A Study on the Measurement Method of Driving Range of Electric Vehicles Under Different Ambient Temperatures

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Abstract: The driving range under high and low temperature conditions is the concerns of consumers about the performance of electric vehicles. In order to study the influence law of ambient temperature on the driving range of electric vehicles, this paper has developed a measurement method for measuring the driving range. Through the tests of the endurance test at room temperature, high temperature and low temperature for eleven electric vehicles, the research aims to study the range of electric vehicles under different ambient temperatures. The influence law of ambient temperature on the accuracy was obtained. It provided foundation for further improving operating characteristics and energy efficiency analysis of the vehicle.

1. Introduction

China's new energy vehicle (NEV) market has been growing rapidly. By the end of June 2018, the total sales of NEVs had reached 1.99 million units, including 1.62 million units of electric vehicles (EV), accounting for 81.4 percent of the total number of NEVs. EVs consume less energy per unit distance (e.g. 100 km) than traditional fuel vehicles. Therefore, the development of EVs is of great significance to energy conservation and emission reduction.[1] A market survey shows that driving range is one of the vulnerabities of EVs concerned by consumers [2], and 29.0 percent of the EV consumers worry that the driving range may be affected by extreme temperatures [3].

Compared to traditional fuel vehicles, EVs are more susceptible to ambient temperature changes as far as driving range is concerned. Studies indicate that ambient temperature may affect the driving range of EVs: The capacity retention of lithium battery is 60%~70% at 0℃, 40%~55% at -10℃, and 20%~40% at -20℃ [3-5]. China has a vast territory, spanning approximately 50 latitude degrees and 62 longitude degrees. Influenced by landform and solar radiation, the air temperature in different regions varies significantly in summer and winter. Therefore, it is of great significance to study the changing regularities of EVs under different ambient temperatures.

Because the electric vehicle has a short driving range, especially in the case of high and low temperature, the driver will have "mileage anxiety" of the driving range. The self-experience of the electric vehicle driver is reduced, which directly affects the user's travel arrangements. Based on the actual problems, this paper studies the measurement method of the electric vehicle driving range under different environmental temperatures according to the performance of electric vehicles in actual use and extreme environment, which is concerned by consumers, the industry and media. The

research provided foundation for further improving operating characteristics and energy efficiency analysis of the vehicle.

2. Research Status

Electric vehicles have become the focus of research and development in the current automotive industry, and driving range is the key performance of research and development. At present, the measurement method of the electric vehicle's driving range is included in the conventional automobile standard, and the advanced foreign countries (regions) have their own standards in the measurement method of the electric vehicles' driving range. It is basically supplemented by the regular vehicle evaluation regulations. Although some key performances have relevant standards in some foreign countries, they have not been adopted in China.

The driving range of electric vehicles' evaluation standards also establishes based on the relevant national standards of traditional vehicles in China. But the existing standards are only the minimum requirements for the vehicle access. GB / T 18386-2005 "The test method for the driving range and energy consumption of the Electric Vehicle" is specified in the test method for the driving range. That is, the NEDC working condition method and 60 km/h at normal temperature. And the official driving range information obtained by consumers in purchasing cars is the value according to the national standard. In addition, China has a vast territory, and most of the regions have large temperature changes in summer and winter. The air conditioning needs to be on in a long time. Both temperature and air conditioning have a large impact on the driving range of electric vehicles, which directly lead to the actual driving range far below official information. At present, there are no relevant standards at home and abroad take into account the driving range test method under different temperature and air conditioning conditions, and cannot provide consumers with more direct and accurate information. In particular, the driving range of electric vehicles is greatly affected by environmental conditions and driving habits, resulting in a large difference in the driving range of electric vehicles between the actual experience of consumers and the official data which is tested according to the national standard.

Therefore, in order to better guide consumers to accurately understand electric vehicles, promote technological advancement in the industry, and promote the development of China's electric vehicle industry, this paper studies and formulates new methods for measuring the driving range based on current evaluation criteria and research methods. Strive to let consumers see the results of the evaluation that is closest to the actual situation.

3. Research Method

3.1. Typical Working Conditions

According to the usage scenarios and geographical requirements of electric vehicles, typical working conditions are combined from 15 different test conditions under the four dimensions of working conditions, temperature, air conditioning and test conditions. The combination of various possible working conditions is shown in Figure 1.

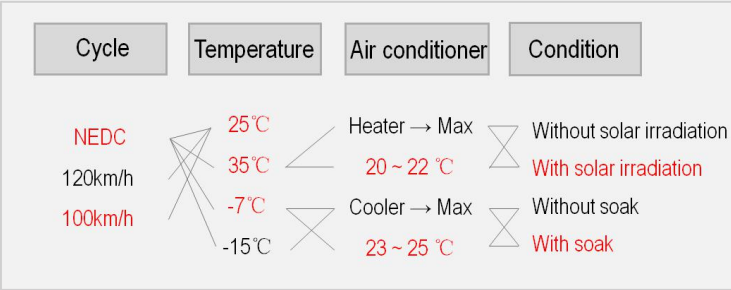

Figure 1: 15 Combinations of different testing condition.

Through the consumer survey, the analysis of the state in use of the Chinese vehicle and the actual test situation of the vehicle, 15 combinations of different testing condition were tested and analyzed, thus the typical working conditions of the measurement were finally determined. As shown in Table 1.

Table 1: The typical working conditions of the measurement.

Cycle	Temperature	air conditioner	test conditions
NEDC	room temperature（25℃）	OFF	With soak（25℃）
	high temperature（35℃）	ON(23-25℃)	With soak（35℃） & illumination
	low temperature（-7℃）	ON(20-22℃)	With soak（-7℃）

The range tests were conducted at three temperature levels, namely, room temperature (25℃), high temperature (35℃) and low temperature (-7℃) in accordance with the typical working conditions of the measurement[6]. The test vehicle was left to soak for 12-36 hours under corresponding temperature conditions before being tested in accordance with the New European Driving Cycle (NEDC) scheme. The air-conditioning system was turned on during high and low-temperature range testing. The temperature in the cab was kept at 23℃~25℃ for high-temperature testing and 20℃~22℃ for low-temperature testing. At the same time, the high-temperature testing must be with illumination.

3.2. Vehicle Specifications

Eight compact vehicles with a body length of 4 m or more and three micro vehicles with a body length below 4 m were selected as the test vehicles. The specifications of the vehicles are listed in Table 2.

Table 2: Specifications of the eleven vehicles.

Model	Curb Weight, kg	Driving Range (rated by MIIT), km	Battery Capacity kw•h
1	1564	351	49
2	1710	320	48.3
3	1470	270	36
4	1410	301	38.5
5	1950	300	47.5
6	1598	300	41
7	2160	352	62
8	1610	200	30
9	1080	255	22
10	1175	151	29.2
11	855	151	18.2

3.3. Test Procedure and Data Logging

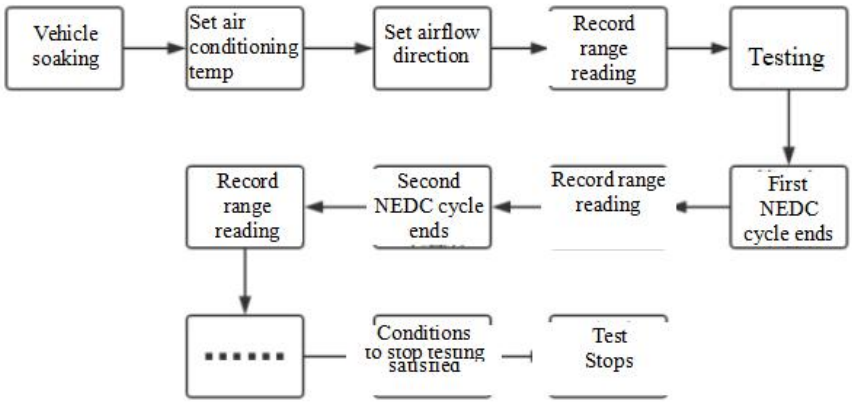

Figure 2: Test procedure.

The test procedure is shown in Figure 2. The tests were conducted continuously on a roller dynamometer under NEDC test conditions until the requirements to stop the test procedure were met [9].The residual range indicated on the dashboard before test (cycle 0) and at the end of each cycle (hereinafter referred to as “dashboard readings”) was collected. In order to maintain the comfort inside the cabin, the air conditioner should reach the required temperature within the specified time and record the time. At the same time, the cabin temperature should be maintained at the corresponding temperature conditions until the test is completed.

4. Driving Range Test Results

4.1. Driving Range Under Different Ambient Temperatures

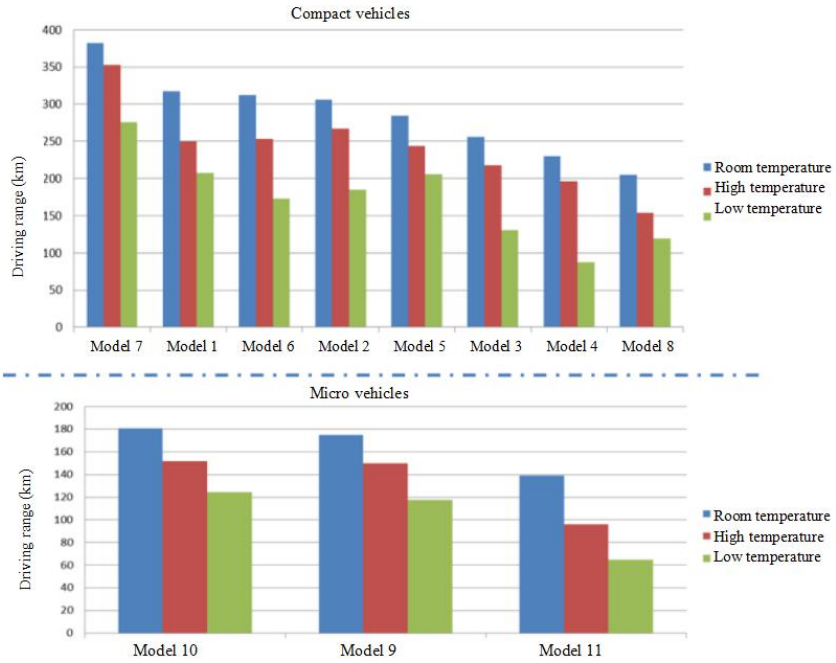

Figure 3: Driving ranges of the eleven vehicles under different temperatures.

Figure 3 shows the driving range of eight compact vehicles and three micro vehicles under three temperature conditions. As shown in the figure, the driving range of the EVs drops significantly under low and high temperatures, especially under low temperature. The driving range of compact vehicles drops 16.1 percent in average under high temperature compared to that under room temperature. The smallest drop is 7.6 percent and the largest 30.9 percent. The driving range drops 40.9% percent in average under low temperature compared to that under room temperature, the smallest drop being 14.3 percent and the largest 62.1 percent. The driving range of micro vehicles drops 20.4 percent in average under high temperature compared to that under room temperature. The smallest drop is 14.4 percent and the largest 30.9 percent. The driving range drops 39.0 percent in average under low temperature compared to that under room temperature, the smallest drop being 31.2 percent and the largest 53.3 percent.

Under high temperature, the driving range of micro vehicles exhibited a greater decrease than that of compact ones, while under low temperature the two exhibited similar decreases. The driving range of some vehicles drops drastically under low temperature as a result of power limitation in the test process. Power limitation leads to speed limitation and stop of the test. This shows that these vehicles are not able to address all possible scenarios and can operate only at low and medium speeds.

Under high temperature, the motor current rises and energy consumption increases with a rising temperature. In the meantime, the parts expand to some extent, reducing the mechanical efficiency and increasing energy consumption [7-8].

Under low temperature conditions, the internal resistance of the cells increases and capacity retention decreases, and the battery discharge performance is further reduced. At the same time, the battery thermal management system of some vehicles will consume power.

4.2.Influence of Air Conditioning Performance on Driving Range

In the high and low temperature environment tests, the air conditioner is required to reach the target temperature within the specified time, it is also necessary to keep the cabin's temperature within the corresponding range throughout the test. The air-conditioning system also consumes power during testing under high and low temperatures [9-11]. In order to improve the driving range, advanced air conditioning technologies such as heat pump air conditioning system will also be applied to the electric vehicle.

5. Conclusions

The driving range of EVs is susceptible to temperature. High and low temperatures may lead to decrease in the driving range to some extent. On average, the driving range of the eleven vehicles under high and low temperatures fell 17.3 percent and 40.4 percent, respectively. In order to increase the driving range of the electric vehicle, improving the electric vehicle's performance in harsh environment and the low-temperature performance of power battery are effective ways.

The measurement method of the driving range of the electric vehicles described in this paper can comprehensively and accurately measure the driving range of vehicles under different environmental temperatures from the actual use scenarios of consumers, which is practical, feasible and effective. In addition, in view of consumers' anxiety about the use of electric vehicles, it is still necessary to conduct in-depth researches and analysis on the energy consumption and the driving range estimation accuracy of electric vehicles at different ambient temperatures.

Acknowledgments

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