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Production Concepts for Inductive Power Transfer Systems for Vehicles

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Abstract: The option of wireless energy transmission in electric vehicles can become the main market driver for electric vehicles due to its distinct advantages, such as range, weight, or costs, over conventional conductive charging solutions. In addition to the great potential, which different research work and realized systems have already shown, there are new requirements for the associated production networks in the automotive industry which must be addressed at an early stage. Furthermore, no solutions currently exist for the industrial production of these components. This paper presents the main components for the feasibility of wireless power transmission in electric vehicles. In addition, the required value chains and processes for the new components of the inductive power transfer systems, and the final assembly for induction coils, which has been developed at the FAU, will be presented. These include the developing of a winding process on a 15-axis special machine, ultrasonic crimping of the litz wire ends, and vacuum potting.

Keywords: charging automation; electric vehicles (EVs); wireless charging; wireless power transfer (WPT); production; automation; inductive power transfer (IPT); manufacturing

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1. Introduction

Over the past years, electro mobility has become an important topic in emission free transportation plans. In combination with renewable energies, it is even possible to keep vehicles carbon neutral. These advantages have triggered the interest in electric vehicles in recent years, but the technology has always been expensive. Significant factors leading to low user acceptance include the large and expensive batteries in short-range vehicles and slow charging solutions. Wireless power transfer (WPT) is focused on solving these current problems, such as the inconvenient plug-in charging process. Modern systems have already demonstrated the potentials of wireless energy transfer in cars [1,2]. However, there are currently no solutions for the industrial production of these components.

Within this paper the results of a feasibility study of contactless charging will be introduced, followed by the production processes for inductive power transfer (IPT) systems as well as automation concepts, which have been developed at the Institute for Factory Automation and Production Systems (FAPS) of the Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU).

2. Components and Types of Wireless Power Transfer

The idea of wireless power transfer has existed since the late 19th century [3]. Currently, a variety of different systems exists with transmitting powers from 10^0 W (e.g., mobile phones) up to 10^5 W to supply power into electrical trains.

Particularly in the field of medical and consumer products, WPT systems are proven and widely used. Aboutfifty years ago, the first WPT artificial implanted heart have been published [4]. At the end of the 1970s, WPT charged electric toothbrushes [5] kicked off the success story of wireless power transfer in the consumer industry. The integration in the industrial production was triggered in the 1990s by automated guided vehicles (AGV), of

which wireless charging was an improvement because of its greater robustness and lower maintenance [6].

WPT systems for electric vehicles (EV) have been a logical extension of this. They have already existed in research projects since the 1970s [7] and have spurred new interest as recent improvements in material and power electronics have arisen. In a direct comparison, automotive applications have requirements that are more stringent in the points of air gaps, power level and power density as well as safety (several nations have defined safety limits, values and zones for the electromagnetic field, e.g.,), compared to AGV applications [6]. In 2021, Momentum Dynamics issued a declaration of CE conformity for its up to 300 kW wireless charging solutions [8].

2.1. WPT Technologies

The use cases of wireless charging are listed in Table 1:

Table 1. Different WPT technologies for EVs [9].

	Stationary WPT	**Semi-Dynamic WPT**	**Dynamic WPT**	
Power rates	3.7–22 kW	3.7–22 kW	>20 kW	
Examples	Home, job or shopping center	Traffic lights, taxi ranks, bus stations	Along gas stations, on motorways	Charging lanes on motorways

2.1.1. Stationary Charging

Private vehicles are usually stationary objects. The typical daily drive time of a private car in Germany is 32 min, and most trips are shorter than 40 km (~25 mi) [10]. Average European distances are half as long as in the USA [11]. Therefore, charging with about 3.7 kW for vehicles with approximately 20 kWh energy storage capacity are sufficient. EV drivers, who do not have the possibility to charge their own equipment, depend on public charging infrastructure solutions. To promote socio-economic acceptance of electromobility, the range has to grow, while charging times have to be reduced by the use of fast charging batteries and charging stations. Otherwise, public infrastructure must be profitable and integrable [12].

2.1.2. Semi Dynamic Charging

A further step is charging in idle positions or slow-driving sections, e.g., taxi stands, traffic light or traffic-calmed sectors, where conductive charging is ineffectual because of the short cycles. These sections can be equipped with switched IPT pads, which are enabled when the vehicles of customers cross these pads. The technology enables energy transfer in cars during waiting periods of conventional urban driving profiles. The benefits are higher ranges and no need of special charging points. Besides economic problems such as higher installation and maintenance costs compared to home based technology, new traffic scenarios have to be researched, evaluated, defined and coordinated with transport authorities [13,14].

2.1.3. Dynamic Charging

The next, more holistic step is supplying vehicles with energy while driving at cruising speed, which eliminates problems like limited range and therefore allows a reduction of battery capacity.

The first major academic project was coordinated by the “Partners for Advanced Transit and Highways” (PATH), led by UC Berkeley [7]. The consortium equipped an electric bus with a pickup system and used a street with a track system (see Figure 1).

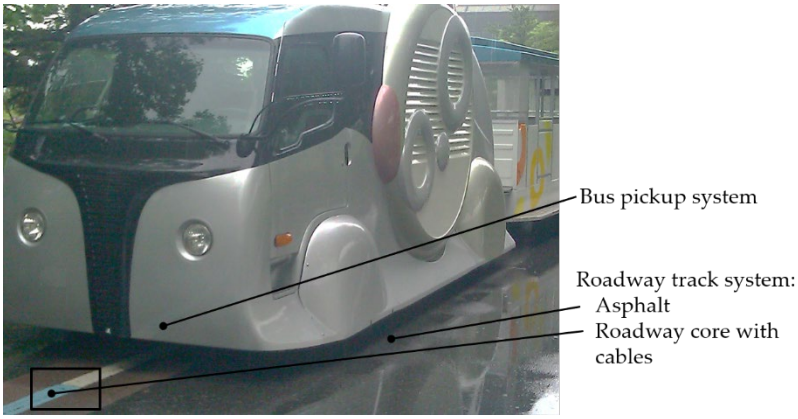


Figure 1. Roadway track system of the KAIST project.

The results of the project have proven that inductive charging while driving is technically working but limited to materials and electronics that have been available at this time. However, the costs of the installation and maintenance of infrastructure must be reduced. Within the last decades many other test tracks have been installed, such as by the KAIST in South Korea for buses, by Bombardier in Germany for tramways, or by Electreon in Sweden and Germany for trucks [15–17].

Nevertheless, there have been no efforts to industrialize the production of the components of this technology and their integration into traffic routes.

2.2. Components of WPT

A WPT system in the variant of IPT consists of a primary and a secondary coil, as well as the associated power electronics and sensors. The primary system delivers the energy and might be installed in the infrastructure (see Figure 1). The secondary system receives the energy to supply the vehicle and is shown in Figure 2. The main components are the coil and the ferrite blocks, which are insulated by a resin as well as the connection cable.

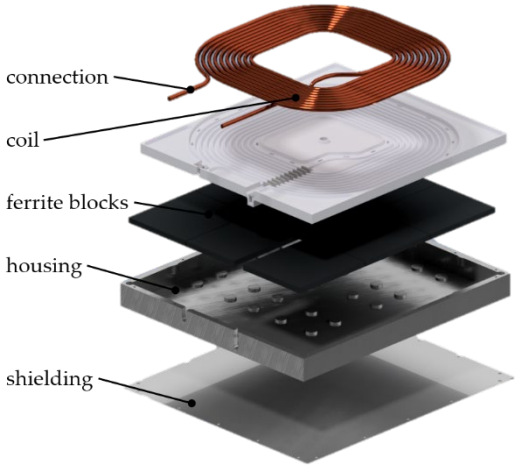


Figure 2. Composition of an IPT module.

Depending on the type of use, charging pads have different coil designs, which result in different production challenges. To give some examples, there are single-sided and double-sided pad structures with e.g., circular, solenoid, H-formed, D-formed, and DDQ-formed coil designs [18,19].

3. Feasibility of Contactless Charging of EVs

According to the state of the art, several hundred kW have already been transferred to moving vehicle systems (see Figure 3) under certain conditions. At a distance of 17 cm, the

South Korean consortium OLEV (On-line Electric Vehicle) has already been shown to have an efficiency of more than 71% at 17 kW, according to official figures. The first test systems established were able to comply with the ICNIRP limit recommendations of 6.25 µT in the relevant areas around the vehicle [15].

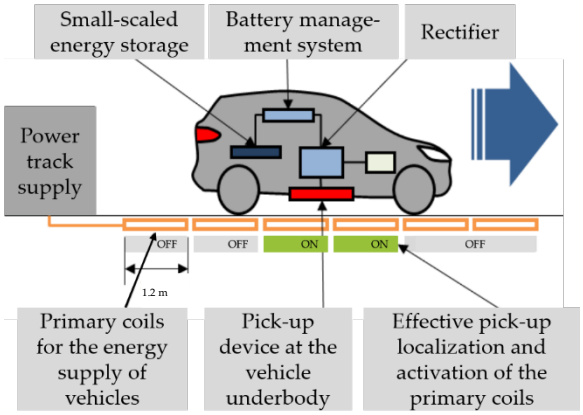


Figure 3. System for WPT in moving cars [20].

Further research is needed, among other things, to increase efficiency and reduce vehicle and infrastructure costs, on the one hand through innovative energy transmission topologies and, on the other hand, through the efficient production and integration of these systems in vehicles and on the road. In particular, automated manufacturing processes are needed to reduce system costs, as very high relative costs are created in the initial migration stages to refinance the infrastructure.

4. Production Concepts for Inductive Power Transfer Pads

The current state of IPT pad production is characterized by small lot sizes and manual work. This often results in fluctuations of quality, which can induce lower power transfer efficiency, damage, or reduced service life expectancy. On the other hand, a higher demand leads to higher lot sizes and automated processes. In the following chapter, process chains will be explained and suitable processes shown.

4.1. Process Chain for IPT Pads

Charging pads consist of different components and materials which are manufactured, handled, and assembled in several production steps (Figure 4 (right)). The first step is the preproduction of the base parts and the housing. The functions of these parts are to position coils, electronics, and ferrites and to encapsulate the system (mechanically, chemically, thermal, etc.).

The following steps (winding and contacting of the high-frequency (HF) litz wires) will be discussed in Sections 4.2 and 4.3.

In another step, the mentioned ferrites and electronic packages must be assembled. The challenges of this production step include the careful handling and most precise dropping of the ferrites, which have tight tolerances, because the position influences the magnetic field.

With rapidly increasing demand for solutions for wireless charging systems, adaptive value chains with a gradually increasing degree of automation have to be created. To reach short cycle times, it is important to process a wide variety of materials safely and with high process stability. The multitude of fields of action for wireless charging systems from a production and material perspective also requires interdisciplinary manufacturing process development. With an initially low level of integration of the electronics in the charging modules, partial pre-assembly and separate delivery of the individual components (coil module, compensation, rectification, etc.) may be necessary, which is accompanied by complex final assembly. Since, above all, the logistics processes and the associated

costs have a significant influence on the further design of the modules, a higher level of integration is to be aimed at in later stages of development. It is also conceivable to integrate the systems into the battery modules, which for reasons of logistics (costs and safety of transport) tend to be produced very close to the final assembly plants.

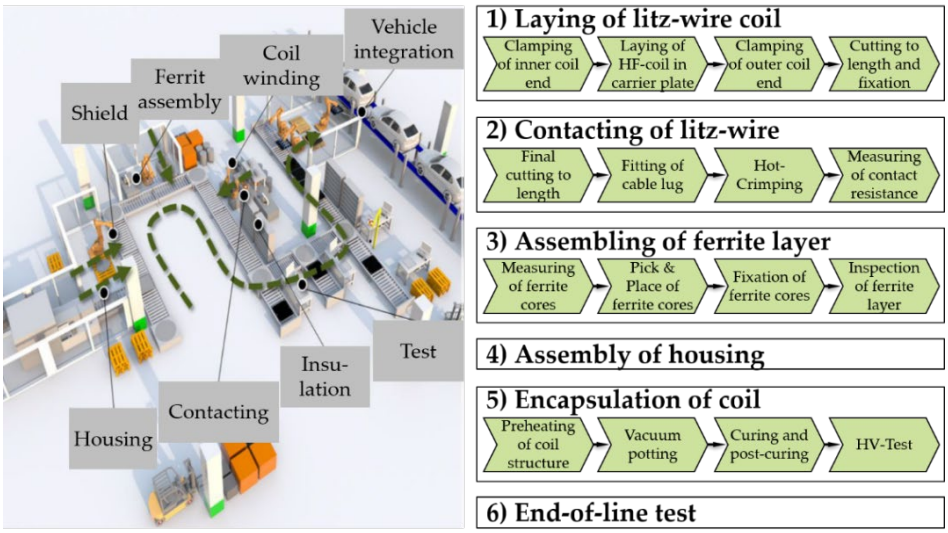


Figure 4. CAD model of a value-added chain [21] (**left**) and process chain of the IPT pad production (**right**).

Additional advantages arise in the case of integration of the electronics close to the target site by minimizing the high-voltage cabling expenditure and the synergetic use of already integrated cooling concepts to be able to ensure the required heat dissipation, especially in higher performance systems.

In the case of highly automated processing and handling of magnetic field guidance materials, e.g., ferrites, the risk of breakage of the brittle material must be considered. In addition to the development and construction of suitable litz-wire laying techniques for optimized winding patterns for better heat dissipation, methods for process-stable, large-series-capable contacting of the several hundred individual wires are to be developed for the high-frequency strands used. Current methods of thermal stripping and contacting via tin baths are not suitable for large series and automotive applications. For the following processes, appropriate buffer systems must be used to meet the required conditions for the curing process of insulation and potting materials and to ensure an approximately constant flow of the material.

In the vehicle final assembly plant, the charging modules are installed in the underbody of the vehicle. At present, there are no vehicle concepts that have been completely designed for a contactless charging option, especially with regard to the body structures including the battery module in the underbody area. Optimal integration, ideally in the center of the underbody to ensure interoperability between vehicle models while preserving mechanical, electrical, chemical and thermal boundary conditions, will only be possible in future generations of vehicles.

Within the next sections, the focus of the IPT pad production will be set on the winding, contacting and insulating technologies of HF litz wires.

4.2. Winding Technologies

The difficulty in automated production of coils is represented by the various coil parameters.

Particularly worthy of mention here are the 3D contour, the structure as a multi-coil system, multipole coils, systems with several HF-litz wires, the winding distance, various radii, winding tolerances, wire intersections and the positioning of the coil ends.

4.2.1. Processing of HF-Litz Wires

The starting point is the use of already stranded wires. The supply path of the strands begins with the supply from storage reels or ones that are cut-to-length. The strands are then pulled through the feeder via a position measuring system and the dancing roll and are then guided to the placement point via guide rollers and the gripper.

4.2.2. Stabilization of Coils

Complex coil constructions have to be inherently stable for several reasons: stability facilitates logistics (e.g., transport of preformed coils from the winding machine to assembly in the housing) and contributes to protecting the sensitive materials in the pads from damage. It simplifies the positioning of components and helps to maintain even complex shapes such as correctly distributed winding distances or to reduce process time. Depending on how the coils are possibly fixed in the pad, e.g., with full encapsulation, they may only have to be self-stable for a short period of time.

There are various options for coil carrier materials and fastening methods that can be divided or combined into mechanical (sewn on textile, staples, base plates with hooks or grooves, rigid coil formers) and adhesive (liquid or sprayed adhesives, adhesive foils, or self-adhesive cables). Various concepts were tested for this purpose. Base plates with grooves enable the high-precision placement of the winding ends. The combination of this plate and a laying tool with, for example, a tool for feeding adhesive strips also enables accurate placement and fixation of the winding. Another tested system includes a vacuum gripper that grips self-adhesive strands and places them on a flat plate. By adding a heat source (hot air or laser), the cables can be fixed directly to the areas that are important for the shape.

4.2.3. Winding of HF-Litz Wires

There are three basic concepts to perform relative movements between the laying tool and the base plate, which are also realizable with robots [22]. While manually produced demonstrators usually have certain imperfections and higher manufacturing tolerances, automated test setups are usually expensive and inflexible. The use of a universal and flexible robot kinematics in combination with the realization of a cad-cam chain makes it possible to use a robot for demonstrator assembly as well as for serial production.

For validation, a layout was created which includes different radii as well as parallel windings and winding intersections. In addition, various installation tests were carried out in which the strands (material, diameter, structure), the shunt radii and the setting radii can be varied. These tests make it possible to draw conclusions about the reproducibility of a pad during the electromagnetic design phase.

For example, an R14 radius can no longer be produced with a 768 $\times$ 0.1 mm HF strand, or a radius of 1 mm with an angle of attack of 90 degrees, but only with insulated strands (e.g., a 300 $\times$ 0.2 mm baked varnish strand).

Within the framework of research, basic production concepts have been realized. In order to achieve high-quality IPT systems, not only the basic production concepts but also the material behavior must be considered in detail. To reflect critical material behaviors, selected production concepts were therefore implemented and scrutinized. Overall, it became evident that self-bonding wires can be processed more easily without external insulation. However, HF litz wires without external insulation have the disadvantage of a lower cohesion of the individual strands and less protection against mechanical damage. As shown, problems can occur in the winding process with tighter curves if the wires are twisted and deformed in the winding direction.

Complex coil constructions require external insulation to keep the wires in shape and ensure sufficient electrical insulation, even in difficult environments. However, inelastic adhesive tapes make stranded wires very stiff and therefore difficult to wind, especially in tighter curves, and the tape needs to be removed before contact to avoid residues and vapors. Outer insulation with silk offers the best compromise, namely high HF stranded

wire stability and good protection against mechanical damage, while at the same time offering flexibility. A disadvantage is the need to wipe the silk before the contacting process to avoid residues and vapors.

In summary, the tests described above can be used to determine production-relevant parameters in order to assess the suitability of HF stranded wires for winding as well as the necessary winding and wire laying tools and to produce prototypes.

4.3. Contacting Technologies

Due to the high number of insulated single wires of a high-frequency litz wire, the process step of contacting is a challenging process. In order to enable an electrical and mechanical connection of the high-frequency litz wire with contact elements such as cable lugs or terminals, the primary insulation of the single wires must be removed. The high number of single wires precludes mechanical stripping prior to the actual contacting process. Chemical stripping processes are also extremely challenging and do not allow a sufficient stripping. However, in order to enable the contacting of primary-insulated litz wires, combined contacting processes can be used. These realize the necessary stripping process directly during the actual contacting. The hot and ultrasonic crimping processes are particularly suitable for this purpose. In both processes, the contacting is realized by a crimping process with tubular cable lugs. On the other hand, the primary insulation is removed thermally. While the hot crimping process utilizes the resistance heating of electrodes and tubular cable lugs for this process, ultrasonic crimping uses only the damping of ultrasonic oscillations. The resulting conversion of oscillation energy into thermal energy also enables a thermal stripping. Furthermore, high-frequency litz wires can be stripped by means of an ultrasonic compacting process. Again, the damping of mechanical oscillations leads to thermal stripping. At the same time, the tooling system used produces a defined node cross section with welded single wires. The compacted high-frequency litz wire can subsequently be welded onto contact terminals using the ultrasonic welding process. A direct welding of high-frequency litz wires with terminals is rather difficult to implement since the primary insulation hinders the welding process [23].

4.4. Insulation Technologies

After the connection, the pad must become robust, electrically insulated and protected from external influences (water, dust, salt, etc.).

The insulating matrix around the high-frequency litz wire coil is a combination of the primary and secondary insulation. While the term secondary insulation clearly refers to resin encapsulation, the primary insulation can be divided into the litz wire enamel (standardized according to IEC 60317, IEC 60851) and the wrapping made of natural or synthetic materials.

In the context of this study, the primary and secondary insulation differ significantly in terms of production and function. For the primary insulation, the individual wires are covered with a thin, electrically insulating enamel. The additional wrapping of the high frequency litz wires is done by banding, extrusion or spinning with natural silk, nylon, polyamide, polyester, polyethylene or polyimide. Despite the large number of individual conductors, this leads to a high degree of cohesion of the strand and to a high mechanical stability during the laying of the coil. The secondary insulation ensures the protection of the electrical components against mechanical and chemical environmental impact and the dissipation of generated heat. A dielectric potting material should be selected to keep eddy current losses low and to prevent electrical breakdown [24–26].

5. Implementation on a Concrete Demonstrator

Within the E | Profil project funded by the BMWi and DLR, a demonstrator was set up at FAU. The design is specified in accordance with WPT3 SAE J2954 [27]:

- WPT Power class, 11 kW
- Coil-to-Coil efficiency > 96%

- Dimension: ~300 mm × 300 mm (based on SAE2954 (WPT3 Z1)) [27]
- Input: 11.1 kVA and 400 V
- Stranded HF litz wire

The selection and implementation of the processes for the project demonstrator will be described in the following sections.

5.1. Laying of the Litz Wire

After the controlled uncoiling of the stranded wire from the supply reel, the stranded wire is laid with a coiling tool. For this purpose, a specific guide and wire tension control for stranded wire have been integrated into a custom universal 15-axis winding machine. The wire is guided to the deposit point and deposited in a rotating spool carrier with guide grooves which remains in the subsequent spool module (see also Figure 5 (left)).



Figure 5. Manufacturing cell for flat coil winding (**left**), ultrasonic welding system and contacted litz wires (**right**).

5.2. Contacting

Within the scope of the production of the demonstrator, various contacting solutions for contacting the high frequency litz wire are being evaluated. These include the already mentioned technologies of hot and ultrasonic crimping, but also processes that enable a contacting on contact terminals. The primary insulation used complicates terminal contacting in particular. Nevertheless, it has been shown that torsional ultrasonic welding can also be used to weld primary-insulated litz wires directly onto contact terminals. In a two-stage process, the litz wire is compacted, stripped and welded onto the terminal. However, necessary gap dimensions between the tools as well as burning residues require further optimization of the welding process. Furthermore, the ultrasonic crimping process shows to be an energy-efficient alternative contacting technology for tubular cable lugs. However, there is also a demand for further optimization of this process in order to ensure that the technology is suitable for series production. The hot crimping process has proven to be an extremely robust and well-suited process. The achievable contacting quality is subject to only minor fluctuations. By slightly adjusting the process parameters, it is also possible to join taped and PAI primarily insulated high-frequency litz wires to tubular cable lugs. Therefore, the hot crimping process is used as a reference contacting process in this research project. However, the extremely promising torsional ultrasonic crimping and welding process will be further optimized for future applications. Figure 5 (right) shows, in addition to exemplary test samples, the ultrasonic welding system used and various contacts produced.

5.3. Insulating

A dielectric potting material should be selected as secondary insulation to keep eddy current losses low and to prevent electrical breakdown. Epoxy resin is characterized by excellent product and process properties and is therefore widely used in encapsulation processes [24].

Several sub-process steps are necessary to prepare a self-leveling, thermosetting, dielectric molding mass. Figure 4 gives a detailed view of the insulation process and its integration into the IPT process chain. Each sub-process step is characterized by different process parameters.

The process for encapsulating the electrical components consists of the resin preparation, the dosage and the mixing of the resin and hardener, the potting, and finally the curing of the molding mass. During the preparation phase, the resin and the hardener get tempered and dried to reduce moisture and set the process relevant viscosity for the mixing and potting. The mixing step is needed to homogenize the resin and hardener to a reactive molding mass. Within this step, the polymerization begins and the potlife must be monitored carefully. The potting phase is the actual insulation process of the IPT, where the molding mass is dosed via the casting nozzle into the coil and carrier. By processing in a vacuum chamber (see Figure 6a), a higher degree of litz wire impregnation can be achieved [26]. After the potting, the coil is transferred to the curing stage, where the crosslinking and therefore the viscosity of the resin material increases. By processing in a convection oven, the material specification such as the glass transition temperature and the degree of crosslinking can be set to defined values. By varying these, the challenges in the processing of resin-based insulation materials for wireless power transfer applications can be evaluated in more detail.

The studies of M. Kneidl et al. [26], summarized the most important process parameters of the complete encapsulation process, which result in a good product quality of the insulation system. By analyzing the process chain, the overall process time is mostly determined by the curing step of the insulation resin. Therefore, the curing time can be reduced by 75% with increased temperatures of up to 80 °C. Another positive effect due to higher material and curing temperatures is a better impregnation of the high-frequency litz wires, due to the lower viscosity of the resin. This results in optimized dielectric properties. Further on, optimizing the insulation quality by using a vacuum process is dependent on the type of primary insulation, which is used for the litz wires [26].

5.4. Assembly of the Ferrites

For the assembly of the ferrites, the following process steps result in the system setup, shown in Figure 6b). The system components are mounted on the workstation base with numerous mounting options. The components include the cycle chains as provisioning tools for material replenishment, a cobot as the central handling device with the vacuum gripping system, and the measuring station with an optical 2D industrial camera.

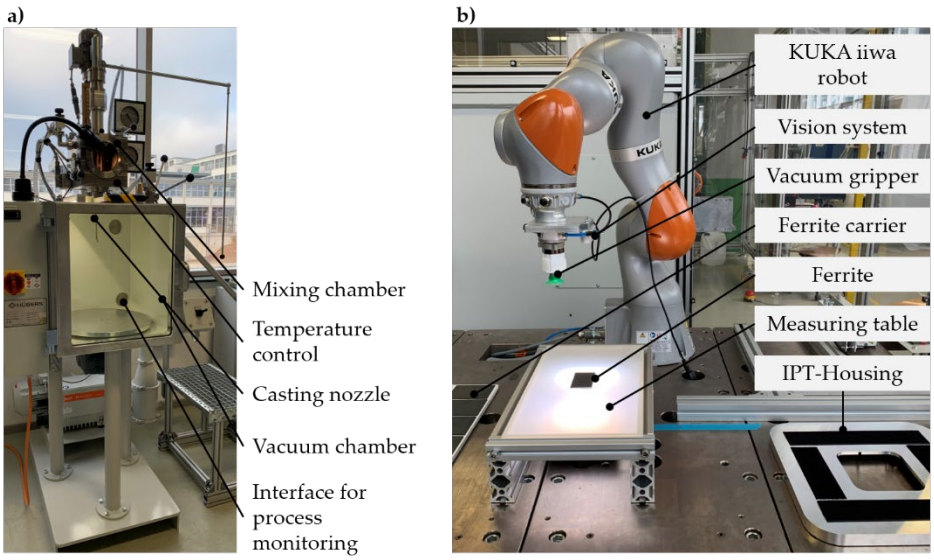


Figure 6. Vacuum potting machine (**a**), robot-based ferrite structure assembly (**b**).

In the first process step, the fixture of ferrites in the charge pad housing is prepared. The fixation can be realized by adhesives, tapes or varnishes.

The next process step is the individual conveying of a ferrite through the system. In interaction with the vacuum end effector, the robot arm takes a ferrite tile from the workpiece carrier and conveys it to the measuring table. For the robot to pick up the ferrite, the control program must know the information about the arrangement and current stock of materials in the workpiece carrier. A constant supply of compressed air for the vacuum gripper is necessary so that a secure fixation can be maintained permanently. The most important tasks are the safe holding of the workpiece and the fast and collision-free movement through the process plant. All stations must logically be accessible in the COBOT's workspace.

For high process speeds, the travel distances must be kept as short as possible and non-linear. This means that speed-optimized conveying additionally contributes to economical production. However, adapted and linear movements should be used for the "pick-up", "measure" and "assemble" process stations. This increases the process reliability and precision of the work steps and ensures collision-free pickup and assembly processes.

The optical 2D industrial camera records the geometric dimensions, any damage present, and the orientation of the current ferrite on the backlit measuring table. The COBOT moves to a defined position in the detection range of the camera. There it remains in a waiting position until the inspection is completed. The dimensions in length and width of the ferrite, as well as its position on the vacuum gripper, are recorded with a certain accuracy. These data can be evaluated and interpreted with suitable software. The *actual* values are compared with the *target* values and manufacturing tolerances from the data sheets. In addition to the deviations of the ferrite dimensions, the deviations from the ideal position of the tile on the gripper is also checked.

When picking up from the blister, twisting or displacement of the breakpoint could occur due to incorrect orientation of the ferrite. All captured and determined data is fed back into the process and included for the assembly process. After being conveyed from the measuring station, the ferrite reaches the mounting station. The COBOT moves to the planned position for the current tile above the housing. The correct position is defined to the robot controller using the coordinate system for the layout according to the loading pad design. Using the information from the survey station, it is known whether the current ferrite has deviations in its manufacturing dimensions and in its position on the gripping system. If this is the case, the robot controller can make the necessary corrections. This means that the ferrite is brought into a suitable position by the movements of the COBOT. The correct positioning of the ferrite tile is thus achieved. However, the accuracy of this result depends on the quality of the measurement data and the robot accuracy. The ferrite is over its assigned place and is ready for the curing of the chosen fixation.

6. Test Technologies

A first test bench is used for recording the efficiency, the offset, the temperatures and the EMC emissions of the pad. Initially, various concepts were developed for recording the above-mentioned variables, whereby the determination of the efficiency or the associated measurement of current and voltage proved to be the most difficult task. Due to the high frequencies of the voltage at the charging pads, it was not possible to use the most common measuring devices. A further challenge was the necessary galvanic isolation, as few measuring systems available on the market have one.

For this reason, completely galvanically isolated measurement electronics was developed and implemented on a 3-Axis linar production cell. In order to detect possible temperature changes in the charge pads or other components of the contactless power transmission system, a temperature measuring system was designed and developed. In order to be able to carry out EMC measurements, an EMC probe was integrated into the test bench. Through the produced serial cable and the integration into the created LabView, the probe can be used for measurement. At the serial output, it supplies only field strengths

averaged over all spatial axes, but this is sufficient for an evaluation of the measured field strengths. IPT systems, as the limit values to be complied with by legislators, are determined in the same way.

In a second step, an EOL test was build up. It is able to measure the quality factor of the coil or the transmission efficiency in power transmission mode.

7. Conclusions

In this paper, the principle of wireless vehicle charging and the associated process chain were presented. Using the example of a demonstrator set up in the E | Profil project, the process chain for manufacturing a secondary system was presented. The next step is the integration of the charging technology into the infrastructure. As part of the E | Road project launched at FAU in summer 2021, the necessary production steps for concrete roads will be investigated. Important research aspects here are:

- Design of the coil modules suitable for production
- Automation-compatible processes for manufacturing the coil modules
- Integration of the coil modules into the roadway using precast concrete construction methods
- Construction of an electrified test track on the duraBASt demonstration site

The completion of this extensive research work is intended to demonstrate that inductive charging technology is a feasible solution for the mobility of the future.

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Abbreviations

AGV	Automated Guided Vehicles
EMC	Electromagnetic Compatibility
EOL	End Of Line
EV	Electric Vehicle
ICNIRP	International Commission on Non-Ionizing Radiation Protection
IPT	Inductive Power Transfer
HF	High Frequency
OLEV	On-Line Electric Vehicle
PAI	Aolyamideimide
PATH	Aartner for Advanced Transit and Highways
WPT	Wireless Power Transfer

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