Tire-Road Noise

- Basics and an outlook to further reductions of road traffic noise

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AGENDA

- Introduction - Goodyear Innovation Center Luxembourg
- The Balanced Tire Approach
- The Tire’s Regulatory Landscape
- Tire/Road Noise Generation Mechanisms
- Tire and Road Influence on Noise
- Tire Sound Power Measurement
- Tire/road noise trade-offs - Examples
- Future Reduction of Road Traffic Noise
Goodyear Innovation Center Luxembourg

Goodyear in Luxembourg: 3,000+ associates & 50+ nationalities
Goodyear Dunlop Tires

Passenger Car / SUV Tires
- Summer
- Winter
- All Season

Light Truck Tires
- Summer
- Winter
- All Season

Radial Medium Truck Tires
- Steer
- Drive
- Trailer
- Summer/Winter/OTR

Goodyear Innovation Center in Luxembourg supports the product development for Europe, Middle East & Africa (EMEA) and Asia Pacific
The Balanced Tire Approach

• Goodyear Dunlop’s development goal is a **balanced tire** with a strong focus on **safety**-related criteria

• 3-15-50 performances
  – 3 performances on the EU tire label
  – Up to 15 criteria analyzed by automotive clubs and specialized magazines
  – 50+ tires performances considered in the tire development

• Trade-Off: Improving one performance can lead to decreasing another performance.

• Tire development considers 50+ tire performances
• Need for balanced tire performances
• Optimized performances in function of vehicle, road & weather conditions
The Tire’s Regulatory Landscape

**Regulation 661/2009**
- Min requirements for wet grip
- Max. allowed rolling resistance
- Max. Allowed external noise
- Mandatory Tire Pressure Monitoring System (TPMS) for cars

**Regulation 1222/2009**
Tire Labeling
- Information on:
  - Rolling resistance
  - Wet grip
  - External noise

Other laws:
- Chemical rules (REACH)
- Emissions from manufacturing
- Energy Efficiency
- ...

- EU tire regulation combines two key aspects:
  - ✓ environmental performances (rolling resistance and noise)
  - ✓ safety (wet grip)
Tire Regulation 661/2009
Noise Requirements

- Noise limits dependent on tire width
- Significant noise reductions over last decades due to demanding regulation
- Progressive implementation of Noise, Wet Grip and Rolling Resistance limits until 2020

+ new Rolling Resistance limits (Nov. 2016)
+ new Rolling Resistance (Nov. 2016)
+ Wet Grip limits (Nov. 2016)
Two Regulations Linked to Tire/Road Noise

**Tire Noise**
Reg. (EC) No 661/2009
- 80 km/h coast-by (C1&2)
- 70 km/h coast-by (C3)
- engine off and neutral gear

**Vehicle Noise**
Reg. (EC) No 540/2014
- 50 km/h
- constant speed test
- acceleration test

- Significantly different noise testing in tire and vehicle legislation
Tire/Road Noise as a Source of Vehicle Noise

Vehicle Noise Reg. (EC) No 540/2014

• Balancing of the different noise sources required to reach an overall vehicle noise target under the vehicle noise regulation.
Tire/Road Noise Generation Mechanisms

- Tread element impact
- Running deflections
- Road texture impact
- Stick-slip adhesion
- Air turbulence
- Air displacement
- Stick-snap adhesion
- Helmholtz resonator
- Pipe resonators
- Horn amplification
Tire/Road Noise Generation

- Key role of road surface in all aspects of tire/road generation

TIRE
- construction, mold shape, material, tread design

VEHICLE
- acoustic absorption

ROAD
- texture, roughness, porosity, acoustic absorption, ...

Tire/road interaction → sound radiation → sound propagation

27/11/2018
Tire and Road Influence on Noise

Laboratory noise test at 50 km/h on a drum with 2 different road surfaces.

- 6 tires of the same size with very different construction and tread pattern
- 1 slick tire (no tread pattern) with low noise construction

- Significant potential of road surface properties to influence tire/road noise
Effect of Road Surface on Tire/Road Noise

Video illustrating the effect of the road surface on tire/road noise

smooth road replica

coarse road replica
Most relevant road surface characteristics impacting tire/road noise:

- Macro- and Megatexure
- Porosity (sound absorption)
Tire Sound Power Measurement

• A sound source radiates power [W] and this results in a sound pressure [Pa]. Sound power is the cause. Sound pressure is the effect.

• The sound power is the average normal intensity over a surface enclosing the source, multiplied by the surface area.

• Performed tire sound power measurements:
  o Semi-anechoic room
  o rotating drum of radius 1.5m covered with a replica of a coarse road surface
  o Slick tire of size 205/55R16
  o Load: 4000 N; inflation pressure: 2.2 bar; speed: 60 km/h
Low Spatial Resolution Method Based on Sound Pressure (1)

- Setup based on standard ISO 3745
- 7 microphones on a hemisphere of radius 1.5 m around the tire
- Assumption of symmetric noise radiation about the tire mid-plane
Low Spatial Resolution Method Based on Sound Pressure (2)

\[ L_{\text{psurf}} = 10 \log_{10} \frac{1}{S} \left[ \sum_{i=1}^{N} S_i 10^{0.1L_{pi}} \right] \]

\[ L_W = L_{\text{psurf}} + 10 \log_{10}(S/S_0) + C \]

- \( L_{\text{psurf}} \) = surface sound pressure level [dB, ref.: 20 \( \mu \)Pa]
- \( L_{pi} \) = sound pressure level of microphone \( i \) [dB, ref.: 20 \( \mu \)Pa]
- \( S_i \) = partial area of half-hemisphere associated with microphone \( i \)
- \( S \) = \( \pi r^2 \), total area of half-hemisphere
- \( N \) = number of microphone positions
- \( L_W \) = sound power level [dB, ref.: 1 pW]
- \( S_0 \) = 1 m\(^2\)
- \( C \) = correction term for room temperature and atmospheric pressure
High Spatial Resolution Method Based on Sound Intensity (1)

- Sound intensity scanning probe, called LMS Soundbrush
- Handheld probe with the 3D sound intensity sensor and fixed camera used for the position tracking
- Sound intensity vectors by means of solid sphere with four phase-matched microphones in tetrahedron configuration

High Spatial Resolution Method Based on Sound Intensity (2)
High Spatial Resolution Method Based on Sound Intensity (3)

\[ f_c = 630 \text{ Hz} \]

\[ f_c = 800 \text{ Hz} \]

\[ f_c = 1000 \text{ Hz} \]

\[ f_c = 1250 \text{ Hz} \]
High Spatial Resolution Method Based on Sound Intensity (4)

$f_c = 1600$ Hz:

$f_c = 2000$ Hz:

$f_c = 2500$ Hz:

$f_c = 3150$ Hz:
Comparison of Both Sound Power Methods

- Sound power levels radiated through the half-hemisphere resulting from both measurement techniques (overall and 1/3rd octave band, A-weighted)

The sound power level for the individual 1/3rd octave bands differs on average by 0.5 dB(A). The overall sound power level differs by 0.2 dB(A).
Examples - tire/road noise trade-offs

**Example 1: slick tire**

<table>
<thead>
<tr>
<th>235/40R19</th>
<th>Noise at 50 km/h</th>
<th>Rolling Resistance</th>
<th>Straight Aquaplaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>slick tire (*) (low noise construction)</td>
<td>67 dB(A) Ref. level</td>
<td>Ref. level</td>
<td>Ref. level</td>
</tr>
</tbody>
</table>

(*) A slick tire does not meet the minimum legal safety requirement and cannot be used on public roads.

**Example 2: tread compound**

<table>
<thead>
<tr>
<th>Ref. tread compound</th>
<th>Noise at 50 km/h</th>
<th>Rolling Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>High hysteresis tread compound</td>
<td>-0.5 dB(A) 25 % worse</td>
<td>Ref. level</td>
</tr>
</tbody>
</table>

- Noise measured on ISO10844 test track
- Examples are illustrative and cannot be considered as a general rule.

- The noise level of a slick tire is close to the lowest achievable noise level for that size due to the absence of most tire/road noise generation mechanisms.
### Examples - tire/road noise trade-offs

#### Example 3: tire belt

<table>
<thead>
<tr>
<th></th>
<th>Noise at 50 km/h</th>
<th>Tire Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard belt</td>
<td>Ref. level</td>
<td>Ref. level</td>
</tr>
<tr>
<td>Heavy belt</td>
<td>-0.3 dB(A)</td>
<td>10 % heavier</td>
</tr>
</tbody>
</table>

#### Example 4: tread groove volume

<table>
<thead>
<tr>
<th></th>
<th>Noise at 50 km/h</th>
<th>Rolling Resistance</th>
<th>Straight Aquaplaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ref. tread pattern</td>
<td>Ref.</td>
<td>Ref. level</td>
<td>Ref. level</td>
</tr>
<tr>
<td>25% lower groove volume</td>
<td>-0.5 dB(A)</td>
<td>= Ref. level</td>
<td>15 % worse</td>
</tr>
</tbody>
</table>

- Noise measured on ISO10844 test track
- Examples are illustrative and cannot be considered as a general rule.

- Majority of tire design changes influence:
  - noise generation mechanisms
  - physical phenomena linked to other performances
Future Reduction of Road Traffic Noise

**CURRENT APPROACH**

- **Vehicle**
  - separately optimized for:
    - noise
    - safety
    - environmental impact
    - ...
  - Reg. (EC) 540/2014
- **Tire**
  - separately optimized for:
    - noise
    - safety
    - environmental impact
    - ...
  - Reg. (EC) 661/2009
  - Label (EC) 1222/2009
- **Road**
  - separately optimized for:
    - noise
    - safety
    - environmental impact
    - ...
  - No regulatory noise requirements
  - Noise mapping in EU
- Noise reduction with lowest trade-off on other **vehicle** performances
- Noise reduction with lowest trade-off on other **tire** performances
- Noise reduction with lowest trade-off on other **road** performances

**HOLISTIC APPROACH**

- **Vehicle / Tire / Road**
  - overall optimized for:
    - noise
    - safety
    - environmental impact
    - ...
  - Balanced requirements
- Noise reduction with lowest trade-off on overall performances
Illustration of a Holistic Approach

Vehicle

Tire

Road

Overall

- Maximum benefit for society by considering:
  - improvement potential from all actors and
  - associated trade-offs from all actors
Conclusions

• Progress in tire technology resulted in:
  - tire/road noise levels approach slick tire level (lowest achievable)
  - lower remaining noise reduction potential with more pronounced trade-offs

• Majority of tire design changes influence:
  - noise generation mechanisms
  - physical phenomena linked to other performances

• Key role of road surface characteristics in all aspects of tire/road noise generation

• Holistic approach for road traffic noise abatement:
  - three major actors: tires, vehicles and roads
  - consider feasibility and potential of all individual actors
  - highest societal benefit
Thank You For Your Attention