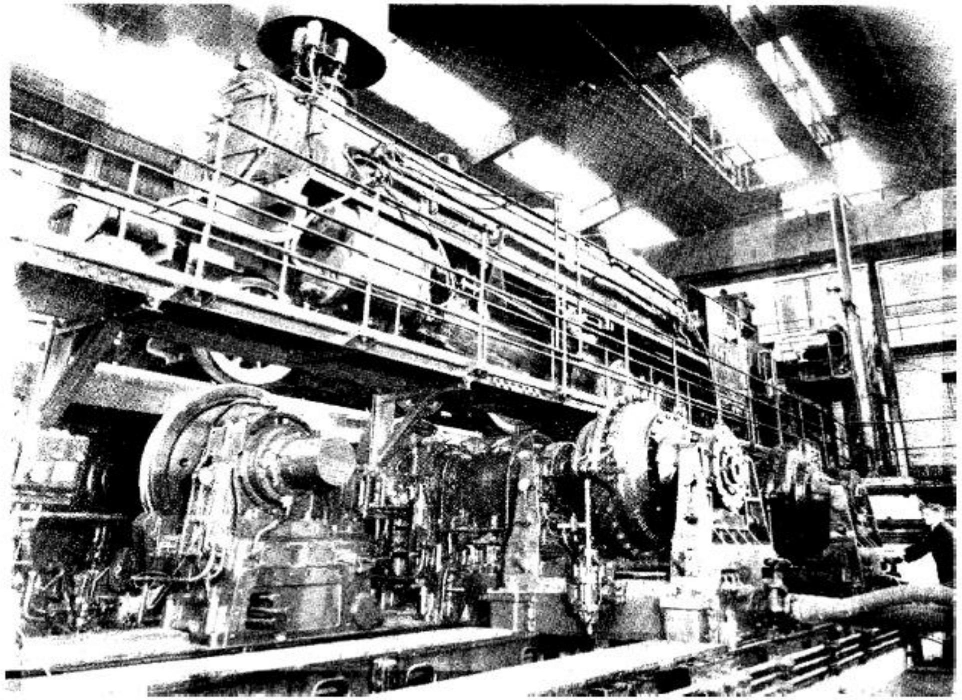
- Roller rig = substitution of a part of a railway infrastructure which carries and leads a vehicle

Roller rigs

- Real-life scale roller rigs



The roller rig built by DB-AG in Munich [1], [4]



The roller rig in Swindon [1]

- R&D of the first generation of ICE high-speed train
- Dynamic behaviour under different conditions
  - speeding in the straight track
  - acceleration and braking behaviour
  - ride on a track with deviated geometry

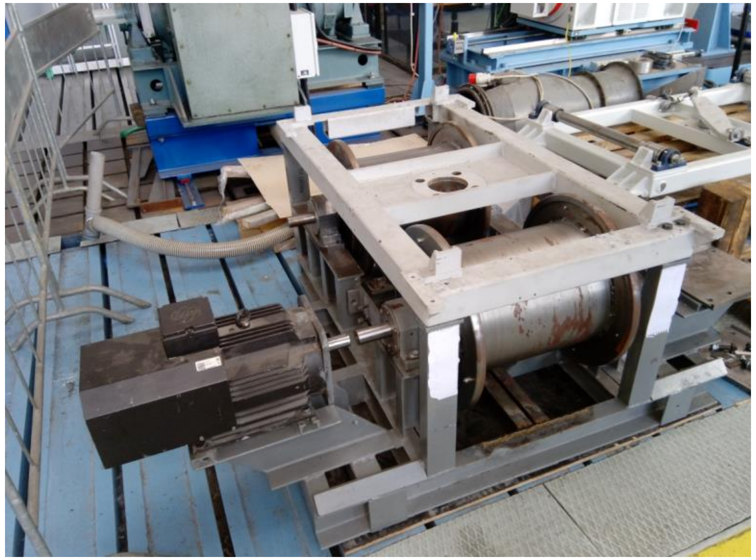
- Traction power measurement of steam locomotives

Roller rigs

- Scaled roller rigs (reduced dimensions)

The roller rig - Faculty of Mechanical Engineering at CTU in Prague

- Education – dynamic behaviour of bogie (oscillation frequency, wavelength)
- Research abilities [2] [3] – dynamic behaviour (independently rotating wheels, active steering of wheelsets)



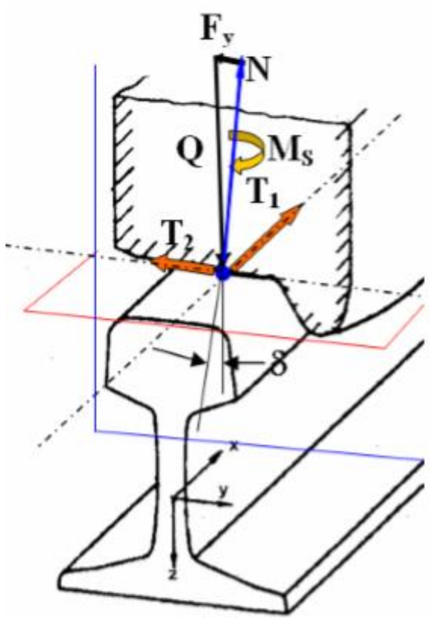
The roller rig - Faculty of Mechanical Engineering at CTU in Prague

- Under construction till these days
- 1st goal – **adhesion coefficient** measurement

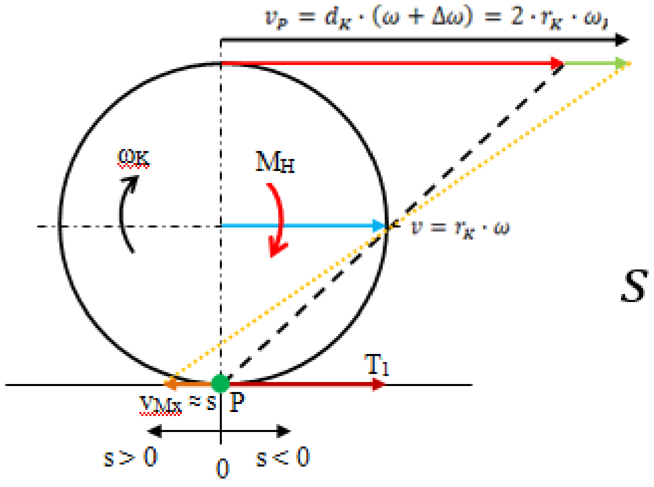
Roller rigs

- Adhension coefficient

$$T_1 = Q\mu$$

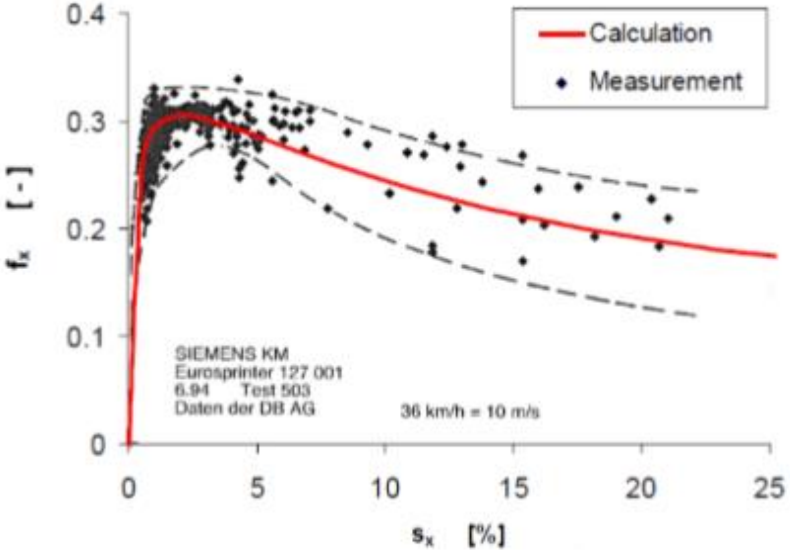


Wheel-rail contact forces [6]



Wheel slip deduction [6]

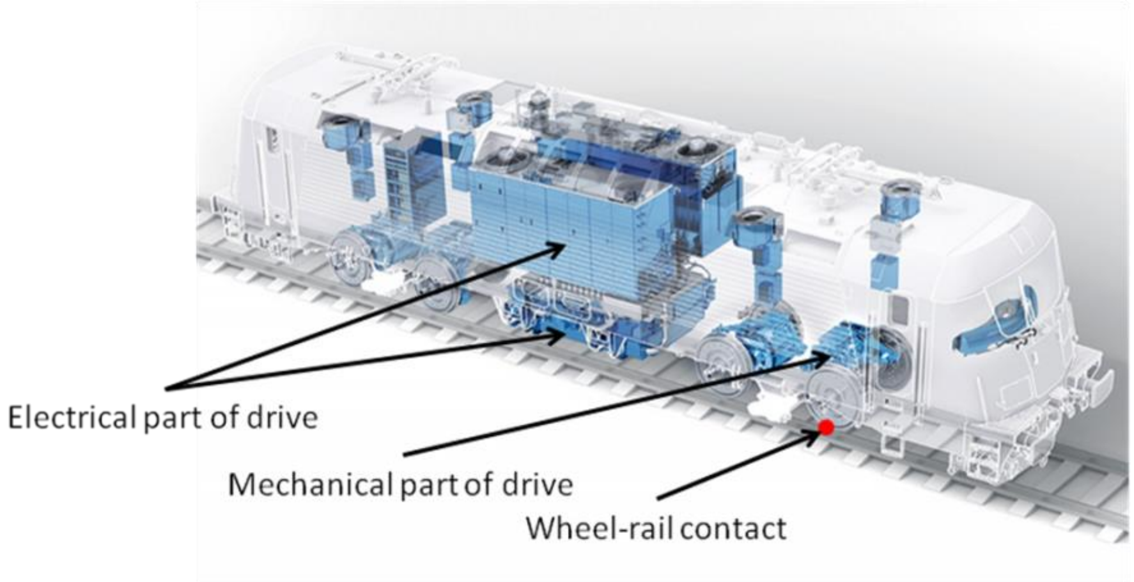
$$s = \frac{r_K \omega_K - v}{v}$$



Comparison of measured and calculated coefficient of adhesion [7]

Simulations - Torsion oscillation research

- Transition and electromechanical phenomena
  - Torsion dynamics and oscillation excited by harmonic components of the traction motor electromagnetic torque

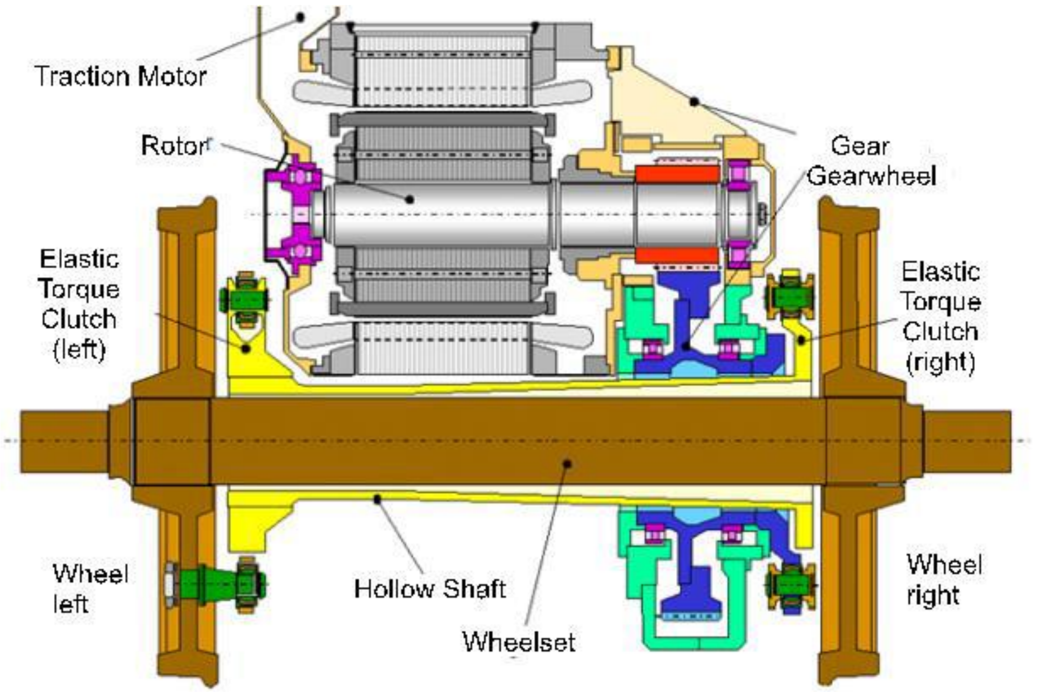


Visualization of fundamental model parts [9]

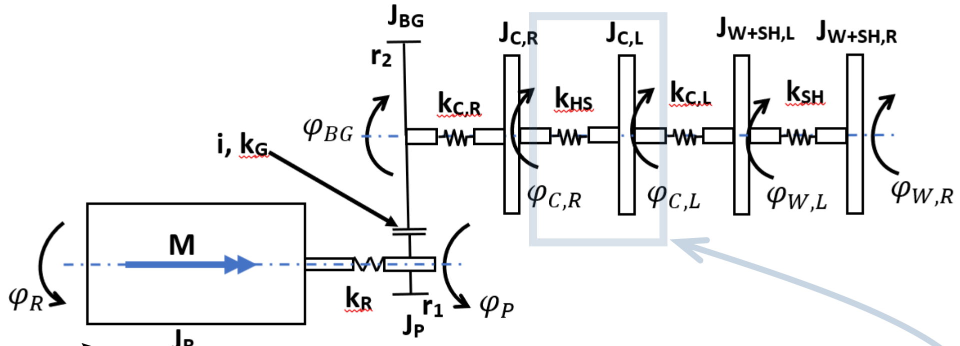
  - Fundamentals and function descriptions of the model as a whole were published in [6] [8] [9]

Simulations - Torsion oscillation research

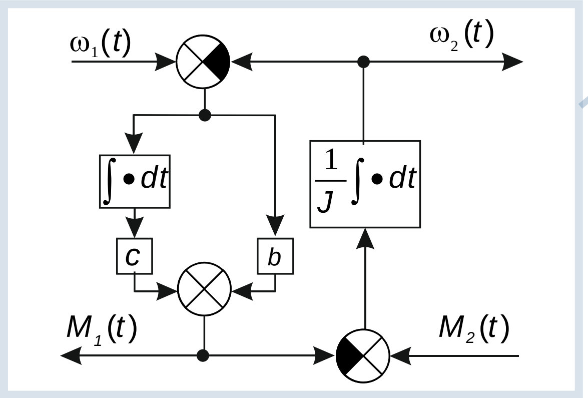
- Fully-sprung mechanical drive of a locomotive = mathematical (simulation) model



Locomotive fully-sprung drive - cross section [6]



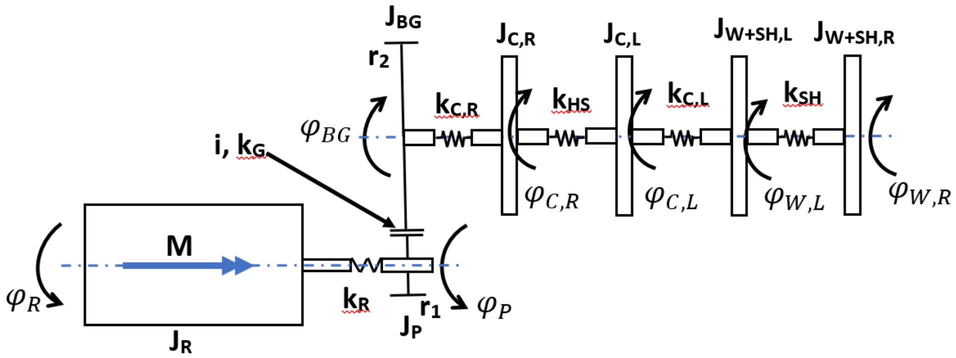
Schematic torsion system



Mass and spring mathematical representation [6]

Simulations - Torsion oscillation research

- Fully-sprung mechanical drive of a locomotive = mathematical (simulation) model

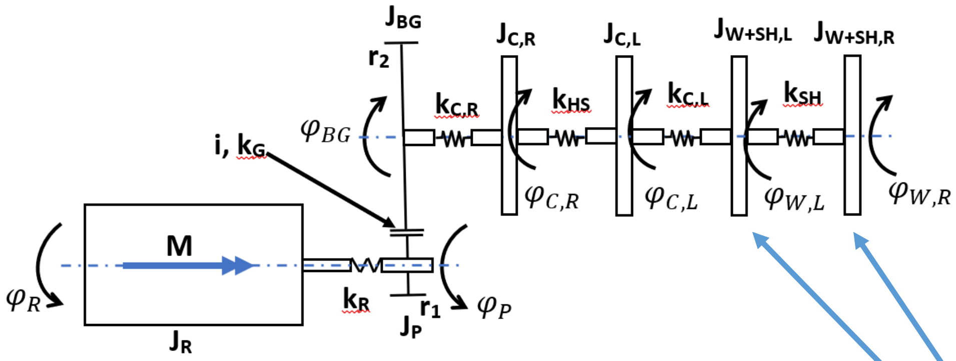


Schematic torsion system

- Natural frequencies
- Natura modes

Simulations - Torsion oscillation research

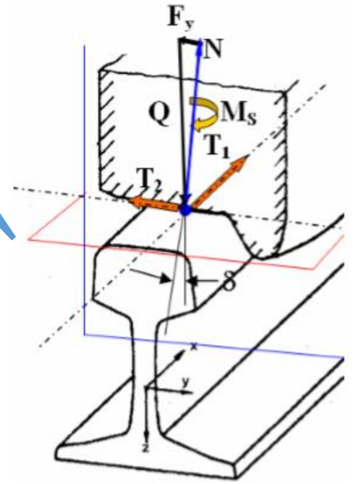
- Fully-sprung mechanical drive of a locomotive = mathematical (simulation) model



Schematic torsion system

- Natural frequencies
- Natura modes

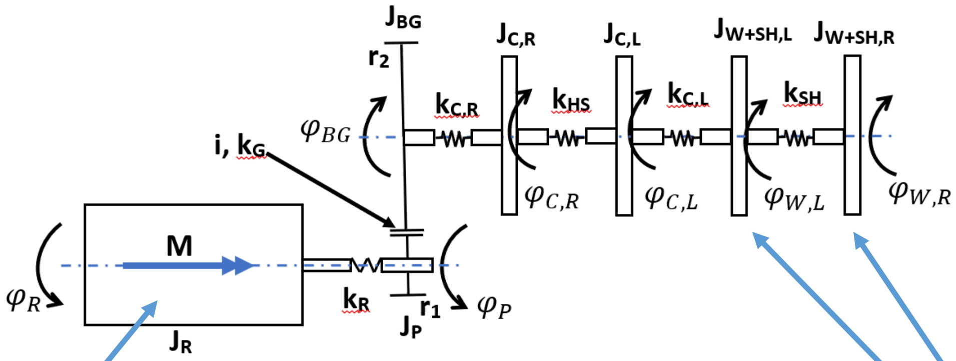
$$T_1 = Q\mu$$



Wheel-rail contact forces [6]

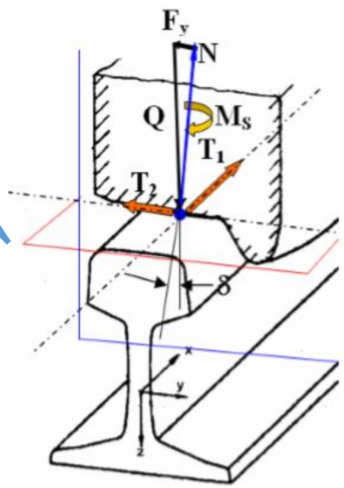
Simulations - Torsion oscillation research

- Fully-sprung mechanical drive of a locomotive = mathematical (simulation) model



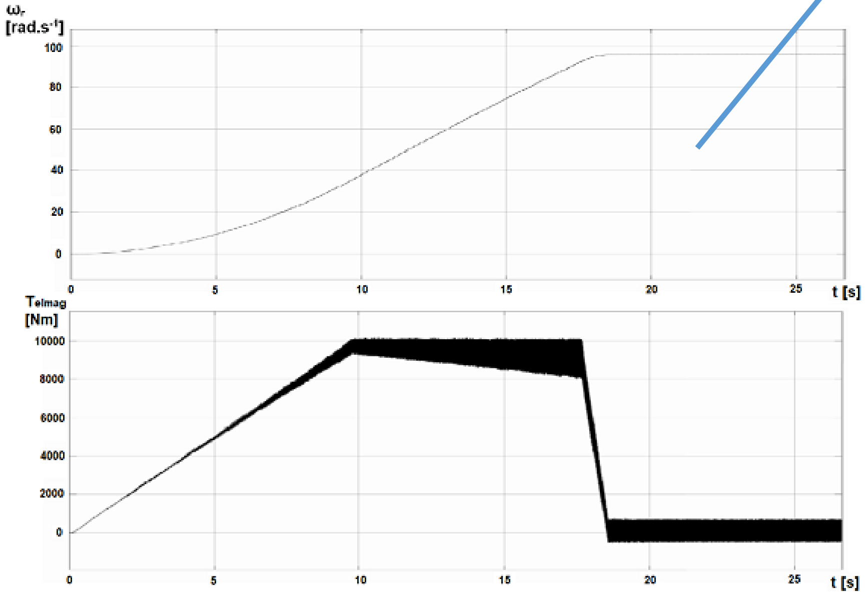
Schematic torsion system

$$T_1 = Q\mu$$



Wheel-rail contact forces [6]

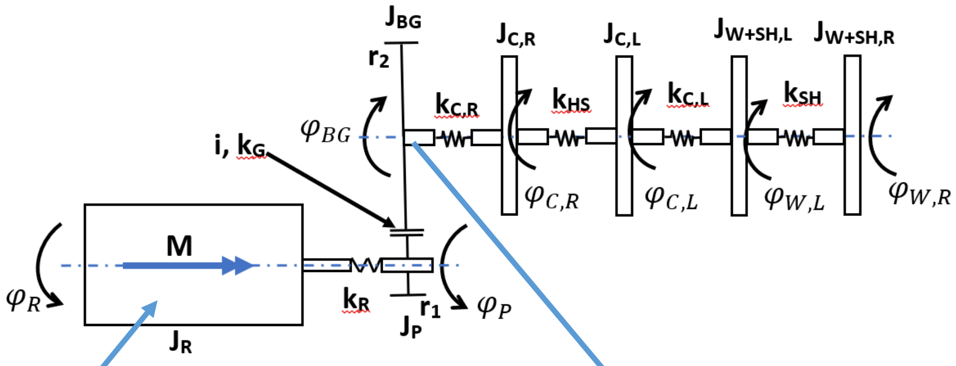
- Natural frequencies
  7th nat. freq. – 2401,1 Hz
- Natura modes



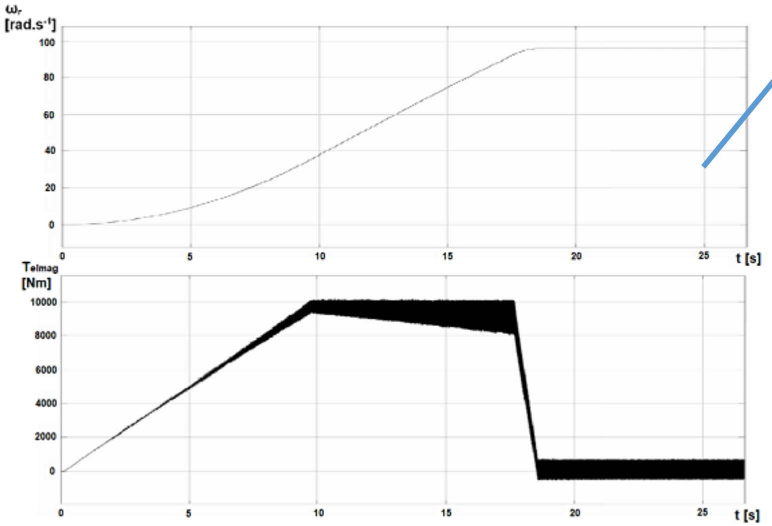
Rotor speed and rippled torque of asynchronous motor

Simulations - Torsion oscillation research

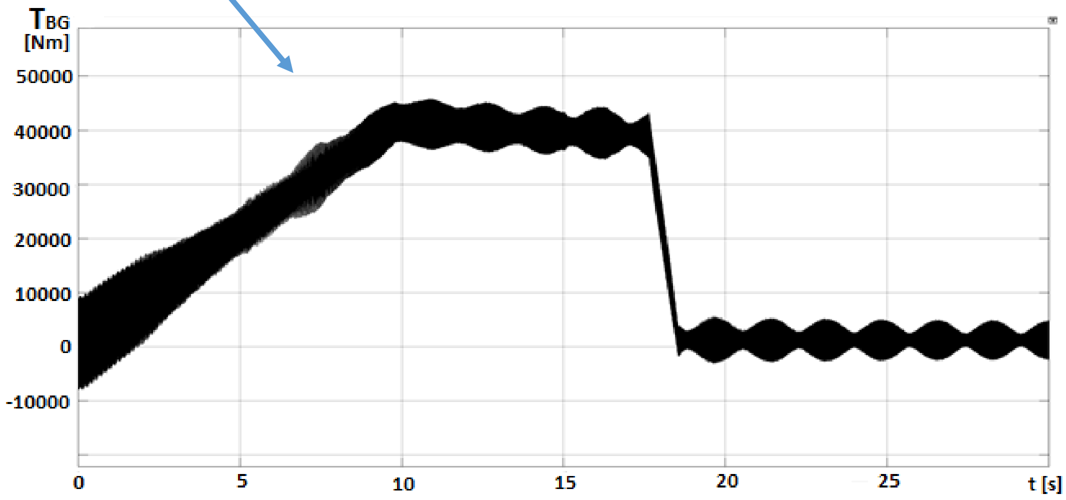
- Fully-sprung mechanical drive of a locomotive = mathematical (simulation) model



Schematic torsion system



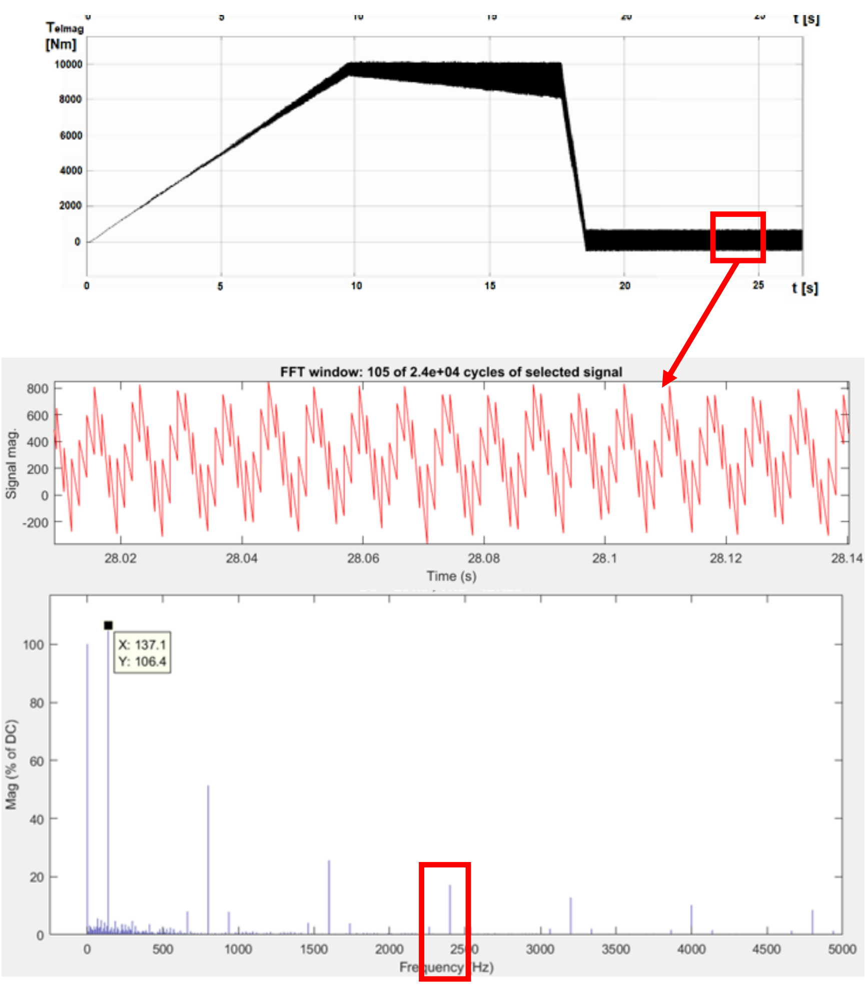
Rotor speed and rippled torque of asynchronous motor

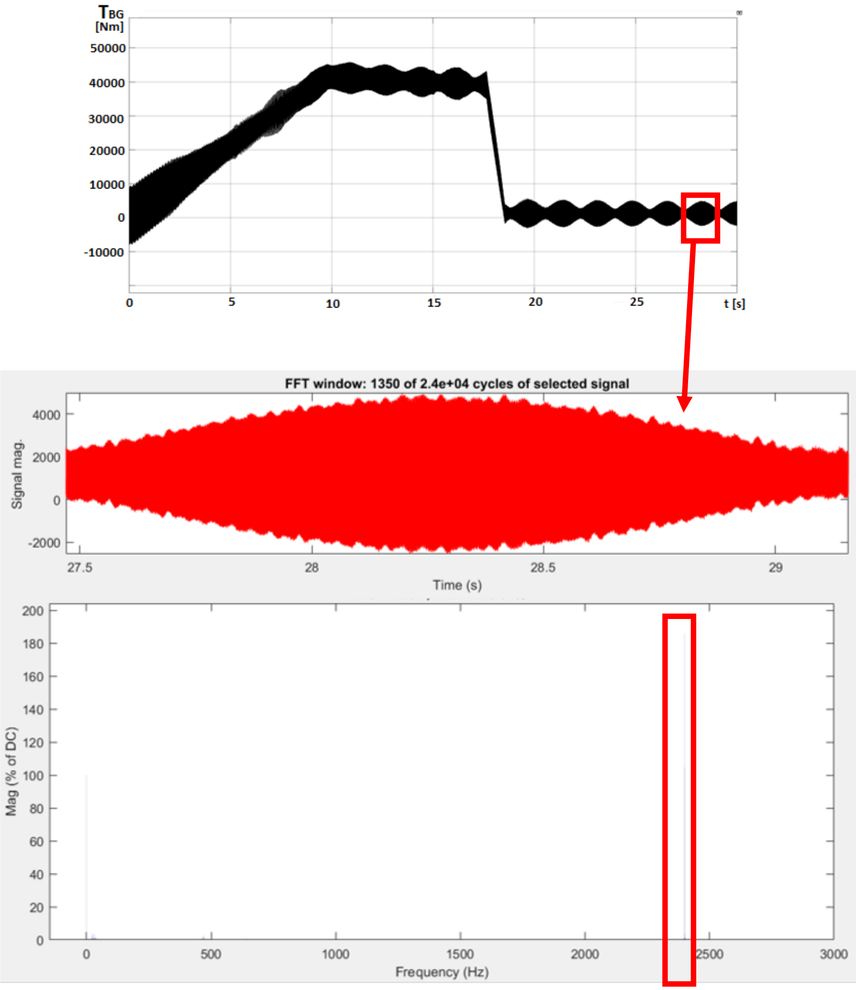


Course of gearwheel accelerating torque

Simulations - Torsion oscillation research

- Fully-sprung mechanical drive of a locomotive = mathematical (simulation) model





2400 Hz

2400 Hz – 105%
2401 Hz – 185%

Conclusion

- 1. The roller rig – tool enabling adhesion measurements, possibly torsion oscillation measurement
- 2. Simulations oriented towards torsion oscillations
  - Significantly high magnitudes can be observed (even in steady states, not only transition phenomena)
  - The problem is not the overloading with the respect to strength of components, but damage cumulation and its effect within lifetime of components
  - The research is oriented towards possibilities of the reduction of the oscillations

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Disclosure statement

The content of this contribution does not infringe any copyrights, patents, know-how of anybody else or rules of the grant provider.

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