

# REAL-ROAD ENERGY CONSUMPTION CHARACTERISTICS OF ELECTRIC PASSENGER CAR IN CHINA: A CASE STUDY IN SHENZHEN

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## ABSTRACT

As the increasing complains of the electric passenger car owners about the lower pure electric mileage under real-road driving condition than the regulation standard test result, the annual real-road energy consumption characteristics of 20 MPV electric passenger cars in Chinese city, Shenzhen, have been investigated to analyze the effect factors causing the energy consumption difference between these two results.

Results showed that the annual variations of real-road energy consumption rate of each month were agreed with the variations of air conditioning using duration. The highest and lowest energy consumption rates were obtained in July and March, which increased the energy consumption rate of whole vehicle about 24% in the maximum extent. The difference of the energy consumption between real-road and regulation standard test was attributed to the effects of air conditioning using and driving condition (driving velocity and acceleration distribution), which have been qualified in this paper.

**Keywords:** electric passenger car, real-road energy consumption characteristics, air conditioning using, driving condition

## 1. INTRODUCTION

To solve the two key issues of the environmental protection and energy conservation, electric vehicle is introduced into the transport sector due to its superior advantages of zero emission and high efficiency energy conversion characteristics. However, because of the lower energy density of the onboard battery of the electric vehicle compare to the gasoline or diesel fuel of the traditional ones, the short driving mileage seriously restricts its development [1-2]. In additions, the obvious

decrease of the mileage with the use of air conditioning in summer and winter often caused the complaints of the electric vehicle owners.

The energy consumption characteristics of the electric passenger car in every country's regulation standard are evaluated by the chassis dynamometer method implementing specific test cycle with no use of air conditioning. In current Chinese regulation standard (GB/T 18386-2017), NEDC is the chosen test cycle [3]. However, the real-road energy consumption characteristic is influenced by many parameters and can be divided into traffic condition (driving velocity and driving acceleration), road infrastructure (road grade or surface roughness), environmental parameters (temperature or wind speed), and driver's driving aggressiveness, which finally caused the gap between these two energy consumption results [4-6].

In this paper, the annual real-road energy consumption characteristics of 20 MPV electric passenger cars in Chinese city, Shenzhen, have been investigated and compared to the regulation standard test result. The effect factors on the energy consumption difference have been summarized and qualified.

## 2. EXPERIMENTAL VEHICLE AND DATA ACQUISITION

### 2.1 Experimental vehicle

In this paper, the annual data of 20 MPV electric passenger cars in Shenzhen have been collected, which the specifications have been summarized in Table 1.

Table 1. Vehicle specification

Parameters	Value
Length*width*height(mm)	4560*1822*1630
Curb weight(kg)	2380

Motor maximum power(kW)	120
Motor maximum torque(N·m)	450
Motor type	DC motor
Battery capacity(kW·h)	82
Battery type	lithium iron phosphate

## 2.2 Data acquisition and preprocessing

Because of the excursion of the GPS's zero point and other data transmission errors, the acquisition data should be preprocessed, and the processing rules has been listed below.

The driving velocity below 0.5km/h was treated as stationary, and the points with driving velocity above 150km/h and the acceleration above 6m/s<sup>2</sup> or below -6m/s<sup>2</sup> had been removed, and the acceleration was calculated according to Eq.(1).

$$a_{i,i-1} = \frac{V_i - V_{i-1}}{t_i - t_{i-1}} * \frac{1000}{3600}, k = 1, 2, \dots, k \quad (1)$$

The real-road energy consumption rate with the unit of kW·h/100km was calculated by Eq.(2).  $v$  is the vehicle driving velocity, which was collected by the GPS module of the data collection device.  $U$  and  $I$  were the output voltage and current of the onboard battery, which were obtained by the OBD module.

$$EC = \frac{100 \times (\int UI dt / 3600000)}{\int v dt / 3600} = 0.1 \times \frac{\sum(UI)}{\sum v} \quad (2)$$

The sampling frequency of the data collection device was fixed at 1Hz. The real-time data was uploaded to the server through the 4G net, thus enabling year-round 7\*24 data acquisition from July, 2017 to June, 2018, and the annual average mileage of each electric passenger car was 31,000km.

## 3. RESULTS AND DISCUSSION

### 3.1 Annual variations of real-road energy consumption characteristics

The annual variations of the real-road energy consumption characteristics have been shown in Fig.1. Results showed that the annual average value of the energy consumption rate was 20.36 kW·h/100km, which was slightly higher than the regulation standard test value under NEDC (20.00 kW·h/100km). In additions, both the value of energy consumption rate and the error range showed a first decreasing then increasing variation trend. The highest value was obtained in July, which was

23.81 kW·h/100km, 19% higher than the regulation standard test value. And the lowest value was obtained in March, which was 19.15 kW·h/100km, 4% lower than the regulation standard test value. The differences between the real-road and regulation standard test value could be attributed to the variations of using of air-conditioning and driving condition, which would be discussed in the below separately.

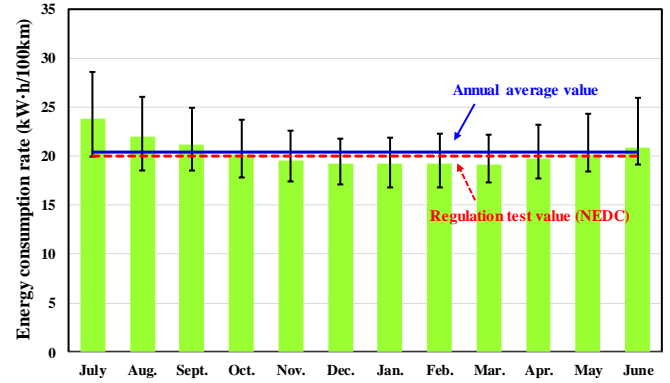


Fig.1. Annual variations of real-road energy consumption rate

### 3.2 Effect of air conditioning on real-road energy consumption characteristics

To investigated the effect of air conditioning on real-road energy consumption characteristics, the air conditioning using duration in each month should be counted firstly. According to the questionnaire's average result among the 20 drivers of the experimental passenger car in this study, the air conditioning was turned on when the environmental temperature was up to 28°C or below to 12°C. The variations of the daily maximum and minimum environmental temperature have been presented to estimate the number of days using air conditioning in a round of year as shown in Fig.2.

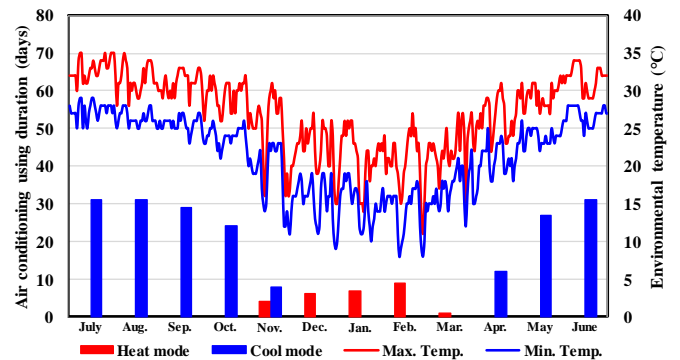


Fig.2. Variations of environmental temperature and air conditioning using duration

Results showed that the shortest air conditioning using duration was found in March, which was the same month of the lowest real-road energy consumption rate obtained. Comparing the highest energy consumption rate of July and the lowest value of March, it indicated that air conditioning using increased the energy consumption rate about 4.66 kW·h/100km in the maximum extent, about 24% increase of the whole vehicle energy consumption.

### 3.3 Effect of driving condition on real-road energy consumption characteristics

To separate the effect of air conditioning on the real-road energy consumption characteristics, only the data of March, 2018 has been analyzed for investigating the effect of driving condition. The effect of the driving condition on energy consumption could be divided into the factors of driving velocity distribution and the driving acceleration distribution.

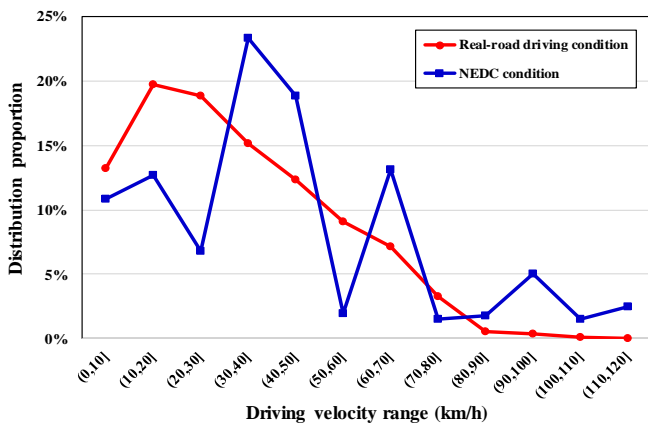


Fig.3. Driving velocity distribution under real-road driving and NEDC conditions

Fig.3 shows the driving velocity distributions of the real-road driving condition and the NEDC condition. It worth noting that the driving conditions with zero driving velocity (idling condition) have been dismissed. It could be found that the driving velocity distribution was concentrated in the low driving velocity range under real-road driving condition, and the largest proportion was the range of 10-20km/h. However, the driving velocity distribution was concentrated in medium velocity range under NEDC conditions, especially the range of 30-50km/h. This resulted the average driving velocity under NEDC condition (43.44km/h) was about 55% higher than the real-road driving condition (28.05km/h).

The variation of real-road energy consumption rate with the change of driving velocity is shown in Fig.4. Results showed that with the increase of the driving velocity, the real-road energy consumption rate first decreased then increased quadratically with the driving velocity extending, and the lowest value was obtained in the driving velocity range of 40-50km/h. The first decreasing trend of energy consumption was because of the movement of the motor's operation points, from the low efficiency region to the high efficiency region. And the subsequent increasing trend was mainly attributed to the increase of air resistance and rolling resistance.

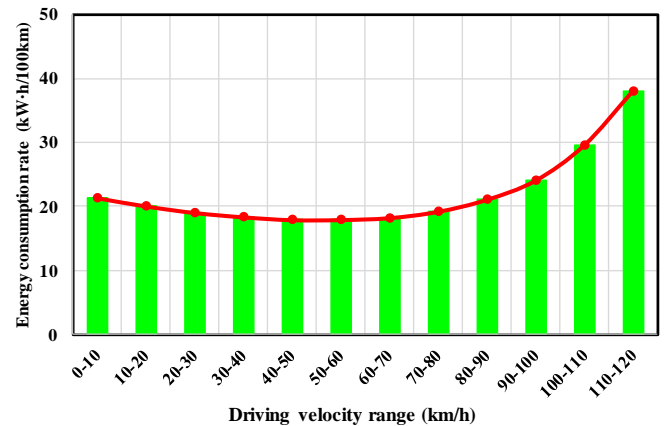


Fig.4. Variation of real-road energy consumption rate with the change of driving velocity

The energy consumption under NEDC condition was 19.81 kW·h/100km which was calculated according to each driving velocity range proportion. This indicated that the effect of the driving velocity distribution caused a different energy consumption of 0.66 kW·h/100km between real-road and regulation standard test.

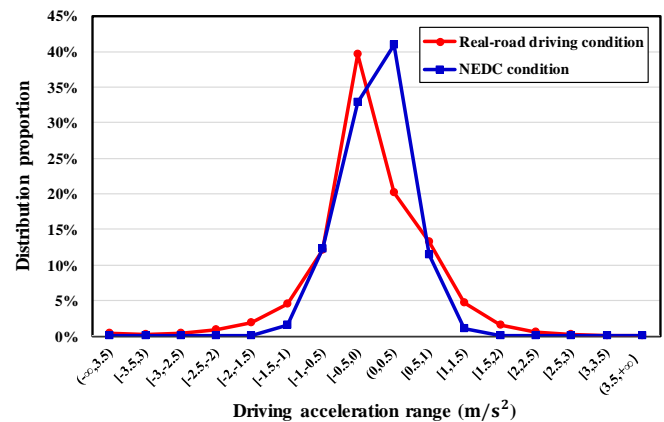


Fig.5. Driving acceleration distribution under real-road driving and NEDC conditions

The largest driving deceleration proportion and absolute negative acceleration value were beneficial to recover more braking energy resulting in a decrease in the energy consumption rate. The driving acceleration distributions of the real-road driving condition and the NEDC condition are shown in Fig.5. It worth noting that the driving conditions with zero acceleration (idling condition and constant velocity condition) have been dismissed, only the acceleration and deceleration conditions have been maintained.

Results showed that the driving acceleration distribution presented normal distribution, the largest proportion of the acceleration range was  $[-0.5,0)$   $m/s^2$  under the real-road driving condition, however, was the range  $(0,0.5)$   $m/s^2$  under the NEDC condition. The proportion of the deceleration condition was 59.67% under the real-road driving condition, which was higher than the NEDC condition (46.61%). The average negative acceleration was  $-0.77m/s^2$  which the absolute value was higher than the NEDC condition ( $-0.74 m/s^2$ ). This proved that the braking recovered energy under real-road driving condition was more than the NEDC condition, and indicated that the effect of the driving acceleration distribution caused a different energy consumption rate of 0.19  $kW\cdot h/100km$  between real-road and regulation standard test.

velocity distribution and acceleration distribution contributed to -3.3% and -1.0%, respectively. Finally, the real-road energy consumption was 1.8% higher than the regulation standard test result.

#### 4. CONCLUSION

In this paper, the real-road energy consumption characteristics of 20 MPV electric passenger cars in Shenzhen, China have been investigated. The conclusion can be reached as the following.

The annual average real-road energy consumption rate was 20.36  $kW\cdot h/100km$ , which was slightly higher than the regulation standard test value under NEDC (20.00  $kW\cdot h/100km$ ), about 1.8%. The highest and lowest values were obtained in July and March respectively, which was agreed with the air conditioning using duration variation. Air conditioning using increased the energy consumption rate of whole vehicle about 24% in the maximum extent.

The effect factors including air conditioning using, driving velocity distribution and driving acceleration distribution which caused the energy consumption rate's difference between real-road and regulation standard test. Air conditioning using contributed an average of 6.1%, driving velocity distribution and acceleration distribution contributed to -3.3% and -1.0%, respectively.

#### ACKNOWLEDGEMENT

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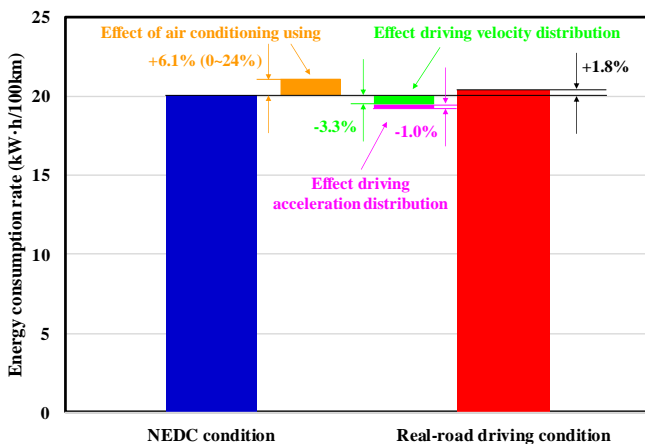


Fig.6. Contribution of the each effect factor on energy consumption between real-road driving and NEDC conditions

To sum up, the difference of the energy consumption between real-road and regulation standard test could be attributed to the effects of air conditioning using, driving velocity distribution and driving acceleration distribution, and could be qualified as below, as seen in Fig.6. Results showed that the effect of air conditioning using contributed 0~24%, an average of 6.1% higher of real-road energy consumption, and the effects of driving