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Foreign object detection technology in wireless charging system for electric vehicles

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Abstract:

With the development of the electric vehicle wireless charging field, the landing of the technology is accompanied by several obstacles, including foreign objects in the charging area has become a major problem affecting charging efficiency and safety. Therefore, this paper studies the foreign object detection technology in the wireless charging system, first summarizes the types of foreign objects that mainly affect the system, then analyzes the principles and advantages and disadvantages of various foreign object detection technologies for different types of foreign objects, and finally points out the current problems and future development direction of the current foreign object detection technology, which provides a reference for the subsequent development of foreign object detection technology.

Keywords: electric vehicle, wireless power transfer, foreign object detection, metallic object detection, living object detection.

1 Introduction

Wireless Power Transfer (WPT) is a technology for transferring energy via radio waves or other electromagnetic waves. It aims to realize the transfer of electrical energy from one location to another without a direct physical connection. Specifically applied to the field of electric vehicles, Magnetic Field Wireless Power Transfer (MF-WPT) is currently the mainstream technology development direction[1]. This technology is usually based on the principle of electromagnetic induction and transmits energy through the interaction of high-frequency alternating coupled magnetic fields between the transmitter and receiver. The transmitter is usually located directly under the car charging module, and the magnetic field is distributed in the area between the car chassis and the ground. Due to the influence of natural or man-made factors, foreign objects will inevitably appear in the area of the alternating coupled magnetic field, thus affecting the transmission power and efficiency of car charging, and in more serious cases, it may lead to several safety problems [2-4]. At the same time, the electromagnetic radiation generated in the wireless charging process may also cause harm to living organisms, therefore, the development of foreign body detection technology for wireless charging is imperative [5,6].

2 Types of foreign objects

The so-called foreign objects, such as coins, chewing gum, tin foil, magnetic or non-magnetic metal objects, and some small animals, etc., are not part of the wireless charging system but will affect the transmission performance and safety of the system, or may be affected by the electromagnetic radiation of the system of the object or organisms are called foreign objects. Foreign matter generally includes metallic foreign objects and biological foreign objects.

2.1 *Metallic foreign objects*

Metallic foreign objects are subdivided into ferromagnetic foreign objects and non-ferromagnetic foreign objects, the main difference between the two is whether they can be attracted by magnets, common ferromagnetic and non-ferromagnetic metals as shown in Figure 1.

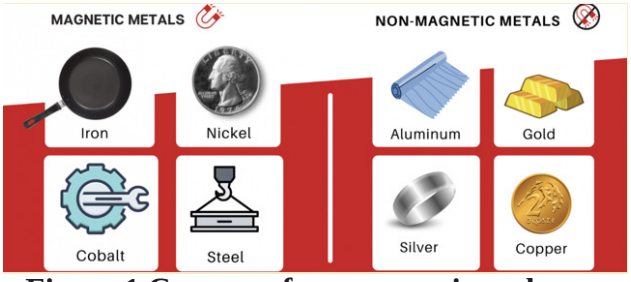

Figure 1 Common ferromagnetic and non-ferromagnetic metals

When non-ferromagnetic metal enters the energy transfer area of the wireless charging system, it only generates the

eddy current effect, and when the ferromagnetic object enters the energy transfer area of the wireless charging system, it generates both the eddy current effect and magnetic effect.

According to the research, the loss of 100cm^3 of iron eddy current can reach 33W, so the existence of metal eddy current will largely reduce the transmission power of the system. When heat dissipation is not taken into account, the iron mixed into the energy transmission area of the wireless charging system will increase by 60°C in 10 min, which is a great safety hazard for the car and the wireless charging system [7]. The magnetic effect is manifested in the concentration of the magnetic field on the metal surface, resulting in uneven distribution of the magnetic field, or making the magnetic field attenuation on the metal surface, which also affects the transmission power of the system.

2.2 *Living foreign objects*

In the process of popularization of wireless charging of electric vehicles, its use of the site will inevitably be widely spread to all aspects of life, so some small creatures and even human beings themselves will have a high probability of exposure to the electromagnetic field that exists in wireless charging. In the wireless charging of electric vehicles, the magnetic coupling resonant electromagnetic field frequency is between 100kHz-50MHz, which belongs to a high-frequency electromagnetic field, according to the current research, high-frequency electromagnetic field will have a certain impact on the organisms in various aspects, and the electromagnetic radiation generated by the organisms will have a serious impact on the health of the organisms [8-10]. Therefore, it is very necessary to avoid the close and direct contact of living organisms with the high-frequency electromagnetic field in the wireless charging area.

3 Foreign Object Detection Technology

The electric vehicle wireless charging foreign object detection technology is a safety feature used in wireless charging systems. Its purpose is to detect the presence of foreign objects in the charging area during electric vehicle charging to avoid potential safety risks and damage. Typically, this technology uses sensors or other detection devices to monitor the charging area for the presence of unauthorized objects. Different detection and inspection technologies have different advantages and characteristics for different types of foreign objects.

3.1 *Detection technology for metallic foreign objects*

The current detection techniques for metallic foreign objects are divided into two main aspects, one is to impose a set of auxiliary coil detection techniques independent of the charging system, and the other is a technique that directly utilizes the system parameters for detection.

3.1.1 *Auxiliary coil detection technology*

This method usually involves laying the detection coil on top of the transmitting coil, and when the metallic foreign object is close to the detection area, the inductance, impedance, and other parameters of the detection coil will change, thus realizing the detection of the foreign object. However, if the size of the metallic foreign object is very small, the parameters of the detection coil are not easy to change, and there are also problems such as the detection of blind zones. Therefore, how to improve the sensitivity of the detection coil system and eliminating the detection blind spot of the system has become the main problem solved by various researchers in recent years.

The advantage of the auxiliary coil detection technology is that it has low cost and good reliability, and its sensitivity can be improved by adjusting the relevant algorithms or rationally designing the array of detection coils to eliminate the detection blind zone [11]. However, the detection coil takes up a certain amount of space, and when the detection technology is not aligned between the transmitting coil and the receiving coil, the detection accuracy will be affected to a certain extent.

3.1.2 *System parameter detection technology*

For the detection of metallic foreign objects, it is also possible to determine whether there are foreign objects intervening by detecting changes in certain parameters of the charging system, such as voltage, current, resonance frequency, power loss, quality factor of the coil, and so on.

The advantage of the system parameter detection technology is that its realization method is very simple and does not need to take up additional space, but when the size of the metal foreign body is very small, the change of the system parameters caused by the system is not obvious, so the ability of this technology for the detection of small metal is a problem that needs to be solved urgently, and at the same time, when the charging coil is shifted, it will also affect the ability of the system detection.

3.2 *Detection technology for Living foreign objects*

Due to the complex characteristics of living organisms, the accuracy and real-time requirements of the detection system are high, in recent years, the birth of many new technologies for the detection of living organisms and foreign objects pointed out the direction, such as visual detection technology, ultrasonic detection technology, and

microwave radar detection technology. These technologies not only have the ability to detect different objects but also have unique advantages for the detection of organisms.

3.2.1 *Visual Inspection Technology*

Visual detection technology usually consists of a camera or a thermal imaging camera combined with some image processing techniques, and when a live object (e.g., a person or an animal) is detected in the detection area, the system captures and processes the image to issue an alarm or stop the charging operation. Due to the rapid development of artificial intelligence in recent years, machine learning is widely used in image processing techniques. Machine learning uses datasets for training to automatically learn data features from a model, which reduces the amount of work involved in feature engineering and is highly adaptable and accurate.

The technology has many advantages, for the detection of organisms can achieve high detection sensitivity and, at the same time has the diversity and flexibility, for a variety of foreign objects, including metal foreign objects have a certain role, coupled with the fact that its system can be adapted and optimized according to the actual application scenarios, has become a major hotspot in the foreign object detection technology today.

3.2.2 *Ultrasonic Inspection Technology*

The ultrasonic detection i.e. ultrasonic sensors are used to detect objects in the charging area. When objects are close to the sensor, they reflect ultrasonic signals which the system can detect and take action accordingly. The system can detect and take action on the objects in the charging area,

Ultrasonic detection technology is known for its high resolution, high accuracy, and low cost, for the detection of living organisms can be dynamic monitoring and real-time feedback, and the application environment is also very wide. On the other hand, this detection technology has the advantages of good directionality and, a wide measurement range. It is not easily interfered with by external environmental factors such as dust, light, electromagnetic field, etc., which makes it very suitable for the detection module of the living creature in the wireless charging system.

3.2.3 *Microwave Radar Detection Technology*

Microwave radar foreign object detection technology is a system that utilizes microwave radar technology to detect the presence of an abnormal object or the presence and location of an object in a specific area. First, the system sends microwave signals to a specific area through one or more microwave antennas. These microwave signals propagate at a specific frequency and wavelength, and when the microwave signals encounter an object, they will be reflected and captured by the receiver, obtaining information about the reflected object and thus determining the object's characteristics.

The foreign object detection technology of microwave radar has certain similarities with ultrasonic detection technology. In addition to the advantages that ultrasonic detection systems have, this technology can also achieve a wide range of detection area coverage, and multi-target high-precision detection capability, which is more suitable for the environment of large charging places. It is very helpful for the detection of organisms in wireless charging systems.

4 Current Problems and Future Directions of Foreign Object Detection

4.1 *Current Problems*

(1) Low Accuracy and Reliability: Existing foreign object detection technologies continue to present challenges in terms of detection accuracy and reliability. Although many detection methods and systems have been proposed, practical results may vary in different environments and have limited ability to detect small or hidden foreign objects.

(2) High industrialization cost: Some efficient foreign object detection technologies such as infrared thermography, millimeter radar, and other devices in the current proposed foreign object detection scheme may face high costs in practical applications, including equipment costs, installation costs, and maintenance costs. This may limit their feasibility in large-scale applications and increase the total cost of the wireless charging system.

(3) Lack of harmonized testing standards. Different manufacturers and research organizations may adopt different testing methods and indicators. This leads to a lack of uniform evaluation and comparison standards, which makes the promotion and application of the technology somewhat affected.

4.2 *Future Direction*

(1) Combination with emerging technologies. The current artificial intelligence technology, machine learning and big data, and other emerging technologies are rapidly emerging and widely used, so the foreign object detection technology of wireless charging of electric vehicles can also ride on the wave of artificial intelligence, using these cutting-edge technologies to optimize the detection algorithm, improve the degree of hardware integration, and use machine learning and other technologies to improve the reliability and sensitivity of detection and so on. Therefore, opening up new research in the field of artificial intelligence in the future is one of the important

development directions of foreign object detection technology.

(2) Enhance the anti-interference ability of foreign object detection in electric vehicles to the environment. Popularizing electric vehicle wireless charging technology means that wireless charging technology is widely used in various scenes in life, so its foreign object detection technology should also be closely integrated with these scenes. Environmental factors, human factors, and other aspects should be fully considered to ensure that the foreign object detection technology can still play its role accurately, effectively, and safely under extreme weather or man-made interference.

(3) Increase the attention to biological foreign objects. The current research on foreign body detection technology for electric vehicles mainly focuses on metal foreign bodies but pays relatively little attention to biological foreign bodies, and it has a certain degree of limitation. Therefore, with the development of technology and popularization of application, safety will be paid more and more attention to, and therefore the importance of detection of biological foreign bodies is increasing, so future research should pay more attention to biological foreign bodies, and develop more scientific and effective detection methods. In the future, we should pay more attention to the detection of foreign bodies, develop more scientific and effective detection methods, and accurately and rapidly realize the detection of foreign bodies in the wireless charging of electric vehicles.

5 Conclusion

This paper analyzes and researches the foreign object detection technology in the wireless charging system of electric vehicles, starting from the type of foreign objects, characterizes the metal foreign objects and biological foreign objects that mainly affect the charging system, then introduces different detection technologies for different foreign objects and analyzes their feasibility and advantages and disadvantages. Finally, it points out the current problems and future development direction of foreign object detection technology, which provides technical accumulation for the further improvement and landing of this foreign object detection technology in the field of wireless charging of electric vehicles in the future.

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