Determination of Aerodynamic Burden in Rail Tunnels using Measurements and Simulation

Dr. Johannes Rodler
Dr. Bernd Hagenah
Gruner GmbH, Wien (A)
Contents

> Scope of work
  > Approval of rolling stock
  > Pressure loads in rail way tunnel

> Guidelines
  > OEBB - requirements
  > TSI - Technical Specifications of Interoperability
  > EN14067 - rail way / aerodynamics

> Measurement 1:1 scale
  > Measurement site / setup
  > Measurement device

> Measurement results

> Calculation results

> Conclusion
Pressure Variations in Railway Tunnels

\[ v_{tr} = 230 \text{ km/h} \quad L_{tr} = 400 \text{ m} \]

![Graph showing pressure variations over distance and time for railway tunnels with specified speeds and lengths.](image-url)
Impact of Pressure Variations in Tunnel

> Pressure load on infrastructure
  > Built in Components
  > Equipment e.g. Doors / Dampers

> Pressure load on trains
  > Railcar Body, Windows, Doors
  ⇒ special attention in mixed traffic situations

> Passengers
  > ⇒ individual perception!
  > comfort criteria (max. pressure variations in a given time interval)

> Sonic boom

part of energy is emitted at the portal in form of a micro pressure wave
Guidelines

> UIC - International Union of Railways
  > UIC - Codex 779-11 - Determination of railway tunnel cross-sectional areas on the basis of aerodynamic considerations ⇒ comfort criteria

> ÖBB-Infrastruktur - Anforderungskatalog an Triebfahrzeuge für die Zulassung im Netz der OEBB
  > Impact on the oncoming or overtaking train
  > vtr > 160 km/h ⇒ evidence of conformity

> TSI SRT (2008)
  > technical specifications of interoperability relating to safety in railway tunnels ⇒ aerodynamic criteria

> EN 14067 Bahnanwendungen - Aerodynamik
  > Teil 3: Aerodynamik im Tunnel
  > Teil 5: Anforderungen und Prüfverfahren für Aerodynamik im Tunnel
Aerodynamic Criterion / Pressure Signature

\[ \Delta p_N \]  \quad \text{frontal wave of the train nose entering the tunnel}

\[ \Delta p_{fr} \]  \quad \text{tunnel passage (friction)}

\[ \Delta p_T \]  \quad \text{rear wave generated by train tail entering the tunnel}

\[ \Delta p_{Hp} \]  \quad \text{passage of the train nose}
### Characteristic Limits

Requirements for an interoperable train passing through a tunnel tube at a speed of $v_{tr} < 250$ km/h

<table>
<thead>
<tr>
<th>Train type</th>
<th>Reference case</th>
<th>Criteria of the reference case</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$v_{tr}$ [km/h]</td>
<td>$A_{tu}$ [m²]</td>
</tr>
<tr>
<td>$v_{tr, \text{max}} &lt; 250$ km/h</td>
<td>200</td>
<td>53,6</td>
</tr>
<tr>
<td>$v_{tr, \text{max}} \leq 250$ km/h</td>
<td>250</td>
<td>63,0</td>
</tr>
</tbody>
</table>
The authorization of new rolling stock on Austrian railway sections demands investigations on:

- Aerodynamic characteristics (TSI - pressure signature)
- Pressure drop during cross passage of the train nose
- Safeguard on field service personnel against aerodynamic impact
- Aerodynamic impact on passengers on the platforms

Extensive measurements were carried out from 26th to 29th of August 2011 on "Westbahn" line.
KISS WESTbahn / Measurements on the platform

Graz, 23. / 24. April 2012

- > 150 m
- 90 m
- > 20 m
- 90 m

Meteorologie

Luftgeschwindigkeit

Luftgeschwindigkeit

Trigger

Trigger
KISS WESTbahn / Measurements near the track
### KISS WESTbahn / Measurements in the Tunnel

<table>
<thead>
<tr>
<th>Tunnelabschnitt</th>
<th>Länge [m]</th>
<th>Querschnitt [m²]</th>
<th>Wandreibung $\lambda$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melker Tunnel</td>
<td>1845</td>
<td>78</td>
<td>0.02</td>
</tr>
</tbody>
</table>
Measurements / Measurement Site (550 m from Portal)

USA

Druckmessplatte

Trigger

DAQ
Pressure Measurement

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured area</td>
<td>-6895 to +6895 Pa</td>
</tr>
<tr>
<td>Maximal error</td>
<td>0.33 %</td>
</tr>
<tr>
<td>Resonance frequency</td>
<td>70 kHz</td>
</tr>
</tbody>
</table>

Sample Rate 300 Hz!
Measurements / Measurement started with Trigger
Measurement Results

$198.9 \text{ km/h} \geq v_{\text{train}} \geq 201.6 \text{ km/h}$

$v_{\text{wind}} \geq 3.5 \text{ m/s}$

$v_{\text{wind}} \leq 1.2 \text{ m/s}$
Calculation with ThermoTun

ThermoTun is a computer programme by Prof. Vardy accepted worldwide for the simulation of trains in tunnels and of tunnel systems.

The correctness is confirmed by extended measurement campaigns.

The following, aerodynamically relevant, unsteady values can be determined (among others):

- Pressure variations of trains passing tunnels and on rolling stocks,
- Traction power requirements for trains in railway tunnels,
- Averaged air speed in the railway tunnel tube,
- Distribution and concentration of pollutants and smoke in railway tunnels.
Calculation Results
Calculation Results

Calculation for $A_{\text{Tunnel}} = 53.6 \text{ m}^2$

- $\Delta p_N = 1.34 \text{ kPa}$
- $\Delta p_N = 1.03 \text{ kPa}$
- $\Delta p_N = 0.76 \text{ kPa}$
## Calculation Results

<table>
<thead>
<tr>
<th>Source of pressure drop</th>
<th>reference</th>
<th>actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frontal wave $\Delta p_N$</td>
<td>1.7 kPa</td>
<td>1.34 kPa</td>
</tr>
<tr>
<td>Tunnel passage (friction) $\Delta p_{Fr}$</td>
<td></td>
<td>1.03 kPa</td>
</tr>
<tr>
<td>Rear wave $\Delta p_T$</td>
<td></td>
<td>0.76 kPa</td>
</tr>
<tr>
<td>Sum $\Delta p_N + \Delta p_{Fr} + \Delta p_T$</td>
<td>3.7 kPa</td>
<td>3.13 kPa</td>
</tr>
</tbody>
</table>
Summary

> The approval of new rolling stock demands 1:1 scale measurements of the pressure loads in railway tunnels
> The requirements for an interoperable train passing through a tunnel tube are given for specific cross-sectional areas
> Calculation of the pressure loads with simulation software (validation based on measurements) are accepted
> The approval of the new STADLER KISS WESTbahn in the Austrian rail network were carried out based on extensive 1:1 scale measurements
> The simulation of pressure loads for specific cross-sectional areas were done with TermoTun software
Determination of Aerodynamic Burden in Rail Tunnels using Measurements and Simulation by Gruner

Thank you for your attention!