WIRELESS POWER TRANSFER – USEABLE IN ROBOTS?

Cem Som, Vice President Midcom Europe

WURTH ELEKTRONIK MORE THAN YOU EXPECT
AGENDA

- World of Robots
- Wireless Power Transfer (WPT) Technology
- WPT in AMR/AGV
MARKET BRANCHES

Trade (Amazon, Alibaba,..)

Industry

Logistics (DHL, UPS,..)

Automotive

Medical

Agriculture
WHAT ARE WE TALKING ABOUT?

AMR (Autonomous Mobile Robots)

AGV (Automated Guided Vehicles)

Forklift
Global Mobile Robot Manufacturers 2022

Source: AGV network website
Global Mobile Robot Market

Material Transport Mobile Robot Market

Revenues vs Installed Base (2018-2027)

Source: Interact Analysis 2022

© Interact Analysis 2022
Global Automated Guided Vehicle Market

OPPORTUNITIES AND FORECAST,
2020-2027

Global Automated Guided Vehicle Market is expected to reach $13.52 Billion by 2027.

Growing at a CAGR of 16.6%
(2020-2027)

Source: https://www.alliedmarketresearch.com/automated-guided-vehicle-market
WHAT IS THE MOTIVATION BEHIND CHANGING TO AMR/AGV?

- Severe lack of availability of skilled personnel
- Start with automation of simple tasks in the work flow (e.g. 20% of global pallet movements can be done by AMR)
- Implementation cost will be compensated fast due to possible 24/7 usage and reduced personnel cost
- Reduced vulnerability of operations (e.g. war, pandemic (staff sick or quarantined))
<table>
<thead>
<tr>
<th>Fatal Accident Type</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crushed by vehicle tipping over</td>
<td>42</td>
</tr>
<tr>
<td>Crushed between vehicle and a surface</td>
<td>25</td>
</tr>
<tr>
<td>Crushed between two vehicles</td>
<td>11</td>
</tr>
<tr>
<td>Struck or run over by a forklift</td>
<td>10</td>
</tr>
<tr>
<td>Struck by falling material</td>
<td>8</td>
</tr>
</tbody>
</table>

Source: [Safety in Numbers and OHCSA report](#), the US industry in 2018
Now, why Wireless Charging?
Next 5 years. What Trends will become standard in the AGV/AMR Industry?

<table>
<thead>
<tr>
<th>Inductive Wireless Charging</th>
<th>42 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloud robot management system</td>
<td>23 %</td>
</tr>
<tr>
<td>Natural Nav replaces Laser Nav</td>
<td>32 %</td>
</tr>
<tr>
<td>Other (indicate in comments)</td>
<td>4 %</td>
</tr>
</tbody>
</table>
IF YOU USE AGV OR AMR, HOW DO YOU CHARGE THEM?

20 ANSWERS

- Charging cable with power supply: 7 (35%)
- Battery change with changing stations: 3 (15%)
- Automated charging system with grinding connections: 9 (45%)
- Inductive point charging system: 5 (25%)
- Battery change with additional stacker: 0 (0%)
- Guideline system installed in the ground: 2 (10%)
INTRODUCTION TO WIRELESS POWER TRANSFER

Inductively coupled magnetic resonant system

- Frequency: kHz regime
- Distance: short range regime

Maximum Transmission Efficiency [1]

\[ \eta_{\text{max}} = \frac{\kappa^2 Q^2}{\left(1 + \sqrt{1 + \kappa^2 Q^2}\right)^2} \approx 1 - \frac{2}{\kappa Q} \]

High Q

- \( \kappa \) coupling constant
- \( Q \) quality factor

coupling $\kappa$ is often limited by boundary conditions of the application

High Q coils allow
- long transfer distance
- higher freedom of positioning

\[
\eta_{\text{max}} = \frac{\kappa^2 Q^2}{(1+\sqrt{1+\kappa^2 Q^2})^2} \approx 1 - \frac{2}{\kappa Q}
\]
3D FEMM ANALYSIS OF WPT MODEL-ANGULAR MISALIGNMENT
The coupling factor drops already below 0.4 at a distance of half of the coil radius!
Coupling versus coil displacement
AC Loss Behaviour of Wireless Power Transfer Coils

- AC behavior of each coil is determined by interplay of wire type, winding geometry, number of layers and density of turns.
- Litzwire coils outperform their solid wire counterparts.
- Solid wire coils with high density of turns show strongest derating.
Improvement using ferromagnetic shielding

Without shielding

With shielding

Tx_Rx with shielding
Magnetic field simulation full ferrite

$r_{\text{in}} = 5 \text{ cm}$
$r_{\text{out}} = 10 \text{ cm}$
$n_{\text{turns}} = 10$
$L = 32.6 \mu\text{H}$
$I_{\text{peak}} = 10 \text{ A}$
Magnetic field simulation with center hole

\[ r_{\text{in}} = 5 \text{ cm} \]
\[ r_{\text{out}} = 10 \text{ cm} \]
\[ n_{\text{turns}} = 10 \]
\[ L = 32.3 \mu\text{H} \]
\[ I_{\text{peak}} = 10 \text{ A} \]
Magnetic field simulation with 6 stripe ferrite shielding

\[
\begin{align*}
    r_{\text{in}} &= 5 \text{ cm} \\
    r_{\text{out}} &= 10 \text{ cm} \\
    n_{\text{turns}} &= 10 \\
    L &= 25.6 \mu\text{H} \\
    I_{\text{peak}} &= 10 \text{ A}
\end{align*}
\]
**TECHNICAL PARAMETERS (COIL RELATED)**

All parameters can be tailored e.g. to the application or regional approval

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
<th>Typical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>100 W to 16 kW</td>
<td>3 kW</td>
</tr>
<tr>
<td>Efficiency</td>
<td>&gt;90%</td>
<td></td>
</tr>
<tr>
<td>Voltage</td>
<td>15 – 60 V</td>
<td></td>
</tr>
<tr>
<td>Current</td>
<td>40 – 70 A</td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td>80 – 150 kHz</td>
<td></td>
</tr>
<tr>
<td>z – Distance</td>
<td>5 – 250 mm</td>
<td>40 mm</td>
</tr>
</tbody>
</table>
Coils – Electronics – Battery have to match to reach the best result for the application
Wireless energy systems

1. Stationary Wallbox
2. Stationary charging pad
3. Mobile Unit and mobile charging pad
4. Battery system
5. Energy management etaHUB
WIRELESS CHARGING CONCEPTS

Charging & Service Area
Source: emeia.sumitomodrive.com

Charging strip during work
Source: Magment website

Process Integrated Charging Spots
Source: Wiferion
LACK OF STANDARDS

Currently no standard

Activities ongoing/starting in the Wireless Power Consortium WPC

Areas which use AMR/AGV´s are currently mostly closed, optimized systems. Therefore the need of a standard/interoperability is maybe not top priority.

EV´s have a standard/approval as here interoperability is a topic (like in mobile phones)
SAE J2954

Nevertheless:
All solutions have to fullfil regulatory requirements e.g. C E , EN55011, SAE, FCC, RED
ADVANTAGES OF A WIRELESS POWER SOLUTION

- Completely sealed e.g. IP 68 resistance
- Precise positioning at charging spot (automated solutions)
- Omnidirectional positioning
- Applicable to all vehicles used in the process
- No metal contacts - No sparks
- Maintenance free - no cleaning or contact replacement needed