

Improving Ride Comfort in Freight Wagons with Link Suspension Running Gear using Hydraulic Dampers

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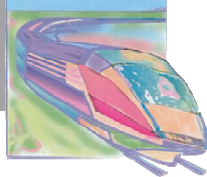
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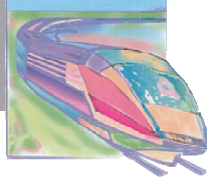
Outline

- Background
- Link Suspension Characteristics
- Running behaviour of standard two-axle freight wagons
- Improvement of running behaviour with hydraulic dampers
- Conclusions

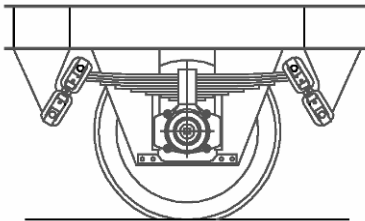


Background

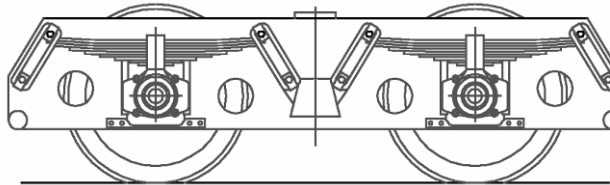
- This study is part of a research project in which the running behaviour of freight wagons is studied.
- The main goal is to make rail freight traffic more competitively.
 - improving ride qualities
 - increasing axle load
 - increasing speed
- Further we want to:
 - learn how freight wagons behave dynamically
 - reduce track deterioration



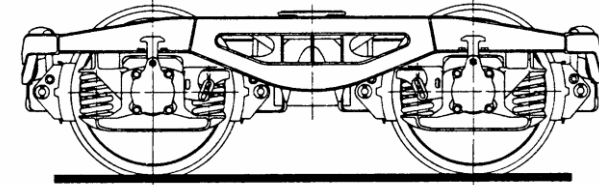
Background



**2-axle wagon
with link suspension**

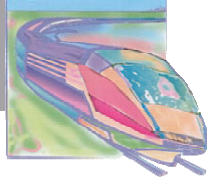


Link-bogie (G-type)



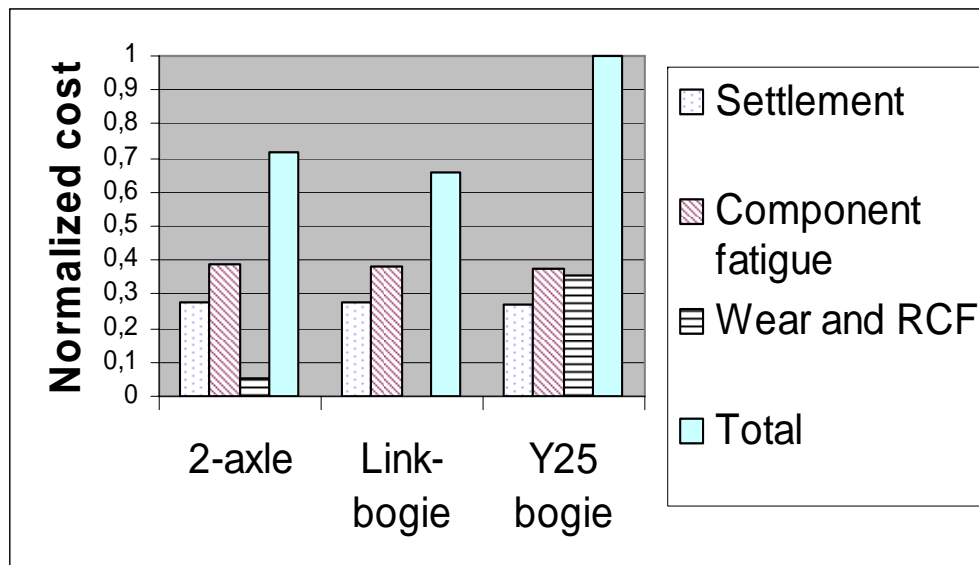
Y25-bogie

- Freight wagons in Europe use in general one of the three standardized families of running gear.
- Link suspension is the most common suspension design in Europe today. The principal design has existed for more than 150 years.



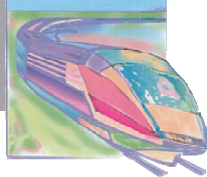
Background

- The quasistatic curving performance of freight wagons with link suspension is good:
⇒ Track-friendly in terms of wear and RCF.
- The running behaviour especially at higher speeds is moderate.



Normalized track deterioration cost / tonkm.

Comparison between standard running gear on a typical Swedish network for freight traffic.



Background

Impact of improved ride quality for freight traffic

- Track forces

⇒ Track forces and hence cost for maintenance due to track deterioration is reduced.

- Transport damage

⇒ Reduced cost for damage of the transported goods.

⇒ Reduced need for packing and lashing.

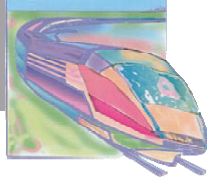
⇒ Attract market segments with high value goods.

- Increased speed

⇒ The average speed for passenger trains has increased considerably the last years and limitations in capacity on railway lines with mixed traffic start to arise.

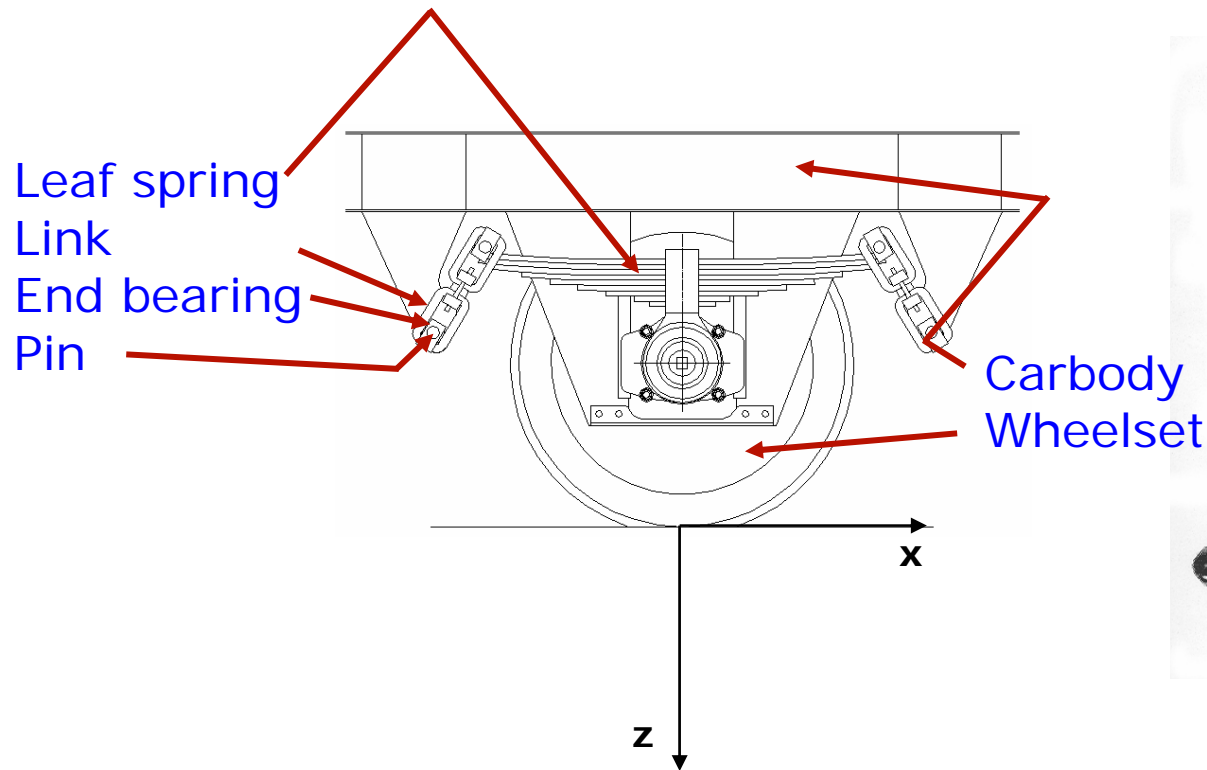
⇒ Increased utilisation of the rolling stock.

⇒ Increased distance for overnight transports.

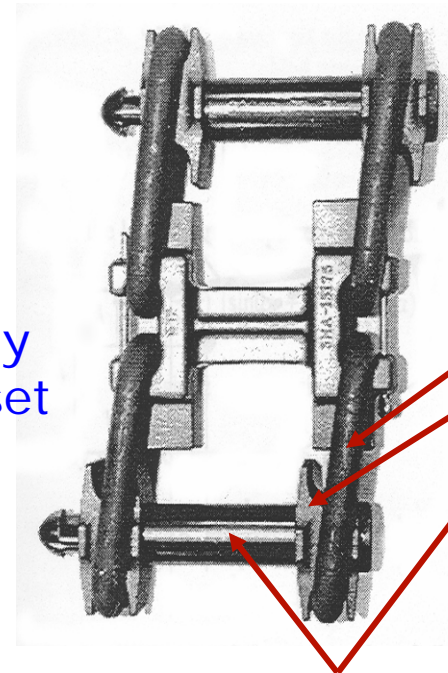


Link Suspension Characteristics

UIC double-link suspension

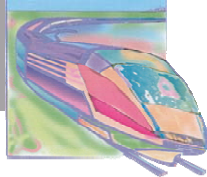


Example:
Lateral
displacement (y)



Link
End bearing
Pin

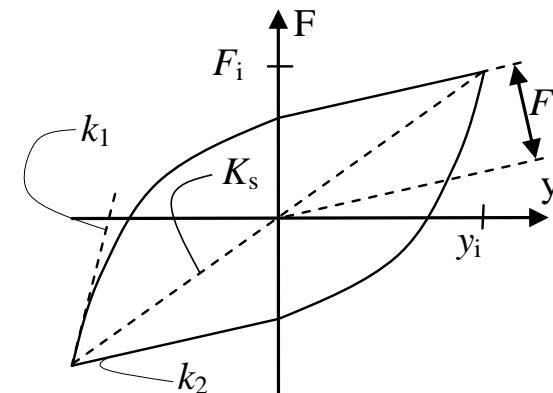
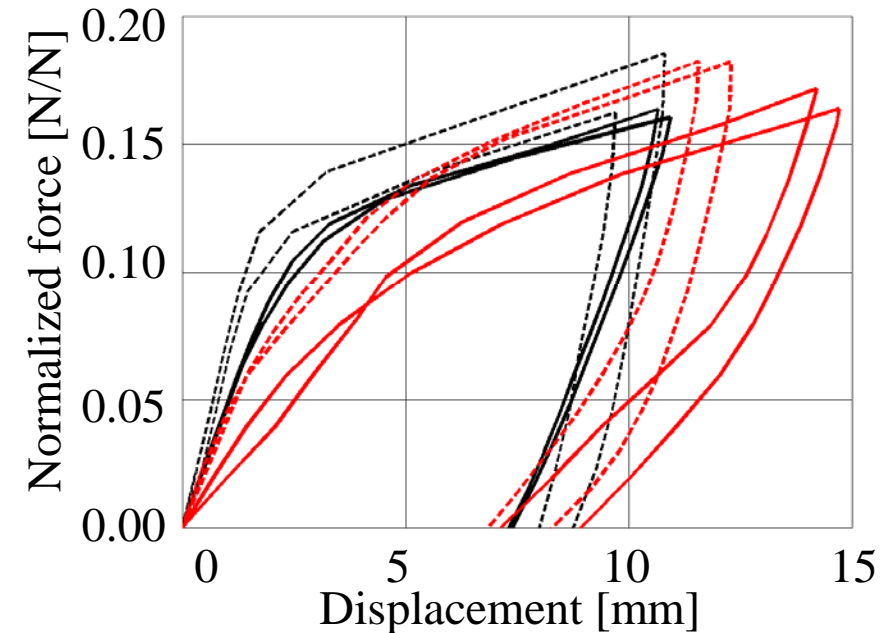
- Characteristics in the horizontal plane are mainly given by the properties of the suspension links, bearings and pins.

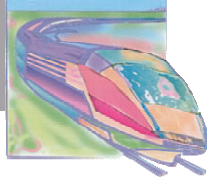


Link Suspension Characteristics

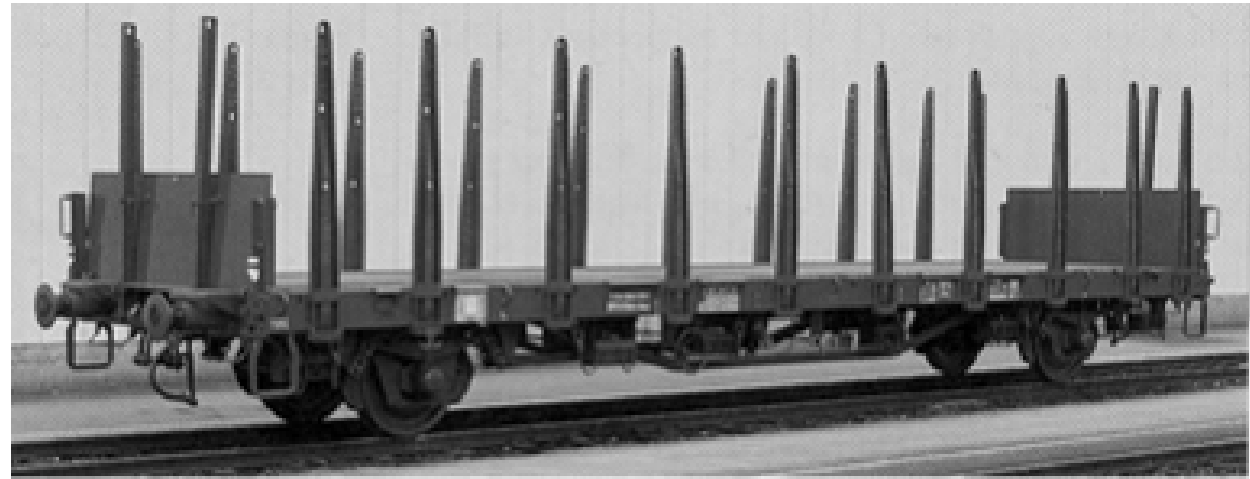
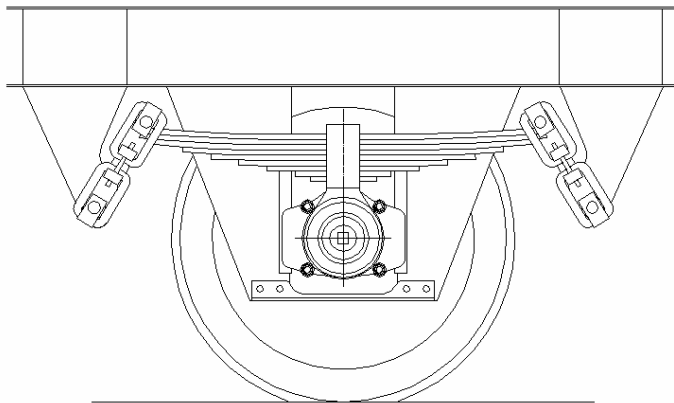
- The lateral and longitudinal characteristics are:
 - Non-linear
 - With considerable variation due to:
 - Manufacturing tolerances
 - Wear
 - Corrosion
 - Moisture or other lubrication

Example lateral link characteristics



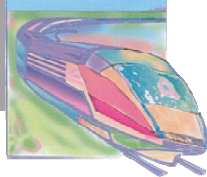


Running behaviour of standard two-axle freight wagons



Standard two-axle freight wagons
with leafspring and double-link
suspension.



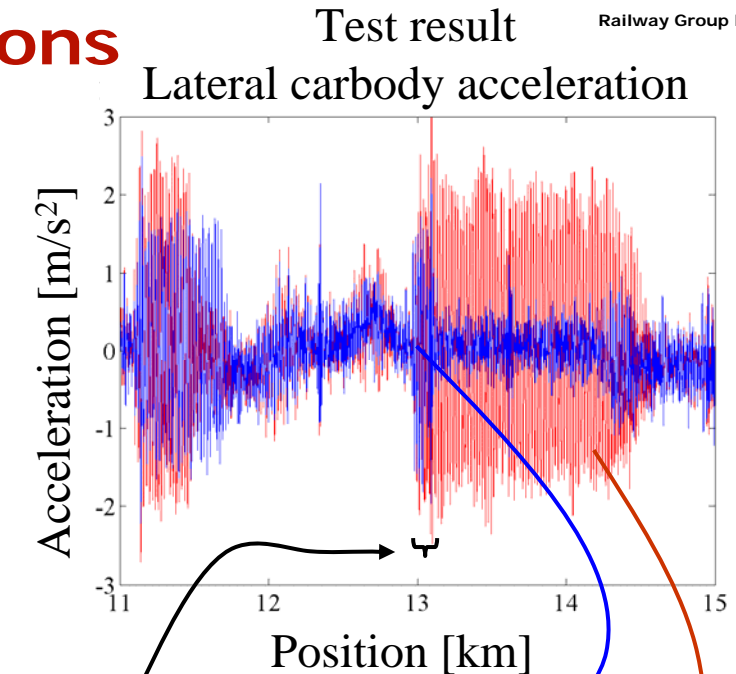


Running behaviour of standard two-axle freight wagons

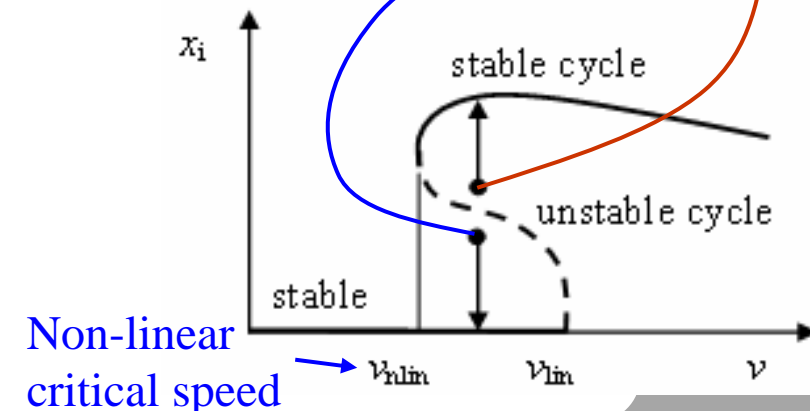
- Behaviour on tangent track.

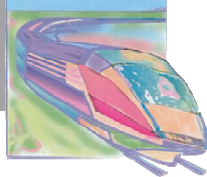
- Non-linear mechanical system.
- Can have coexisting stable attractors for a wide speed range at typical operational speeds.
- Large single track irregularities can change the behaviour from a violent hunting motion to just a reaction to track irregularities or the other way around.
- Can be very sensitive to small changes in initial conditions.

Example: Two repeated on-track tests at 100 km/h under similar surrounding conditions.



Section with large track irregularities.





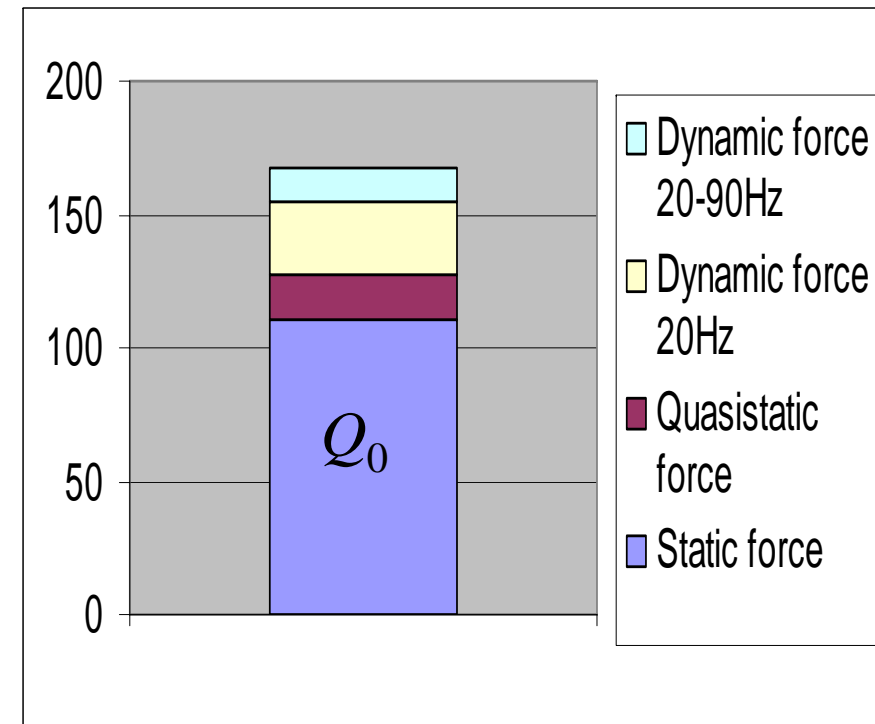
Improvement of running behaviour

- Hunting causes increased:
 - Ride discomfort.
 - Track-forces.
 - The dynamic contribution can typically be of the order:

$$Q_{d20 \text{ Hz}} \sim 0.25 \times Q_0$$

$$Q_{d20-90 \text{ Hz}} \sim 0.10 \times Q_0^*$$
- * Out of roundness not considered.

Vertical track force Q [kN].



Standard freight wagon -- 22.5 tonnes.



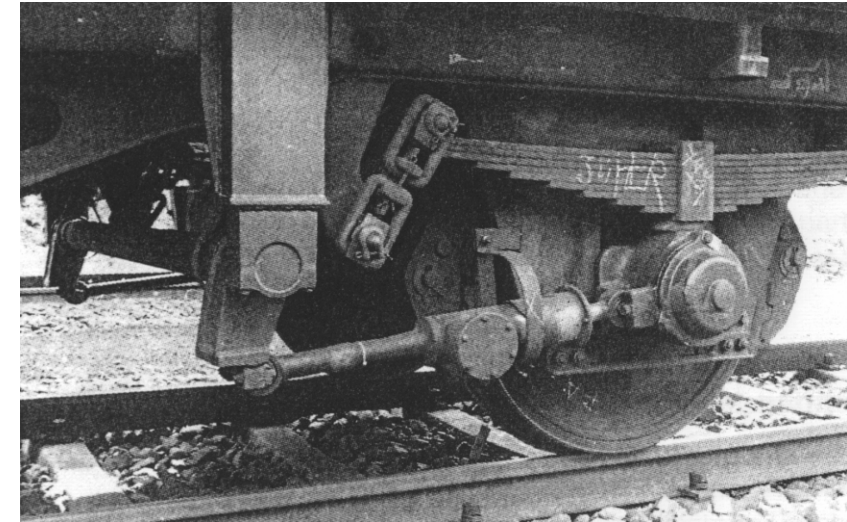
Improvement of running behaviour

- Improved standard running gear.

- High speed (160 km/h) mail service with two-axle freight wagons started in the beginning of the 1990s in continental Europe.
- The wagons have hydraulic yaw dampers.

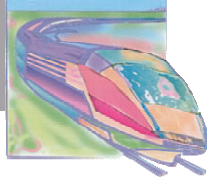
• However;

When these wagons were tested in Sweden the results were not satisfactory and another solution had to be chosen for the new mail service that was introduced in 2001.



Wagon used for
high speed mail
service in Sweden

160 km/h
20 tonnes axleload



Improvement of running behaviour

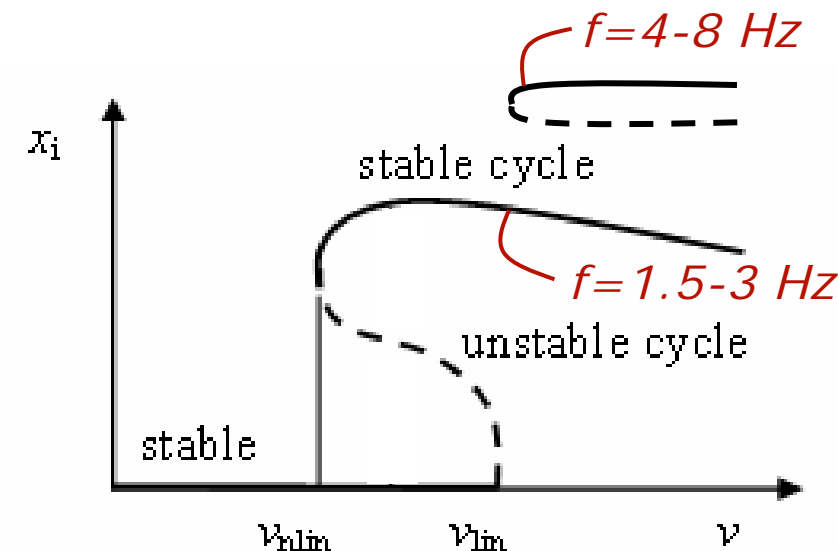
Investigations showed that reason for the non-satisfactory introduction of the continental system in Sweden were that there are for two-axle wagons two principally different hunting modes

- Wheelset hunting (typically 4-8 Hz).
- Carbody hunting (typically 1.5-3 Hz).

that can occur depending on

- Wheel/rail contact conditions
- Suspension characteristics
- Loading conditions
- ...

A combination of lateral and yaw dampers is needed in order to suppress both hunting modes for all types of variable conditions.





Improvement of running behaviour

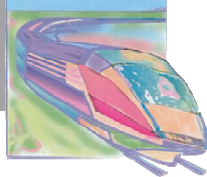
- On-track tests to investigate the dynamic performance.
 - Two-axle wagon Litt: Kbps⁷⁴¹
 - Bogie wagon Litt: Rs⁶⁹¹
 - Tare and at 18 tonnes axleload
 - Speed 100 – 170 km/h
 - Different supplementary damper configurations
 - Original wagon
 - Lateral dampers
 - Yaw dampers
 - Yaw + lateral dampers
 - 15 km long track section
 - Tangent sections and large radius curves
 - Track gauge 1433 – 1438 mm



Two-axle wagon Litt: Kbps⁷⁴¹



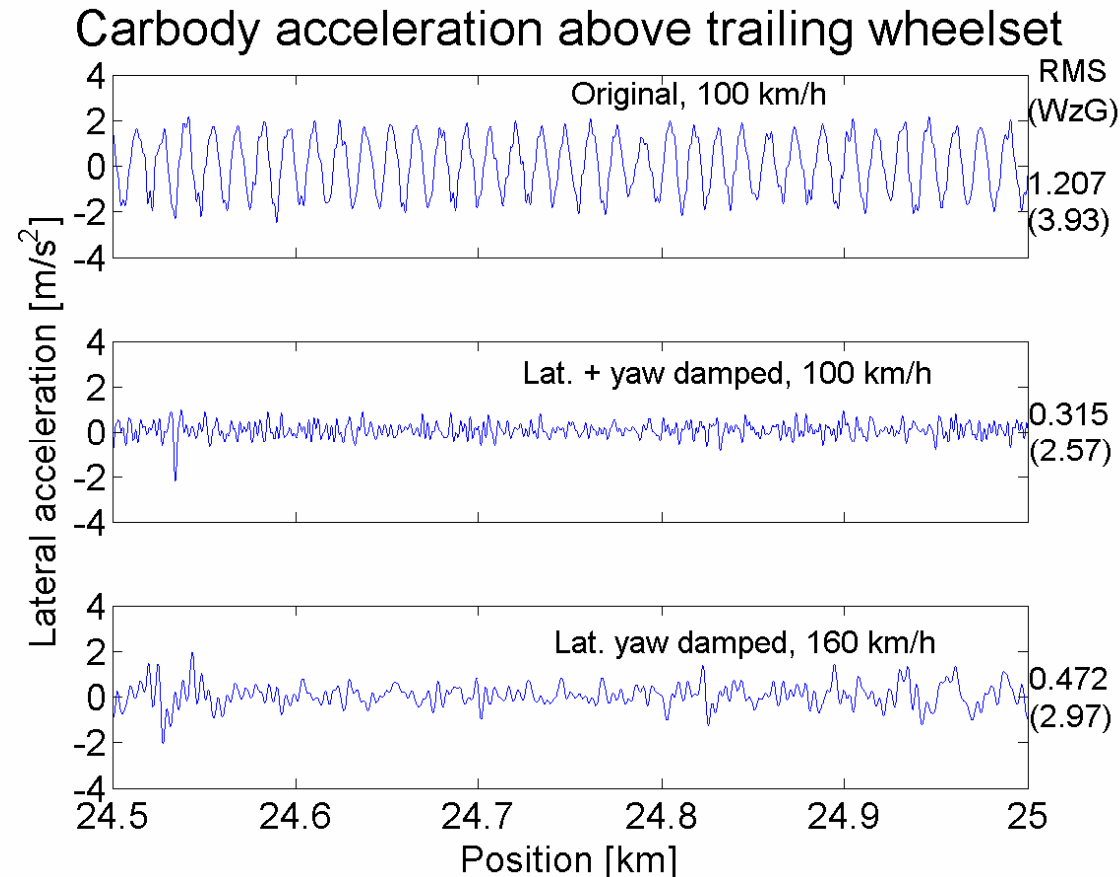
Bogie wagon Litt: Rs⁶⁹¹



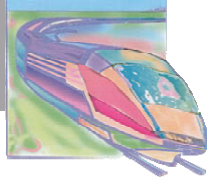
Improvement of running behaviour

- Typical test result

- Two-axle wagon Litt: Kbps⁷⁴¹
- Tare loading conditions
- Considerable reduction in acceleration level between original wagon and configuration with lateral and yaw dampers at 100 km/h.
- The ride comfort at 160 km/h is better than for the original configuration at 100 km/h.



500 m long tangent test section. Track gauge ~1434 mm.
The signals are low-pass filtered at 10 Hz.



Improvement of running behaviour

- Comparison test and simulation

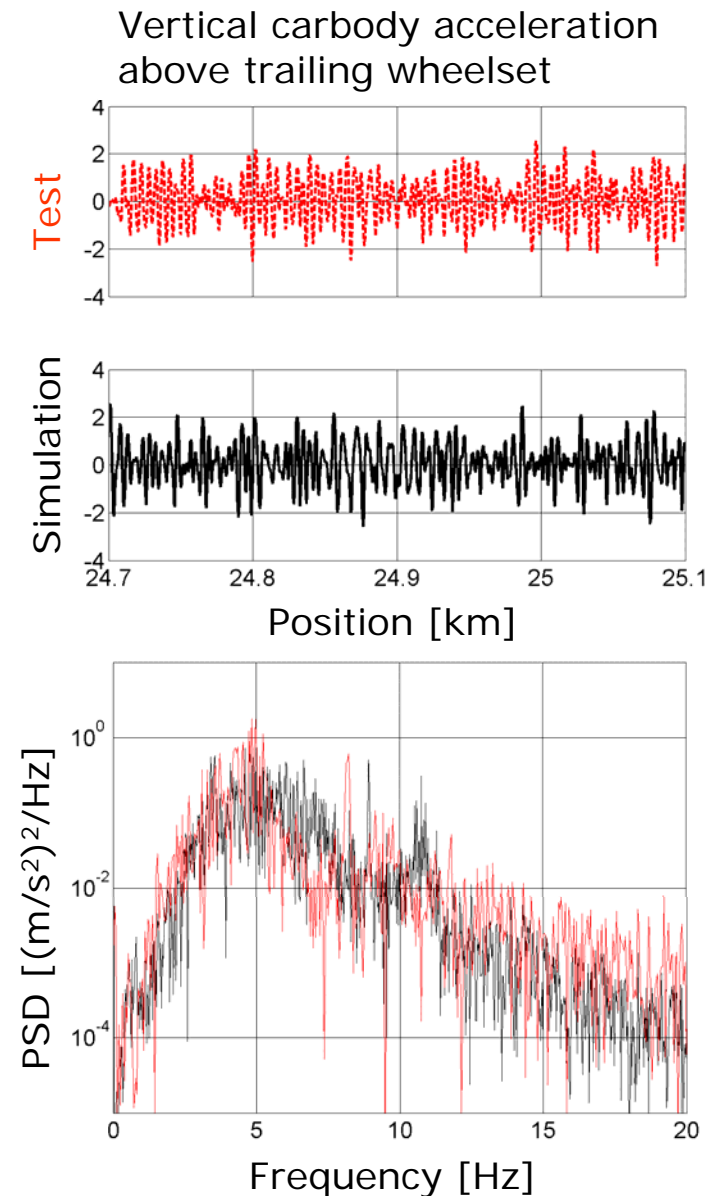
- Multibody dynamic simulation models are developed in software GENSYS.
 - Simulation models including non-linear suspension characteristics and carbody flexibility.
 - The models are verified by comparing test and simulation results.

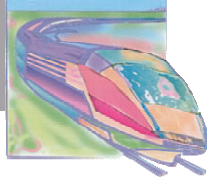
Two-axle wagon Litt: Kbps⁷⁴¹

18 tonnes axleload

- Test

- Simulation



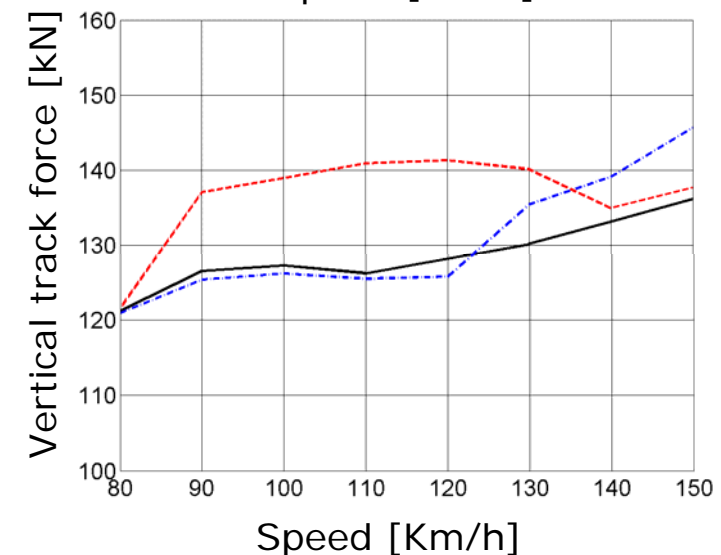
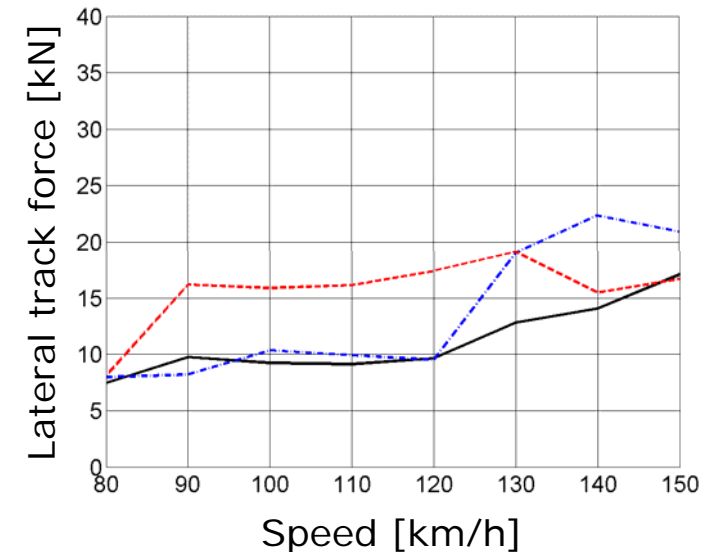


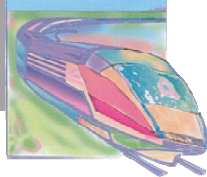
Improvement of running behaviour

- Simulated track forces
 - Original wagon
 - Yaw damper
 - Yaw + lateral damper
- When the ride comfort is improved the track forces are significantly reduced.
 - The vertical track forces Q are reduced with up till 10%
 - A substantial reduction as the cost for settlement and component fatigue is proportional to Q^3

S1002 wheel profile
BV50 rail profile with 1/30 inclination
1438 mm track gauge
 $\lambda_e = 0.06$ at ± 3 mm (UIC519)

Example simulation results





Conclusions

- The quasistatic curving performance for wagons with link suspension is very good.
- It is possible to substantially improve the ride qualities for freight wagons with link suspension.
- A combination of yaw and lateral dampers are needed to achieve satisfactory running behaviour for all wheel-rail contact conditions.
- The variation of the suspension characteristics is considerable. If the stiffnesses are too low the possible improvement by adding dampers is limited.