Towards new infrastructure materials for on-the-road charging

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Outline

- Introduction
  - Different Charging solutions

- Wireless Power Transfer (WPT) Solution

- Challenges from the road infrastructural perspective
  - Structure and maintenance
  - Road materials → Electromagnetic loss
  - Environment

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1. Introduction

- Electrification of Roads- Charging solutions

<table>
<thead>
<tr>
<th>Grid Integration</th>
<th>2012</th>
<th>2016</th>
<th>2020</th>
<th>2025</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Plug-In Charging</strong></td>
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<tr>
<td>Develop On-Board/In-Plug Charging Dev. Adaptive to User</td>
<td>Y</td>
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<tr>
<td>Create Systems for Information on Charge Status</td>
<td>Y</td>
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<tr>
<td>Create Business Models for Charging</td>
<td>Y</td>
<td>Y</td>
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<tr>
<td>Broad Establishment of Infrastructure</td>
<td>Y</td>
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<td><strong>Quick Conductive Charging</strong></td>
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<tr>
<td>Investigate Quick Charging</td>
<td>Y</td>
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<tr>
<td>Broad Establishment of Infrastructure</td>
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<td><strong>Contactless Charging</strong></td>
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<tr>
<td>Develop Contactless Charging (First Applications)</td>
<td>Y</td>
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<td>Broad Establishment of Infrastructure</td>
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<td>Charging While Driving</td>
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<tr>
<td>Investigate &amp; Develop Dedicated Charge While Driving System</td>
<td>Y</td>
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<tr>
<td>Broad Establishment of Infrastructure</td>
<td>Y</td>
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<td>Y</td>
<td>Y</td>
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</tbody>
</table>

Charging infrastructure (European Roadmap, 2012)

- Conductive charging
- Contactless charging
1. Introduction

- Conductive Charging solution

**Light cars**

![Light car image](image1.png)

Plug-in charging devices

**Heavy trucks**

![Heavy truck image](image2.png)

Scania test site

Volvo test track
1. Introduction

Contactless Charging solution

Static way
- Transmission performance 3.3 kW
- Frequency 140 (+50 kHz / -20 kHz)
- Air gap 50 - 170 mm
- Max. length x wide: 1m x 1m (both)

Dynamic way
- Efficiency ≥ 90 % (at 135 mm air gap)
- Positioning tolerance: ± 100 mm
- Positioning support

Opportunities:
- Eliminate the limitations (cost and range);
- More convenient and possibly safer;
- Lower energy cost;
- Integrate renewable resources (wind, solar).

BOMBARDIER test site, Mannheim, DE

Favourite choice for Electrified-Road!!!
2. Wireless Power Transfer (WPT) Solution

- Inductive Power Transfer (IPT) technology

**Rectifier:** DC output voltage
**Converter:** to achieve high output frequencies
**Compensation:** a capacitance to reduce the switching losses

\[ \text{Resonance: } C_1 = \frac{1}{\omega_0^2 L_1}, \quad C_2 = \frac{1}{\omega_0^2 L_2} \]
3. Road infrastructure

- Challenges for an Electrified Road
  - Structure
  - Material
  - Environment

An electrified road by Inductive Charging Technology (PATH, 1994)
3. Road infrastructure

- Structural integrity

Magnetic flux

- Ferrites
- Coils
- Aluminium backplane

Weak areas

Cracking

Rutting

Air gap

MTS Loading

Transfer distance

Overlay (2-5cm)

X-Ray Scanning

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3. Road infrastructure

- Structural integrity

![Diagram of HMA and PCC layers with bending stress and shear stress](image)

Example: failure mechanisms of HMA overlay due to: (a) Traffic and (b) Environment

<table>
<thead>
<tr>
<th>Structural improvement methods</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Overlay systems</strong></td>
</tr>
<tr>
<td>Increased thickness</td>
</tr>
<tr>
<td>Reinforced HMA materials</td>
</tr>
<tr>
<td>Open graded structure</td>
</tr>
<tr>
<td><strong>Closed Joint systems</strong></td>
</tr>
<tr>
<td>Joint materials</td>
</tr>
<tr>
<td>Geometry design</td>
</tr>
<tr>
<td>Stress absorbing membrane interlayer</td>
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<tr>
<td>Geosynthetics interlayers</td>
</tr>
<tr>
<td>Reinforcement interlayers</td>
</tr>
</tbody>
</table>
3. Road infrastructure

- Long term maintenance principles

Periodic activities

- Resurfacing

Large rehabilitation

What about the electrified road?
Feasibility analysis and development of on-road charging solutions for future electric vehicles
3. Road infrastructure

- Road materials → Electromagnetic loss

**Permittivity:** \( \varepsilon = \varepsilon' + i\varepsilon'' \)

**Mixing models**
- CRI model: \( \varepsilon_{\text{eff}}^\beta = \nu\varepsilon_c^\beta + (1-\nu)\varepsilon_m^\beta \)
- LLL model: \( \varepsilon_{\text{eff}}^\beta = \nu\varepsilon_c^\beta + (1-\nu)\varepsilon_m^\beta \)
- Lichtenecker model: \( \varepsilon_{\text{eff}} = \varepsilon_c^{1-\nu} \)
- Chieh-Min model: \( \varepsilon_{\text{eff}} = c \left( \sum_{i=1}^{n} \nu_i \varepsilon_i^\alpha \right)^\beta + k \)
- SK model: \( \varepsilon_{\text{eff}} = \varepsilon_m + \frac{\sum_{i=1}^{n} \nu_i (\varepsilon_i - \varepsilon_m)}{1 - \sum_{i=1}^{n} \nu_i \varepsilon_i + 2\varepsilon_m} \)
- P&I model: \( \varepsilon' = \sum_{j=1}^{n} \sum_{j=1}^{n} \nu_j (\varepsilon_s' - \varepsilon_i') \) for \( \varepsilon_s' \geq \varepsilon_i' \)
  \( \varepsilon' = \sum_{j=1}^{n} \sum_{j=1}^{n} \nu_j (\varepsilon_i' - \varepsilon_j') \) for \( \varepsilon_s' \leq \varepsilon_i' \)

Where, \( \varepsilon'' \) - the permittivity loss part of road material; \( \omega \) - the water content; \( t \) - temperature; \( h \) - thickness; \( f \) & \( l \) - working frequency & Current.
3. Road infrastructure

- Road materials → Electromagnetic loss
  - Example: Permittivity test of bitumen 70/100

![Diagram of test setup]

- LCR Meter
- Computer
- Environment Chamber
- Novel Test Cell inside
3. Road infrastructure

Road materials → Electromagnetic loss

- Example: Permittivity test of bitumen 70/100 (\(\tan\delta = \varepsilon''/\varepsilon'\))

- Permittivity of other road material components will be tested and influence factors e.g. water will be included.
- EM loss estimation and control will be studied.
3. Road infrastructure

- Environmental performance

- Electric Vehicle
- Conventional ICE Vehicle
- Fuel
- Vehicle
- charging infrastructure
- Petrol/gas stations

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Thank you!

• To be continued….