Research on Temperature Rise Performance of EV Charging Coupler

Qianqian Wei*, He Chen, Jiaojiao Wang and Xiao Li
CATARC Automotive Test Center (Tianjin) Co., Ltd, Tian, China

*Corresponding author email: Weiqianqian@catarc.ac.cn

Abstract. In order to correctly evaluate the temperature rise performance for Electric Vehicle charging Coupler more reasonably, this paper analyzed the factors affecting the temperature rise performance, compared the existing standards and regulations. The test and verification activities were carried out from two aspects of temperature rise evaluation method and complex environment adaptability, and a more rigorous temperature rise evaluation method was proposed.

Keywords: Temperature rise, Charging coupler, Reliability.

1. Introduction
Energy saving and environmental protection is an inevitable trend of the automobile industry. With the strong guidance of national policies in China, the electric vehicle industry has developed rapidly, and electric vehicles have been widely recognized by consumers. But in recent years, there have been many fire accidents occurred, while people enjoy the convenience offered by electric vehicle, they still worry about its safety.

The development of electric vehicle involves the coordinated development of automobile industry and energy industry. Providing safe and reliable energy supply for electric vehicles is an important support and key link in the process of industrialization and commercialization of electric vehicles. For conductive charging, the charging coupler, as the link between electric vehicles and charging supply equipment, plays an important role in ensuring charging safety and reliable operation of charging process and realizing reliable real-time interaction between electric vehicles and charging supply facilities.

Temperature rise test is an important test to evaluate the performance of charging coupler. In the process of long-term continuous charging, the temperature rise performance varies due to the aging of materials and frequent using and the adaptability of different environments, etc. Reasonable verification of the temperature rise performance of the charging coupler is crucial to ensure the safety of conductive charging.

2. The Connection Architecture of Charging System
Conductive charging is divided into AC charging mode and DC charging mode. AC charging mode is mainly used in residential areas, with small charging current and long charging time. DC charging mode is mainly used in centralized charging stations, with large charging current and short charging time.

The connection architecture of the two charging modes is shown in figure 1. As the connection link between the electric vehicles and the charging supply equipment, the temperature rise performance of the charging coupler is crucial to ensure the conductive charging safety of electric vehicles.
3. Analysis of Factors Affecting the Temperature Rise Performance of Charging Coupler

As shown in Figure 2, the main factors affecting the temperature rise performance of the charging coupler are: the design of the charging coupler, such as the contact resistance of the terminal pair, load current capacity, charging time, cable cross-sectional area, and the selection of materials; Poor compatibility between charging plug and charging socket of different brands; Factors in use, such as frequent use results in the terminal conductive layer wear and contact resistance increased and conductive performance decline. The charging supply equipment is placed in the outdoor environment for a long time, which has poor durability and is easily affected by the environment such as high temperature, high humidity, rain and snow, sand and dust, and corrosive gas. As a result, the performance of the charging plug will decline, and the phenomenon such as over temperature and ablation will easily occur, which may be transferred to the charging socket in the charging process, resulting in cross-infection.

In this paper, the structure design, material selection and compatibility of charging interface are not considered, we should pay attention to the reliability and operating environment during the service cycle.
4. Analysis of Existing Standards

4.1. Analysis of Temperature Rise Test Standard for Charging Coupler

GB/T 20234.1-2015 is the compulsory inspection standard and CCC certification standard in China. As shown in Table 1, the differences of test methods between GB/T 20234.1-2015 and IEC 62196-1:2014 are mainly reflected in the processing and determination methods of external temperature data. In GB/T 20234.1-2015 and IEC 62196-1:2014, Compliance is checked at an ambient temperature of (25±5) °C, but in IEC 62196-1:2014, the results obtained should be corrected to an ambient temperature of 40°C. For example, when the ambient temperature is 20°C, the temperature correction is 20°C, and when the ambient temperature is 30°C, the temperature correction is 10°C, the range of temperature correction is 10°C~20°C. Therefore, the external temperature values measured according to IEC 62196-1:2014 is 10°C~20°C higher than the external temperature measured according to the GB/T 20234-2015, IEC 62196-1:2014 is more rigorous than GB/T 20234-2015.

Table 1. Temperature rise test standard analysis of charging Coupler.

| Standard | GB/T 20234.1-2015 | IEC 62196-1:2014 |
|----------|-------------------|------------------|
| Ambient temperature | (25±5)°C | (25±5)°C |
| Test current | Load current | Test current |
| | 16A | 22A |
| | 32A | 40A |
| | ≥63A | Rated load |
| Test time | Thermal stabilisation is considered to have occurred when three successive readings, taken at intervals of not less than 10 min, indicate no increase greater than 2 K[3,4] |
| External temperature requirement | For parts which may be grasped: 50°C for metal parts; 60°C for non-metal parts. For parts which may be touched but not grasped: 60°C for metal parts; 85°C for non-metal parts. | The results obtained should be corrected to an ambient temperature of 40°C. For parts which may be grasped: 50°C for metal parts; 60°C for non-metal parts. For parts which may be touched but not grasped: 60°C for metal parts; 85°C for non-metal parts[4] |

4.2. Temperature Rise Test Standard Analysis of Charging Supply Equipment

According to GB/T 18487.1-2015, the internal temperature rise of the charging supply equipment is measured at the ambient temperature of 25°C and the rated load, while the external temperature rise is measured at the ambient temperature of 40°C and the rated load. According to NB/T 33008.1-2018 and NB/T 33008.2-2018, the external temperature rise of the charging supply equipment is also measured at the ambient temperature of 40°C, but the load current is the same as the test current stipulated in GB/T 20234.1-2015.

4.3. Analysis of Temperature Rise Test Method

Through the above comparative analysis, the temperature rise performance of the charging Coupler in different test standards are as follows:

- Ambient temperature: In GB/T 20234.1-2015 and IEC 62196-1:2014, Compliance is checked at an ambient temperature of (25±5) °C, but in IEC 62196-1:2014, the results obtained is corrected to an ambient of 40°C. In NB/T 33008.1-2018 and NB/T 33008.2-2018 and GB/T 18487.1-2015 and IEC 61851-22.2001, Compliance is checked at an ambient temperature of 40°C.
- Test time: The expression of the equilibrium time in different standards is slightly different.
- Test current: The main difference is that when the rated load is less than or equal to 32A, the test current is greater than the rated load current value.
- External temperature requirements: External temperature requirements are specified in IEC GUIDE 117 *Electrotechnical equipment-Temperature of touchable hot surfaces* and will not be elaborated in this paper.

In addition, there is a lack of environmental adaptability assessment in the relevant testing standards of charging Coupler.

**Table 2. Temperature rise test standard analysis of charging supply equipment.**

| Standard | GB/T 18487.1-2015 | NB/T 33008.1-2018 | NB/T 33008.2-2018 |
|----------|-------------------|-------------------|-------------------|
| Ambient temperature | 40°C | 25°C | 40°C |
| Test current | Rated load | | |
| Test time | | | |
| The temperature rise of terminals | | No more than 50K | |
| External temperature requirement | For parts which may be grasped: 50 °C for metal parts; 60 °C for non-metal parts. | For parts which may be grasped: 50 °C for metal parts; 60 °C for non-metal parts. | For parts which may be touched but not grasped: 60 °C for metal parts; 85 °C for non-metal parts.[5] | For parts which may be touched but not grasped: 60 °C for metal parts; 85 °C for non-metal parts.[6,7] |

5. The Research of Temperature Rise Test

5.1. Temperature Rise Performance at Different Ambient Temperatures

5.1.1. Terminal Temperature Rise Test

There are three 200A DC charging Supply equipment with different brands and models but the same wire diameter. The temperature rise performance of the sub-internal terminals is tested under different ambient temperatures.

As shown in table 3 and figure 3, under different ambient temperatures, the temperature rise of the terminals showed a slow decreasing trend with the increase of the ambient temperature, and the maximum difference among the three groups of samples was 1.5k at 40°C and 25°C.
There are three 32A AC charging Supply equipment with different brands and models but the same wire diameter. The temperature rise performance of the sub-internal terminals is tested under different ambient temperatures.

As shown in table 4 and figure 4, under different ambient temperatures, the measured temperature rise of the terminals showed a slow decreasing trend with the increase of the ambient temperature, and the maximum difference among the three groups of samples was 2K at 40℃ and 25℃. It can be seen that ambient temperature has little effect on terminal temperature rise, but great effect on actual terminal temperature. When the use of high ambient temperature, there may be a temperature rise in line with the requirements, but the actual terminal temperature has been very high. Therefore, it is more stringent with a higher ambient temperature.

Table 4. The temperature rise of AC charging coupler at different ambient temperatures.

| Ambient Temperature/℃ | A1# temperature rise /K | A2# temperature rise /K | A3# temperature rise /K |
|------------------------|-------------------------|-------------------------|-------------------------|
| -25                    | 23.9                    | 22.8                    | 23.2                    |
| -10                    | 24.7                    | 26.4                    | 24.5                    |
| 0                      | 24.1                    | 26.4                    | 24.3                    |
| 25                     | 22.2                    | 25.6                    | 22.9                    |
| 40                     | 20.2                    | 23.7                    | 21.2                    |
5.1.2. External Temperature Rise Test

As shown in table 5, the temperature measured at 25 °C after data correction is consistent with the temperature measured at 40 °C. Therefore, according to GB/T 20234.1-2015, at (25 ± 5) °C ambient temperature, the external temperature measurement value of the charging coupler is lower.

Table 5. The temperature rise of parts which may be grasped.

| Ambient Temperature/°C | DC/°C | AC/°C |
|------------------------|-------|-------|
| -25                    | -23.5 | -22.9 |
| -10                    | -8.1  | -7.9  |
| 0                      | 1.6   | 1.6   |
| 25                      | 26.7  | 26.3  |
| 40                      | 41.1  | 41.3  |

5.2. Temperature Rise after Durability

Simulate the temperature and humidity changes, rain and sand dust, salt spray, fatigue and wear that may be encountered in actual use. A durability test was designed. There were three new samples tested for temperature rise performance, and re-tested after high temperature and high humidity aging. Then the life test was carried out, and the temperature rise performance was measured again. Then the aging test was carried out again. After the aging test, the temperature rise performance was measured again. The test results are shown in figure 5. After the aging test, the temperature rise of the new samples decreased obviously. After the life test, because of the terminal clad layer suffered varying degrees of damage, the contact resistance increased and the temperature rose significantly. After the aging test, because of varying degrees of corrosion of the terminal, the contact resistance become larger, and the temperature rise was more obvious. Therefore, for the new product inspection, after the life test and aging test, the re-test of temperature rise performance is very meaningful for the evaluation of temperature rise performance.
6. Conclusion
The temperature rise performance of the charging coupler is very important to ensure the charging safety and reliable operation of the conducting charging process. In this paper, the factors affecting the temperature rise performance of the charging coupler are analyzed, the technical requirements and test methods in related standards are compared and analyzed and tested, the adaptive test and evaluation methods are researched.

With the development of high-power charging technology, the temperature rise control of charging coupler becomes more and more challenging. Temperature rise control technology, test and evaluation methods are still one of the key research topics in the future.

References
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