Experimental analysis of electric vehicle energy consumption under low temperature and shortened test conditions

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Abstract. With the popularization of electric vehicles, more and more attention has been paid to how to select reasonable test methods to evaluate the driving range of electric vehicles. This paper selects two electric vehicle prototypes with different configurations to test the energy consumption of the shortened test cycle at normal temperature and the standard test cycle at low temperature, and analyzes the constant speed working condition in the shortened method and the CLTC-P working condition at low temperature. The results show that both the 100km/h constant speed working condition and the low temperature working condition will cause a significant increase in the energy consumption of electric vehicles, and the energy consumption difference of repeated cycles under the low temperature test condition will also increase significantly compared with that at room temperature. The relevant results are more A comprehensive understanding and evaluation of the energy consumption characteristics of electric vehicles provides a useful reference.

1 Introduction

In recent years, more and more countries pay attention to environmental and energy problems, and actively look for solutions, the development and promotion of electric vehicles has become a key link to solve the problem [1] [2] [3]. Compared with traditional fuel vehicles, electric vehicles have the advantages of high acceleration, mute, and zero emission in the driving process and can participate in the auxiliary services of the national power grid. Therefore, electric vehicles are strongly supported by the state. However, with the increase of possession, the problems of electric vehicles also gradually emerge. for example, due to the limitation of battery technology, the driving range of electric vehicles is not as good as that of fuel vehicles, and the battery efficiency decreases further in a low temperature environment. as a result, the driving range is even more unsatisfactory [4] [5]. Therefore, in order to fully analyze the energy consumption performance of electric

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vehicles, it is necessary to test the energy consumption at room temperature at the same time.

Based on the standard test method, China Automotive Technology & Research Center has put forward a more perfect energy consumption test scheme, that is, service life under Chinese operating conditions. The driving range test in China includes normal temperature driving mileage test, low temperature driving mileage test and high speed driving mileage test. Among them, the normal temperature driving mileage test is combined with CLTC-P and constant speed condition (100km/h). On the other hand, the low-temperature driving mileage test is carried out in the low-temperature CLTC-P test, which runs CLTC-P continuously under the condition of using air-conditioning for heating. On the other hand, the continuous driving mileage test of the high speed is completed at a higher constant speed.

The electric vehicle energy consumption test scheme includes complex urban conditions, high-speed driving conditions and low temperature tests not included in the NEDC test, which can more completely measure the real energy consumption level of electric vehicles [6]. Compared with the test method of GB/T18386-2017 "*Test method for Energy consumption rate and driving range of Electric vehicles*", this paper mainly studies the influence of different factors on the test results of DC energy consumption under this scheme, because it introduces more changes than the test method of energy consumption and mileage of electric vehicles.

2 Testing method

2.1 Introduction of test condition

In this paper, the driving mileage of the test vehicle is tested at room temperature and low temperature respectively. The driving condition of continuous driving mileage at room temperature is shown in figure 1, and the DS section is the constant speed condition of CLTC-P, CSS section and 100km/h section. However, the low temperature mileage test still uses the CLTC-P as shown in 2.
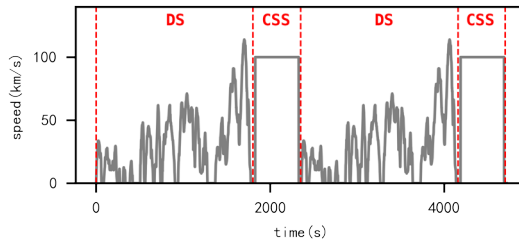
Fig. 1. Normal temperature mileage test condition.
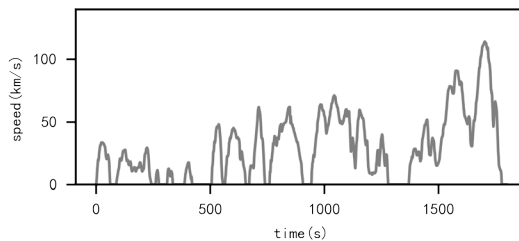
Fig. 2. Low temperature mileage test condition.

Although the high-speed continuous driving mileage test is not carried out, because the DC energy consumption test method is used for the energy consumption test, the energy consumption value of CSS end in the room temperature continuous driving mileage test can be directly obtained as the energy consumption result of the high-speed continuous driving mileage test.

2.2 Test equipment process

This article refers to the test procedure of GB/T18386.1-2021 "*Test Method for Energy Consumption Rate and Driving Range of Electric Vehicles*" to prepare the two test prototypes. In the driving range test at room temperature, the vehicle is immersed at an ambient temperature of (23±3)℃ for 12-15 hours, and then the test is carried out at (23±3)°C to simulate conventional electricity usage scenarios. In the low-temperature driving range test, the vehicle is immersed for 12-15 hours at an ambient temperature of (-7±3)℃, and then the air-conditioning heating is turned on at (-7±3)℃ for the test to simulate the typical winter low-temperature car Scenes.

Use the AVL chassis dynamometer to record the speed of the test vehicle during the test, and use the daily power analyzer to record the power of the test vehicle to calculate the DC energy consumption.

2.3 Data processing

The processing results of the speed data and power data of the normal temperature driving range of the two test prototypes are shown in Fig. 3. Among them, the vehicle has completed four CLTC-P and two constant speed conditions. The data processing results of the low-temperature driving range test are shown in Figure 4. The first test vehicle completed 14 complete CLTC-P, and the second test vehicle completed 7 complete CLTC-P. At the end of the curve, the entire test ended because the speed tolerance could not be met. In this paper, the discrete Simpson integral formula is used to solve the travel distance and energy consumption of CLTC-P and constant speed conditions:
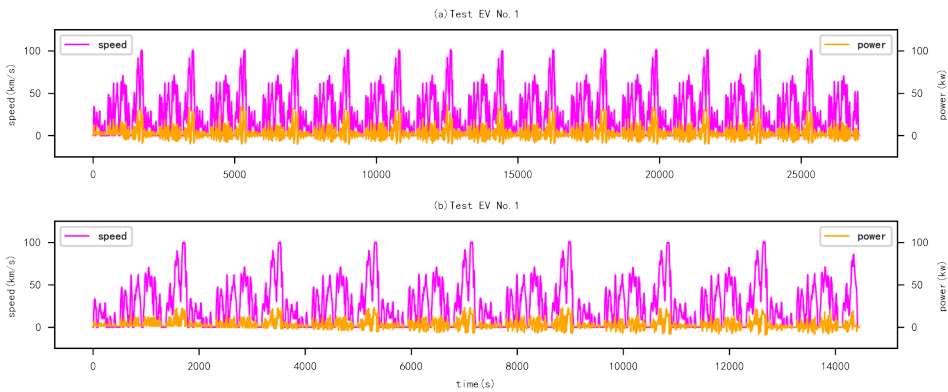
$$I = \int_b^a f(x)\,dx\,(a < b)$$

In each unit, a parabola is used to approximate the curve of the function f(x). Therefore, the discretization of the definite integral can be expressed as:

$$I = \int_b^a f(x)\,dx \approx \frac{b-a}{6n}\left(\begin{array}{l} y_0 + y_{2n} + 4(y_1 + y_3 + \cdots + y_{2n-1}) \\ +2(y_2 + y_4 + \cdots + y_{2n-2}) \end{array}\right)$$
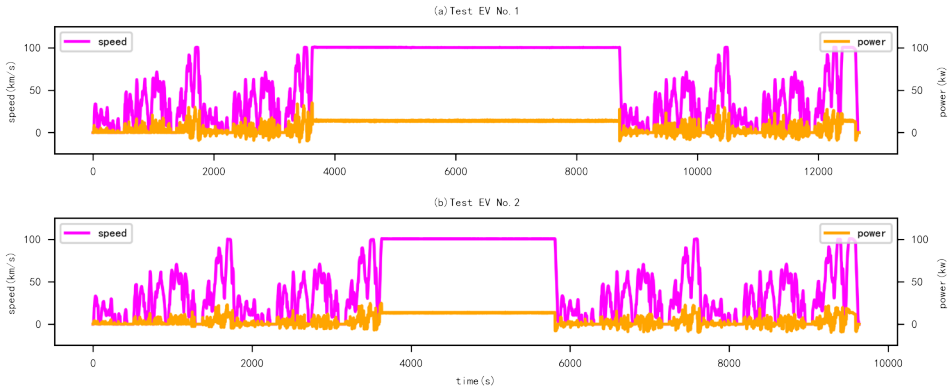
Fig. 3. Test data of normal temperature driving range.

Fig. 4. Test data of driving mileage at low temperature.

3 Results and analysis

This paper has carried out the following three parts of analysis: 1. Comparative analysis of energy consumption in different working conditions of continuous driving range test at normal temperature; 2. CLTC-P energy consumption difference analysis at different temperatures; 3. Difference of energy consumption between cycles under low-temperature driving mileage test.

3.1 Comparative analysis of energy consumption in different operating conditions of continuous driving range test at normal temperature

The normal temperature driving range test includes CLTC-P and constant speed conditions. It can be seen from Figure 5 that the DC energy consumption rate of the two test sample vehicles under constant speed condition of 100km/h is significantly higher than that of CLTC-P. The energy consumption of test vehicle 2 changes more obviously under different conditions, and the DC energy consumption rate under constant speed condition can reach 179.9% of that under CLTC-P condition. The overall energy consumption rate of shortened driving range test is 90.2wh/km, which is 126.6% of CLTC-P DC energy consumption rate. At present, the demand for long driving range of electric vehicles generally involves

long-distance driving, so there must be a large proportion of high-speed conditions. Therefore, the test results of shortened conditions are higher than that of CLTC-P alone, but they can more effectively reflect the user's demand for electric vehicle driving range.

3.2 Energy consumption difference analysis of CLTC-P at different temperatures

Because the DC energy consumption of CLTC-P is tested in both normal temperature driving range test and low temperature driving range test, the DC energy consumption of CLTC-P under different temperatures will be studied in this section, and the influence of temperature on energy consumption will be analyzed. As shown in Figure 6, the energy consumption rate of the test vehicle at low temperature is improved. Compared with CLTC-P at room temperature, the DC energy consumption rate of test sample 1 is increased by 25%, and that of test sample 2 is increased by 63%. In order to maintain the temperature of the cockpit, the additional energy consumption of test sample 2 is significantly higher than that of test sample 1 under the same temperature change. Although the increase of energy consumption of different vehicles in low temperature is different, it can be clearly concluded that low temperature state will significantly affect the driving range of vehicles, so it is necessary to carry out low temperature driving range test when considering the nominal driving range of vehicles.
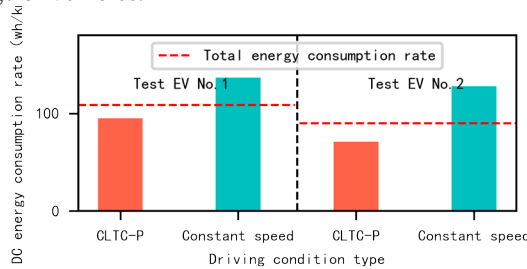
Fig. 5. Comparison of DC energy consumption rate under different working conditions in normal temperature driving range test.
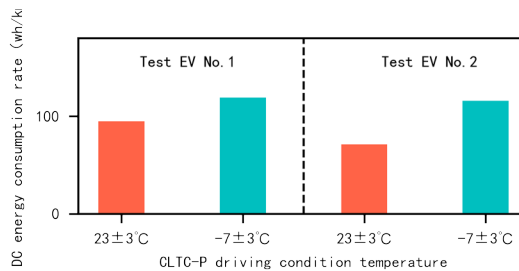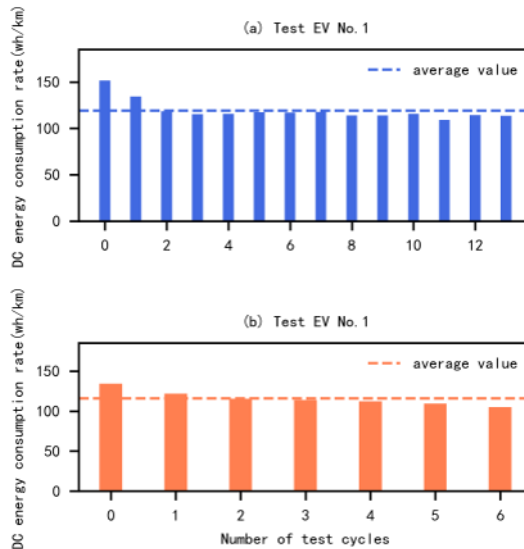
Fig. 6. Comparison of DC energy consumption rate under CLTC-P condition at different temperatures.

3.3 Energy consumption difference between cycles under low temperature driving range test

This section will analyze the change of energy consumption between low temperature and cycle, as shown in Figure 7. It can be seen from Figure 7 that the change trend of energy consumption rate between cycles of the two test vehicles in low temperature environment is

basically the same. At the beginning of the experiment, the cycle energy consumption rate was the highest, reaching 127.3% and 115.8% of the average energy consumption rate respectively. In the middle of the experiment, the cycle energy consumption rate was basically equal to the average energy consumption rate. At the end of the test, the cycle energy consumption rate decreased, which was lower than the average value of the test.

There are two main reasons for the high cycle energy consumption in the initial stage of the test. On the one hand, the cockpit temperature reaches - 7 ℃ due to the early immersion of the vehicle, and the energy consumption of the air conditioner is high in the low temperature state. At the same time, the overall energy consumption is increased due to the high friction loss of the vehicle components in the low temperature state; On the other hand, it can be seen from the power curve in Figure 4 that the brake recovery is low at the beginning of the test, and the test sample vehicle 2 does not carry out brake recovery in the first two CLTC-P. At the end of the test, with the increase of vehicle temperature, the braking recovery efficiency is improved, and the energy consumption of the vehicle is significantly reduced. The maximum difference of energy consumption rate between low temperature test cycles of sample vehicle 1 and sample vehicle 2 is 31.8% and 25.2% respectively, which is higher than that at normal temperature.

Fig. 7. Comparison of energy consumption rate between cycles under low temperature driving range test.

4 Discussion

From the conclusion of the third part, we can see that the energy consumption of electric vehicles has obvious differences in different working conditions and different environments. According to the current national standard test method for driving range of electric vehicles (GB/T18386-2017 test method for energy consumption rate and driving range of electric vehicles), the energy consumption result of electric vehicles is only the test result of single test condition at room temperature. The low-temperature, high-speed and other factors are inevitable in the actual driving process. Through the results of the third part, it can be determined that the influence of low-temperature, high-speed and other factors on energy consumption can not be ignored. Therefore, how to reasonably design a comprehensive

range test scheme of electric vehicles is an important part of the development of electric vehicles, which can effectively improve the authenticity of the range of electric vehicles in the actual driving process, and enhance the driver's confidence in the nominal range of electric vehicles.

5 Conclusion

This paper analyzes the influence of different factors on DC energy consumption test in China.

1) In the normal temperature driving range test, the DC energy consumption test results of CLTC-P condition and constant speed 100km/h condition are significantly different. Compared with CLTC-P condition, the energy consumption of electric vehicle is more than 150% under high-speed condition, which is very important for users. Therefore, the shortening method is conducive to more comprehensive consideration of the driving range under long-distance driving conditions.

2) The energy consumption difference of CLTC-P at different temperatures was analyzed. The results showed that the energy consumption of CLTC-P at low temperature ($-7\pm3℃$) energy consumption increases significantly, so there are still big obstacles in the promotion of electric vehicles in Northeast, northwest and other cold regions of China.

3) At low temperature, the energy consumption difference of repetitive cycle will increase significantly, and the maximum energy consumption can reach more than 30% in the test. It can be inferred that this is caused by HVAC control, and this effect is worthy of more consideration when evaluating the energy consumption of electric vehicles.

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