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Transmitted by the expert from Germany

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Endurance Braking – Reminder on meaning, purpose & suitable requirements

Structure

- Why Endurance Brakes?
- R13 Requirements
- Technical Solutions: Power-limited and Energy-limited
- Summary and Conclusion

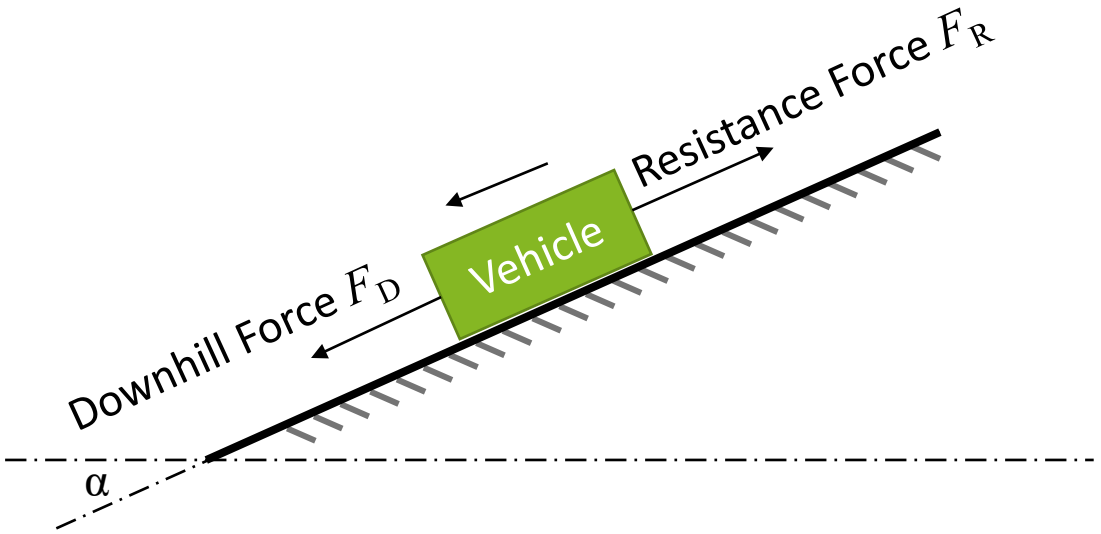
Why Endurance Brakes?

- In 1987, a tractor-semitrailer loaded with fuel lost brake performance and pneumatics near the town of Herborn, Hessen, Germany
- Image shows the molten remains of the tractor cab
- The accident lead to the introduction of endurance brakes into the regulatory framework

https://de.wikipedia.org/wiki/Gro%C3%9Fbrand_von_Herborn

Own image, taken at „Deutsche Arbeitsschutz-Ausstellung“ (Dortmund)

Why Endurance Brakes? (2)



- Trucks have a very high steady state downhill speed if unbraked
- $F_{\mathrm{D}} = m \cdot g \cdot \sin \alpha$
- $F_{\mathrm{R}} = \underbrace{\frac{\rho}{2} \cdot c_{\mathrm{w}} \cdot A \cdot v_{\mathrm{rel}}^2}_{\text{Air drag}} + \underbrace{f_R \cdot m \cdot g \cdot \cos \alpha}_{\text{Tire resistance \& bearing friction}}$

- Steady state downhill speed: $F_{\mathrm{D}} = F_{\mathrm{R}}$
- $m \cdot g \cdot (\sin \alpha - f_R \cdot \cos \alpha) = \frac{\rho}{2} \cdot c_{\mathrm{w}} \cdot A \cdot v_{\mathrm{rel}}^2$
- $v_{\mathrm{rel}} = \sqrt{\frac{m \cdot g \cdot (\sin \alpha - f_R \cdot \cos \alpha)}{\frac{\rho}{2} \cdot c_{\mathrm{w}} \cdot A}}$

Why Endurance Brakes? (3) – Some Numbers

- $v_{\mathrm{rel}} = \sqrt{\frac{m \cdot g \cdot (\sin \alpha - f_R \cdot \cos \alpha)}{\frac{\rho}{2} \cdot c_{\mathrm{W}} \cdot A}}$
- German Highways <= 7% slope → $\sin \alpha$ ~ 0.07, $\cos \alpha$ ~ 1
- f_{R} ~ 0.01
- ρ ~ 1.2 kg/m³
- c_{W} ~ 0.6 (Truck), ~ 0.3 (Passenger Car)
- A ~ 10 m² (Truck), ~ 3 m² (Passenger Car)
- m ~ 40.000 kg (Truck), ~ 2.500 kg (Passenger Car)
- **Steady State Speed for Passenger Car ~ 100 km/h, for Truck ~ 290 km/h**

Current Regulatory Text

5.1.2.4. Endurance braking system

The endurance braking system shall make it possible to maintain a constant downhill speed over a long period of time without the use of the friction brakes.

The following requirements only apply to vehicles specified in Annex 4 paragraph 1.8.1. These requirements are deemed satisfied if the relevant test requirements specified in Annex 4 paragraph 1.8. are met.

5.1.2.4.1. As an equivalent of a long period of time, a time duration of at least 12 min is deemed to be adequate.

5.1.2.4.2. During the time duration specified in paragraph 5.1.2.4.1. the endurance braking system shall be able to maintain an average speed of 30 km/h on a seven per cent down-gradient.

However, for vehicles in which the energy is absorbed by the braking action of the engine alone, the tolerance on the average speed, as specified in Annex 4 paragraph 1.8.2.3., shall be applied

Numeric Requirements for Endurance Brakes

- 5.1.2.4, maintain 30 km/h for 12 minutes on a 7% slope
- Height difference: 420 m
- **Energy** to be dissipated:
  - 44 tons GVW: ~50 kWh (~181 MJ)
  - 26 tons GVW: ~30 kWh (~107 MJ)
- **Power** to be dissipated:
  - 44 tons GVW: ~250 kW
  - 26 tons GVW: ~150 kW

Brake Temperatures on Disc Brakes

- Full brake event 90 km/h to 0 → kinetic energy ~4 kWh
- Own experience: 2-3 full brake events → > 160 °C
- Limit for disc brakes maybe 20 kWh?
- Friction brakes very good with power dissipation, but energy-limited
- Friction brakes not able to dissipate the full potential energy
- Trailers are only* equipped with friction brakes

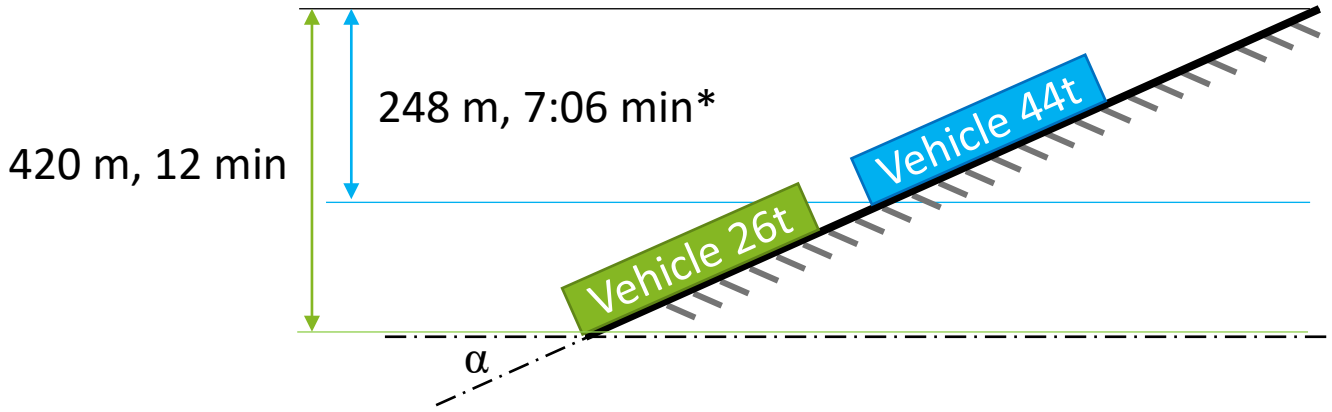
*: Trailers with electric propulsion might be able to recuperate

Technical Solutions for Endurance Brakes

- Engine Brake, limit: *engine coolant temperature (**power**)*
- Hydrodynamic retarder, limit: *retarder fluid temperature (**power**)*
- New: Recuperative brake, limit: *traction battery SoC (**energy**)*
- <u>All of those brakes act on the truck itself, not on the trailer</u>
- Conclusion: Motor vehicle has to dissipate or store the total potential energy of the vehicle combination.
- Consequence for energy-limited endurance brakes:
  - 7:06 minutes instead of 12 min fully laden+trailer
  - This does not fulfil the technical requirement of 5.1.2.4!

Summary and Conclusions

- There are energy-limited and power-limited endurance brakes
- Especially energy-limited endurance brakes are sensitive to vehicle combination weight vs. single vehicle weight
- From our perspective this adjustment to R13 is important



*Since everything is linear: 420 m·26 t/44 t
Additional: 420 m·26 t/64 t = 170 m, ~5 min