Electrification of Roads: Infrastructural Aspect

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Abstract:
Considering the environmental impacts of traditional vehicles regarding emission and use of fossil fuel, Electrical Vehicles (EVs) have become a potential solution for enhancing the sustainability of road transportation sector. In this, the establishment of 'Electrified Road' (E-Road) infrastructure network that allowing for charging EVs conveniently has been given focus to reduce restrains from the battery. Being used as a contactless charging solution, the Inductive Power Transfer (IPT) technology is given as the technical base of E-Road in this paper. Firstly, a brief introduction about the IPT charging system is made, together with the associated pilot efforts towards the application in a dynamic way. Thereafter, from a road infrastructure point of view, the challenge for the infrastructure aspect i.e. the integration of charging facilities into the road pavement and its long term maintenance management are discussed. The authors want to warn the developers in this field to be more aware of the infrastructural aspect since the final success of implementing the E-Road into practice needs not only the charging technologies but also cross-coupling efforts from like road infrastructure.

Keywords: Electrification, Road infrastructure, Inductive Power Transfer technology, Maintenance

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1. Why 'Electrification of Roads'

As an alternative solution, Electric Vehicles (EVs) have been given focus as a potential solution towards enhanced sustainability of the road transportation sector in the long term run. In this, due to the limitations of energy source technologies, recharging opportunities away from home has become a critical concern to achieve widespread demand for the use of EVs. The 'Electrified Road' (E-Road) Infrastructure is defined as a transportation infrastructure that is able to "deliver the electrical power to charge EVs efficiently stationary or even in motion, using specific conductive or contactless charging systems". Within this definition, E-Road can serve as an ordinary road for vehicles driving on and at the same time delivering electrical energy to power EVs (refer in particular the EVs that use batteries). Being a near-field WPT technology, the Inductive Power Transfer (IPT) technology has shown good performance and is being studied actively as a contactless charging solution in a dynamic way.

❖ Opportunities for IPT technology:

- Eliminate the battery limitations for EVs (cost and range);
- More convenient and possibly safer than the conductive solution;
- Lower energy cost than fossil fuel;
- Integration renewable resources (wind, solar) into power grid.

2. How 'E-Road' work

❖ Inductive Power Transfer (IPT) System

A typical IPT system usually consists of an on-board device installed under the vehicle's chassis and an off-board power delivery device mounted inside the road surface. As illustrated that in FIGURE 1, The off-board system that will be integrated into the road surface mainly has three parts:

1) The power supplier provides a DC output voltage by a rectifier;
2) A converter to achieve high output frequencies (normally between 20kHz~100kHz), and combining with capacitances to achieve resonance and reduce the switching loss;
3) A transmitter consisting of coils, ferrite cores and backing plate, which is mutually coupled with the pick-up device.

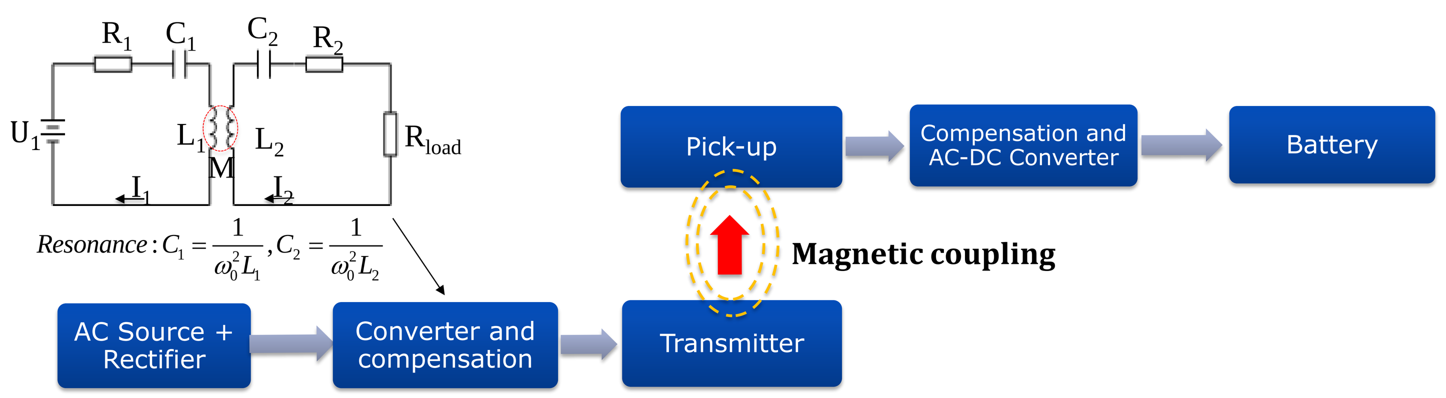

FIGURE 1 Diagram of a typical static IPT system for BEVs

❖ Integration of IPT system into road structure

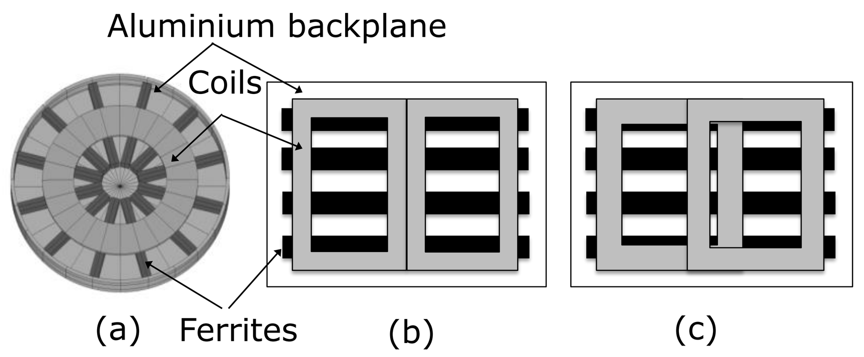

FIGURE 2 Schematic of different transmitter's configurations in IPT Off-board systems

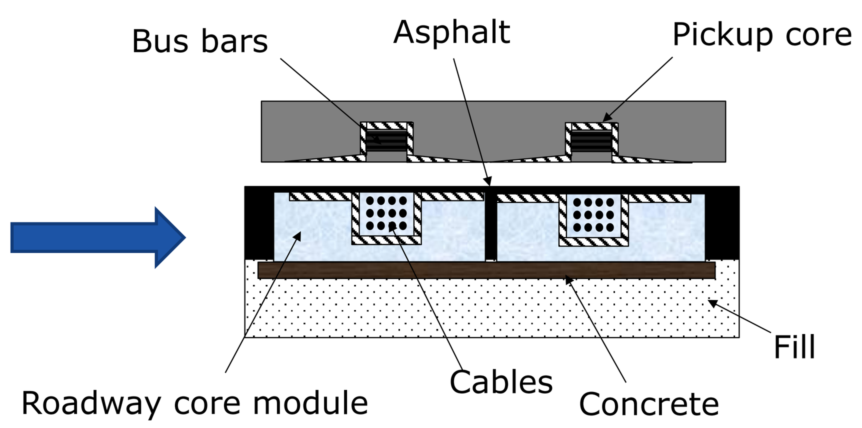

FIGURE 3 Illustration of cross section geometry of roadway and pickup inductor (after PATH, 1994)

3. What contributions from the road infrastructure perspective

The success of the E-Road infrastructure not only relies on the technologies allowing for charging action, but also their appropriate integration into the road structure and the good functionality in the long service lifetime.

1) The fragile materials, e.g. ferrite, have to be integrated into the road pavement to give a long service life in a very hostile environment.
2) The protection of the road structure is also essential. If the E-Road is damaged during their designed service lifetime, it can also affect the IPT systems from functioning properly, leaving the whole system in a malfunction situation.
3) In order to ensure the optimum functionality of E-Road for a very long time and in a cost-effective way, the traditional maintenance technologies and management can be challenged.

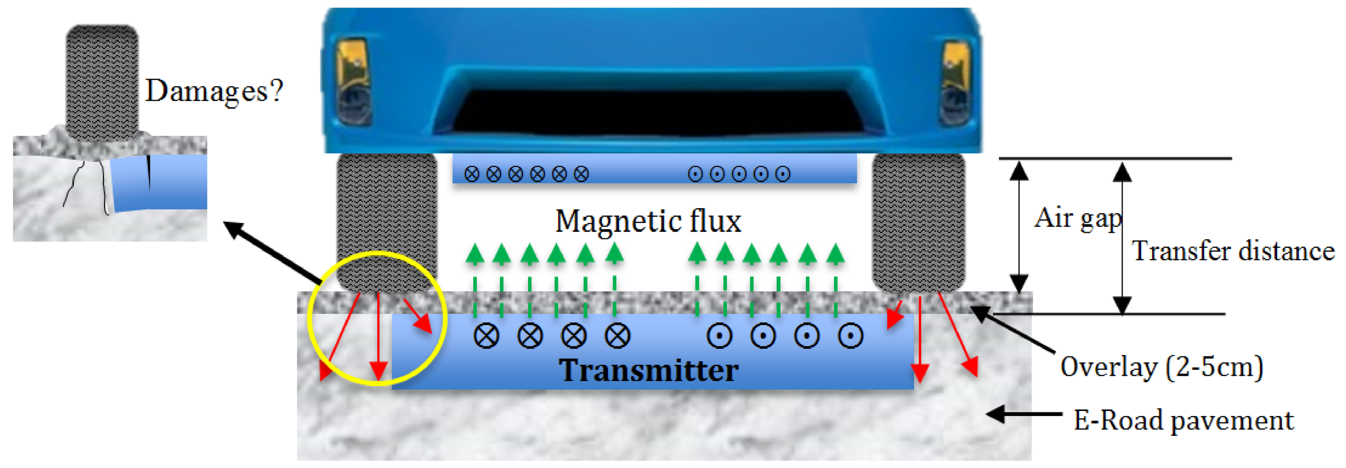

FIGURE 3 An illustration of a potential E-Road structure

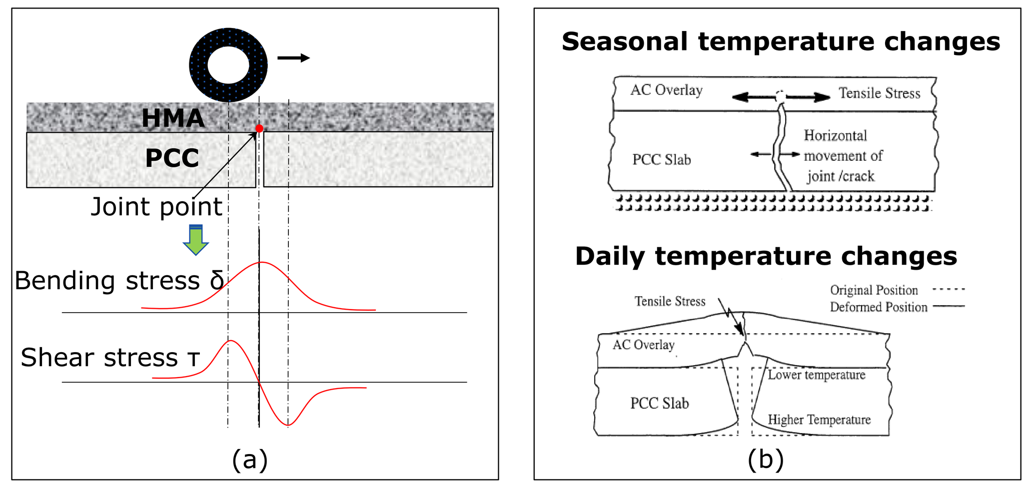

FIGURE 4 Schematic of reflective cracking mechanisms due to (a) traffic loading and (b) temperature variations (after Lytton and Mukhtar, et al.)

TABLE 1 A summary of potential methods for improving E-Road structural integrity

Method			Mechanism	Materials	comment
Overlay systems	Asphalt mixture overlay	Increased thickness	To retard reflective cracking by increasing the thickness of HMA overlay.	Not applicable	A beneficial but not economical way.
		Reinforced HMA materials	To provide greater resistance to stresses by reinforcing the pavement materials.	Polymers modified bitumen (SBS, rubber, carbon black, etc.), short-length (polypropylene or polyester) fibres.	Not expensive and easy for the paving operation.
		Open graded structure	Contains large inter-connecting air voids and can relieve the stresses caused by PCC movements.	Open gradation asphalt mixtures, e.g., SMA and OGFC.	Performs well and reduces noise.
	Surface seals		Be applied before the road surface deteriorates to the stage patching or reconstruction is required.	Hot bitumen or cold bitumen emulsion is sprayed onto the road surface, followed by spreading qualified aggregate chips.	A cost-effective and quick maintenance treatment method of rejuvenating a surface.
	Slurry seals		Be applied in thin overlays (varies from 3 mm to 20 mm) to avoid permanent deformation caused by the traffic.	Mixtures of bitumen emulsion, fine aggregates, filler, water and specific additives.	Extending the life of pavements by protecting them against ageing and the environment, but do not contribute to the structural strength of the pavement.
Closed Joint systems	Joint materials		Be placed between two pavements to accommodate movements, improving waterproofing, riding quality, noise reduction.	coal-tar products, rubber, silicone, and polymer modified asphalt binder	Can accommodate very large movements.
	Geometry design		To optimize gap plate width, thickness, edge geometry and the interface geometry.	Not applicable	Can help reduce the interface stresses or the tensile stresses within the joint materials.
Interlayer systems	Stress absorbing membrane interlayer		Absorb movements at the joints and dissipate stress before it reaches the overlay.	Placing a seal coat made of rubber asphalt binder then rolling in coarse aggregate chips.	Effective to relieve stress and usually varies from 0.6-1.0 cm.
	Geosynthetics interlayers		Use fabrics, grids, and composites to reinforce the HMA overlay, and impregnated in tack coat to absorb excessive stresses.	Geotextile, fiber-glass, geocomposite, etc. tack coat is emulsified and rubberized asphalt.	Mostly mixed used, and the performance highly depends on proper construction procedures.
	Reinforcement interlayers		To reinforce overlay in the event of excessive yielding or fracture of interlayer.	Steel nettings, Glass-fibre grids.	Initial high cost of construction but can extend lifespan longer.

Summary of the findings

From the road infrastructure perspective, this paper tried to survey the potential challenges that have not been taken into account for the success of E-Road infrastructure. The conclusions are given as follow:

- Different charging solutions are being under investigation as options for the future EVs' charging infrastructure. In this, the Inductive Power Transfer technology has shown good characteristics and studied actively as used in the contactless charging solution.
- From the road infrastructure point of view, there is a large challenge over the success of E-Road structure in its long service lifetime.
- Overlay, joint and interlayer systems can enhance the structural integrity of composite road structures. However, their real effectiveness in E-Road is unknown and needs further investigations.
- Long term maintenance management for E-Road is important but also challenged potentially.