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Radial self-steering bogies

Development, advantages and limitations

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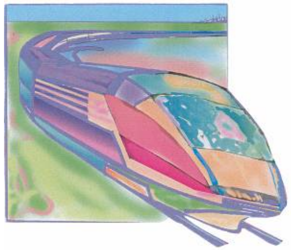

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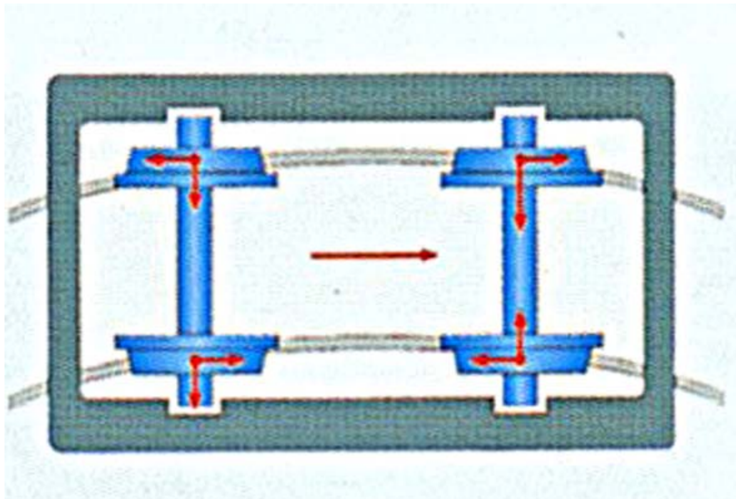
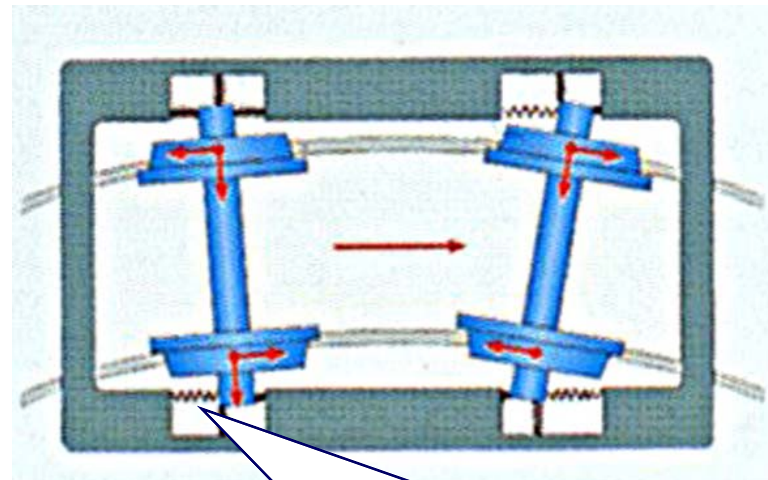
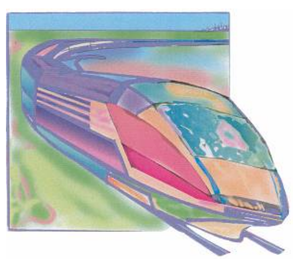
Wheelset guidance





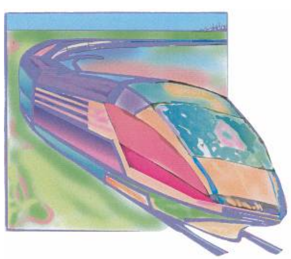
Flexible in longitudinal direction



- Angle of attack on leading wheelset
- Wheel and rail wear (in particular on dry conditions)
- Significant lateral wheel-rail forces (*Y*, *ΣY*)
- Risk of curving noise

Principles of radial self-steering bogies

- Same basic principle as for most two-axle freight wagons, i.e. the wheelsets steers themselves radially by means of conical wheels and wheel-rail friction.
- A soft or flexible wheelset guidance, in absence of adequate damping, will usually exhibit undamped lateral oscillations (instability or hunting) already at quite low speed (below 100 km/h). There is a certain conflict between curving ability (without wear, noise etc) and dynamic stability (i.e. absence of hunting).
- To achieve dynamic stability, damping is essential; in particular **yaw damping** between bogie and carbody (needed also for “stiff” bogies at higher speed).



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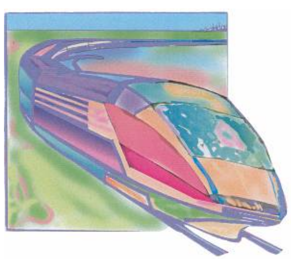
Passenger and commuter cars

375 cars

Radial self-steering bogies desired by the former Swedish State Railways (SJ) as a mean of **reducing excessive wheel and rail wear.**

Order placed with former ASEA (ABB -> Adtranz -> Bombardier).

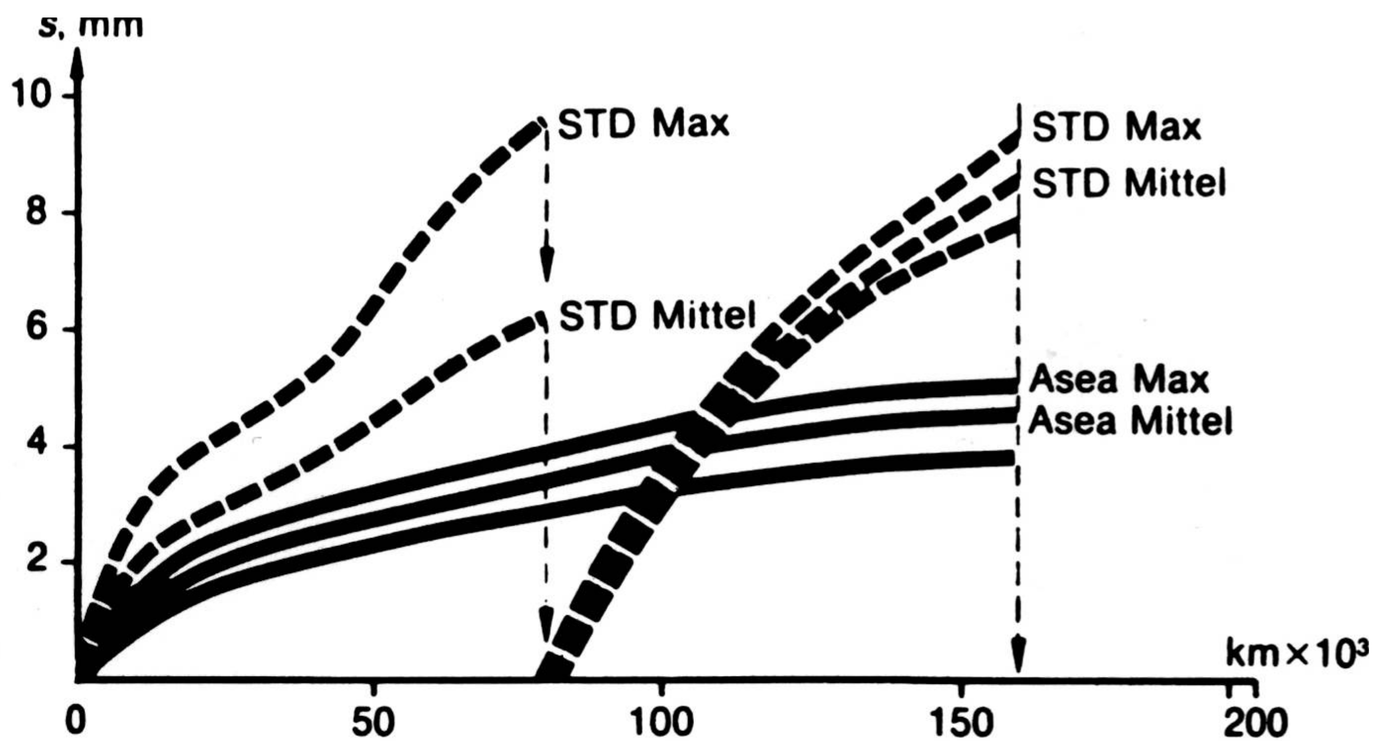
- From 1982 introduced on
  - passenger cars (160 km/h)
  - commuter cars (140-160 km/h); adhesion 15-17 %

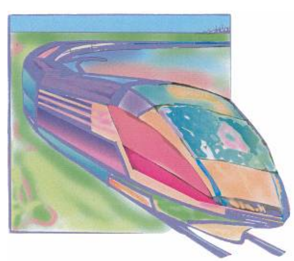


Wheel wear - example

Wheel flange wear for two types of bogies (April-Sep)

- **STD** = standard “stiff” bogies
- **Asea** = Radial steering bogies, as tested by SJ





Fast regional trains

458 cars (end of 2006)

- From 1999 introduced on motor coach trains
- - Oeresund Train Unit (180 km/h) (DK, SE)
- - *Flytoget, Signatur* & *Agenda* (210 km/h) (Norway)
- - *Regina* (180-200 km/h) (SE)

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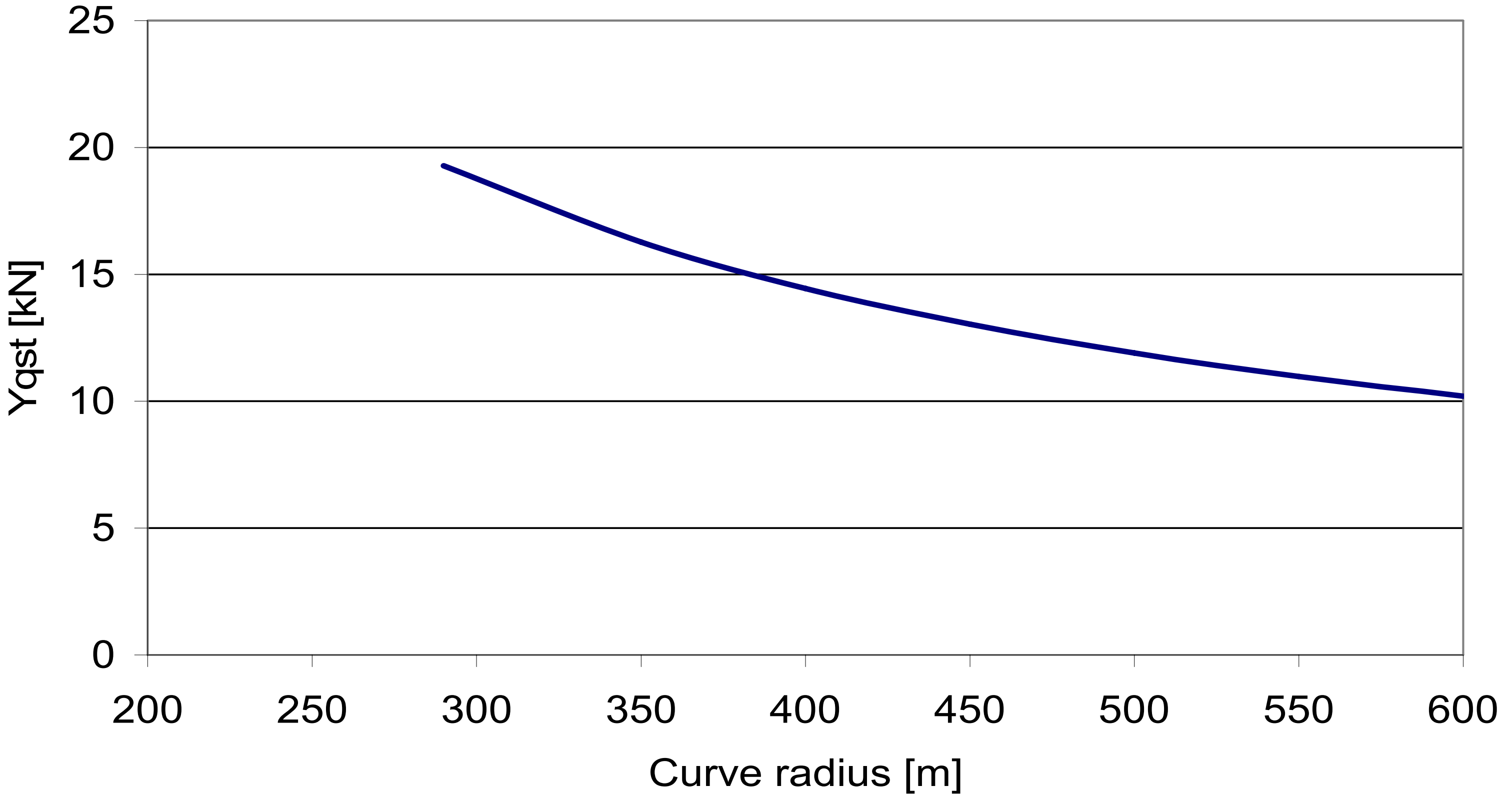
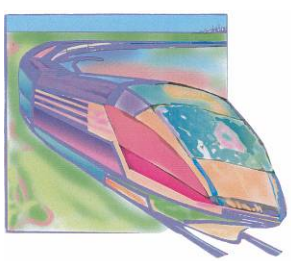
Lateral track forces – example





Lateral guiding force ΣY (50th percentile)
OTU on various tracks (Sweden and Denmark)

Track shift force ΣY_{qst} (99.85th percentile)
Signatur on curvy lines in Norway.

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High-speed tilting trains

230 cars and 44 power units

- From 1990 introduced on *X2000* tilting trains (200 km/h) in Sweden and China.

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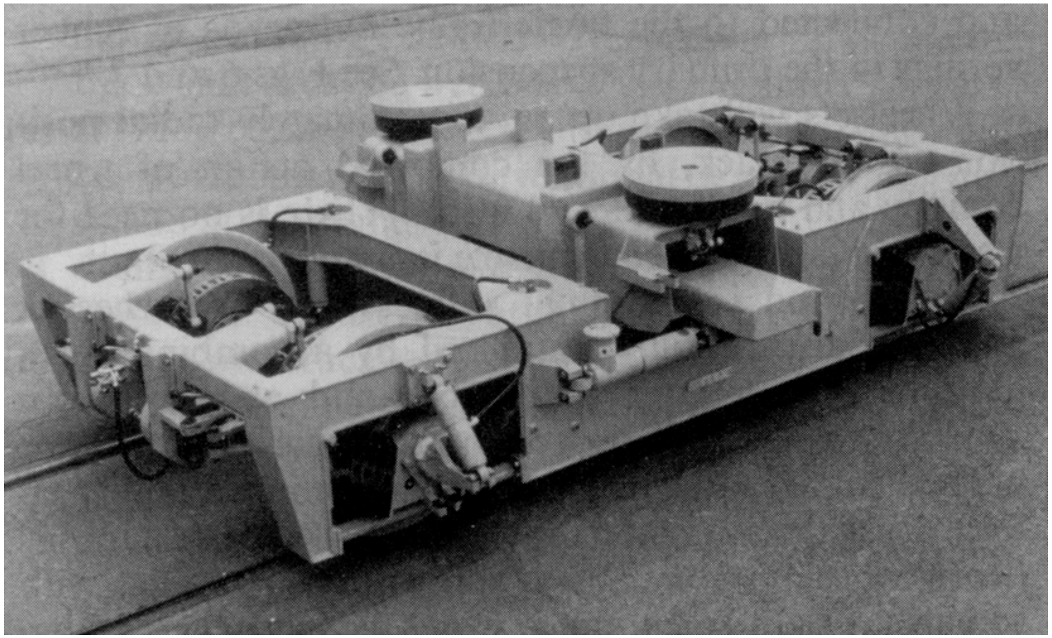
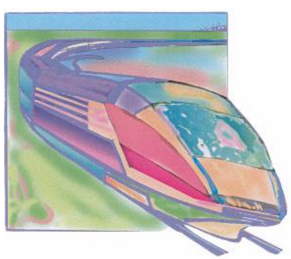
X 2000 tilting bogie



- Typically – at curving with lat acceleration $a_y = 1.85$ m/s^2 the maximum ΣY forces are at 70 % of UIC 518 limits.
- At curving with $a_y = 2.5$ m/s^2 the UIC criterion is still met on normal Swedish tracks.
- Running stability achieved with eq. conicity of 0.3-0.4 on track gauge 1430 mm.

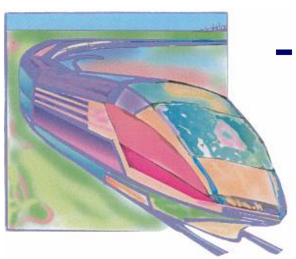


Development for higher speed

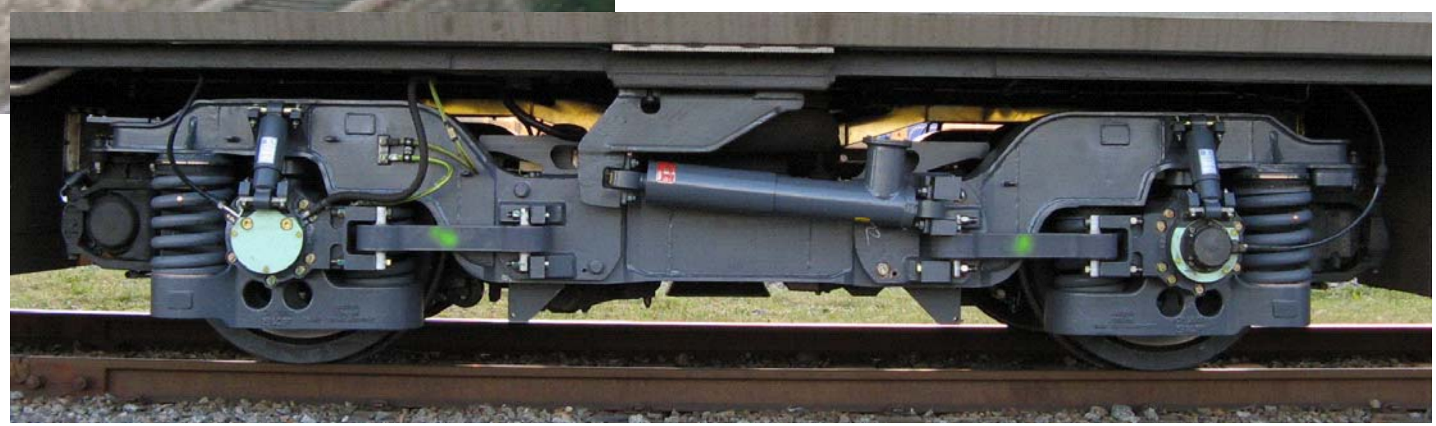
Green Train

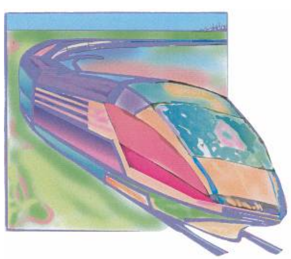
grönatåget

- A Swedish R&D programme aiming at a future generation of ”track-friendly” high-speed trains for Nordic conditions (low noise and energy, winter climate, non-perfect track etc)
- Joint development between Banverket (Swedish National Rail Administration), Bombardier, KTH, etc.
- Bombardier's test bench is a modified ”Regina” train – Regina 250.
- Started in 2005 – to continue until (at least) 2010 – 11.
- Radial steered bogies to be tested – passive and mechatronic.



Regina 250



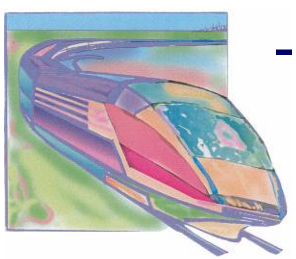


Development for higher speed

Green Train

grönatåget

- Radial self-steering bogies of different guiding stiffness – ”soft” and ”medium”- are tested in summer 2006.
- Tests by multi-body **simulation** as well as **on-track** with instrumented force-measuring wheels.
- Stability criteria on straight track are met (with margin) with both ”soft” and ”medium” settings of wheelset guidance, at test speeds up to 281 km/h and eq. conicity up to ~0.3.
- Lateral track forces are typically 50 – 65 % of UIC limit values.
- Theory and simulations agree and have been favourably validated with on-track tests.



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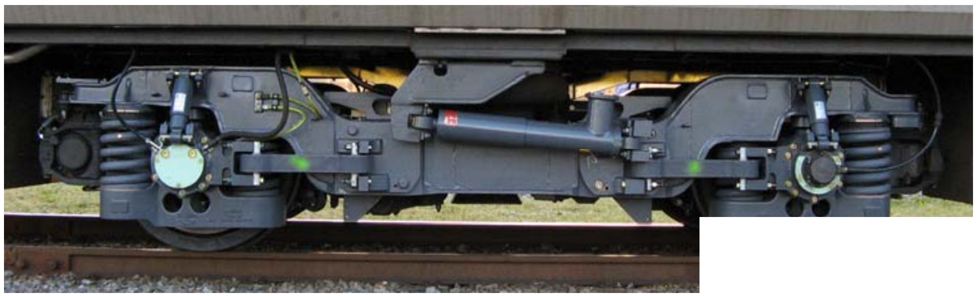
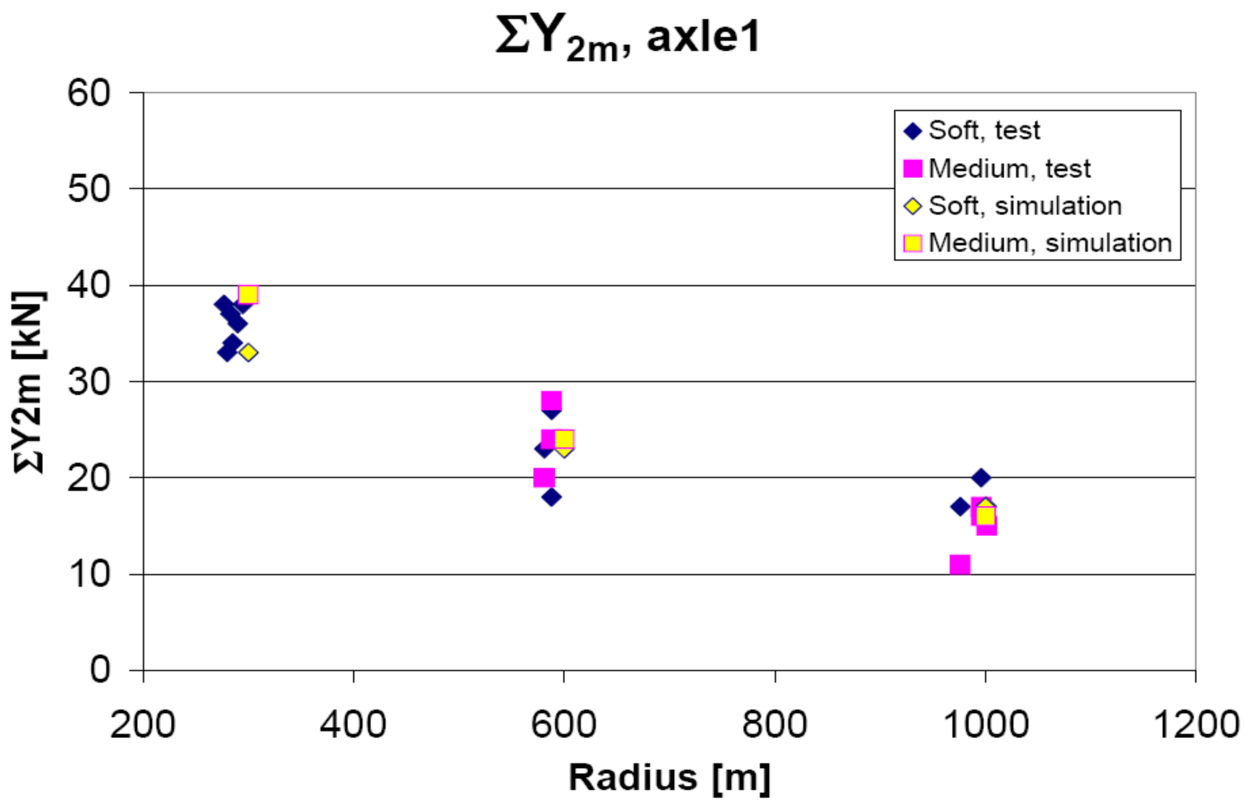
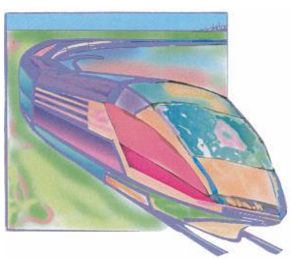
Regina 250



Measured and simulated track shift force



Cant deficiency ≈ 155-170 mm,
i.e. lat acceleration $a_q \approx 1.1\ m/s^2$



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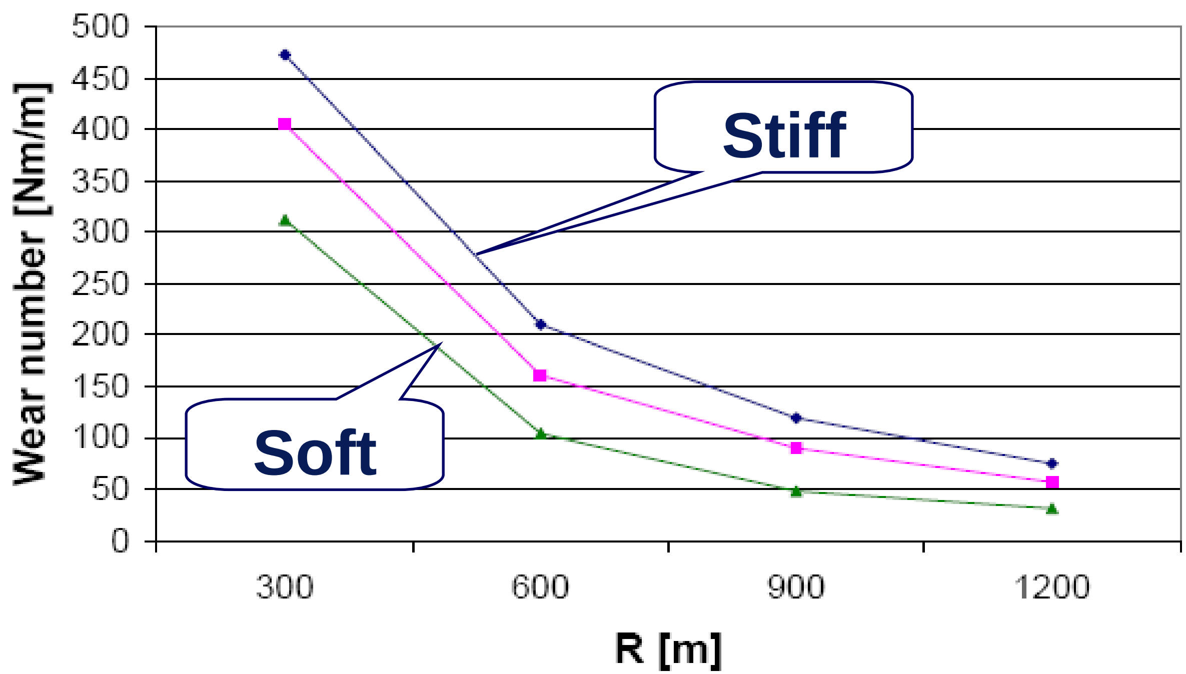
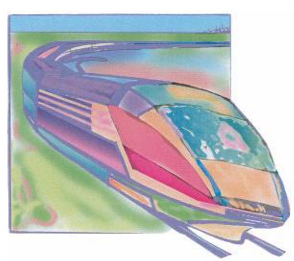
Development for higher speed and track friendliness

- Radial self-steering with optimum wheelset guidance and adequate yaw damping – to achieve both **stability at high speed** as well as a **low wheel and rail wear** on mainline Swedish track. ”Soft” settings give the lowest wheel and rail damage (wear and rolling contact fatigue).



Axle 1, Outer wheel



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Radial self-steering bogies
Advantages based on experience

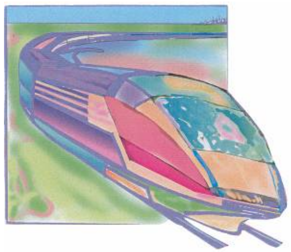
- State-of-the-art radial self-steering bogies are able to steer approx radially in curves of R= 400-600 m

  This is proved to heavily **reduce wheel and rail wear** in practical trains services in Scandinavia.

- Lateral track shift forces ***ΣY*** as well as guiding forces ***Y*** are also reduced. Important for possibility of high lateral curving acceleration.

- With appropriate damping (especially hydraulic yaw damping) **running stability** is assured at various values of eq. conicity. At the highest speeds (250 km/h + 10 %) **conicity** should be limited to **0.3 à 0.4** (UIC 518 requires 0.3).

- Testing and operational experience confirm theory and simulations.



Radial self-steering bogies

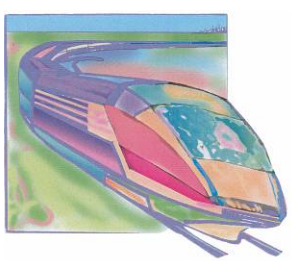
Limitations

- With maintained stability at high speed the wheelset guidance stiffness must not be very low => radial self-steering is **limited to** curve radii ***R* > 400 à 600 m** (depending on top speed).

  However, on many networks such curves are decisive for the total accumulated wheel and rail wear.

- High **tractive forces** may limit the radial steering capability, because radial self-steering is depending on a certain amount of friction (creep) forces. In high-adhesion locomotives radial self steering can not always be managed.

  In local/regional trains with adhesion utilization of 15 - 17 % the radial performance will be appropriate in practice, because high adhesion is only applied occasionally at acceleration at low speed.



Radial steering bogies

Future outlook

- **Marginal cost for track deterioration** should be included in the track access charges on a number of European railway networks. This sharpens the need for ”track-friendly” bogies.
- Ongoing development seems to widen the application of self-steering bogies to **higher speed** (250 km/h and up). Many high-speed trains will be running on various track standards at various speeds, in particular tilting trains.
- **Actively controlled radial steering** – ”Mechatronic bogies” - may be considered as an appropriate mean to achieve still higher performance and track-friendliness. Once active control is robust, fail-safe and affordable, such solutions may be very attractive.