Acta Technica *62* (2017), No. 4A, 155–160

Construction method of electric vehicle urban driving cycle

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Abstract. Aiming at the problem that traditional driving cycle is difficult to represent the characteristics of electric vehicles, a typical large and medium-sized city of Xi'an was selected as the research object, and the construction method of electric vehicle driving cycle was studied. First of all, the test route was constructed based on the sampling with repetition, hypothesis test, and the analytic hierarchy process. Secondly, the original data was denosied by wavelet decomposing and reconstruction. Then, the characteristic parameters of kinematics sequences were determined on the basis of PCA, and the driving cycle of electric vehicle was constructed on the basis of FCM clustering analysis. Finally, the comparative analysis shows that the difference between the driving range of Xi'an driving cycle and the actual driving range is 11.72 km, and the relative error is 3.91%. Therefore, the driving cycle established in this paper is able to truly reflect the overall traffic characteristic of Xi'an, and the driving cycle has high authenticity.

Key words. Diving cycle, analytic hierarchy process, electric vehicle, fcm clustering algorithm
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1. Introduction

Driving cycle is a kind of statistical method to reflect traffic characteristics of a certain area and establish vehicle travel time-speed procedure by using road test kinematics sequences like acceleration, deceleration, uniform velocity, idling, etc [1]. The driving cycle test can simulate the actual operation of the vehicle effectively and measure the vehicle fuel consumption and pollutant emissions accurately [2]. in this paper, a typical large and medium-sized city of Xi'an was selected as the research object; the test route was constructed based on the sampling with repetition, hypothesis test, and the analytic hierarchy process; a heavily owned BYD E6 pure electric vehicle was selected as the test vehicle; driving cycles were constructed based

[1]Acknowledgement - This work was supported by Natural Science Foundation of China (NO.51507013), Natural Science Foundation of Shaanxi Province (NO.2016JQ5012), the Science and Technology research project of Shaanxi Province (NO.2016GY-043), China Postdoctoral Science Foundation (NO. 2017M613034).

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on principal component analysis (PCA) and fuzzy C-means (FCM) cluster analysis method.

2. The Construction Process of Urban Driving Cycle

Considering that the results of urban driving cycle are influenced by urban road type, road length, vehicle population, travel time, traffic flow, etc. So, 4 typical road traffic flows of express way, main road, secondary road, and branch were collected firstly. Secondly, the road type and mileage of Xi'an were investigated. Then, the test route was designed on the basis of traffic flow and mileage, and test were conducted on the test route. Therefore, the construction of urban driving cycle mainly includes 4 steps, namely traffic survey, road test, data processing, and construction of driving cycle, as shown in Fig. 1.

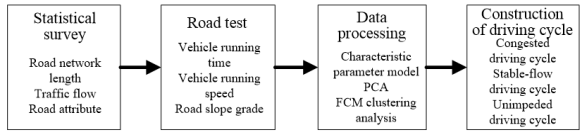

Fig. 1. Construction process of driving cycle

3. Route Construction

Since the road traffic conditions in Xi'an should be comprehensively reflected by the test route, therefore, road network structure and road type length of Xi'an should be analyzed and calculated before test route is built.Based on the sample size of 38.46 km, different types of road length and proportion, traffic flow analysis data and AHP decision model, the proportion and length of the test sample route are calculated by YAAHP, as shown in Table 1.

Table 1. Proportion and length of the test sample road type

Road grade	Proportion	Length (km)
Express way	0.2996	11.52
Main road	0.2480	9.54
Secondary road	0.2685	10.33
Branch	0.1839	7.07

4. The Data Processing of Driving Cycle Test

4.1. Data Denoising Based on Wavelet Decomposing and Reconstruction

Glitches, mutations and other unexpected conditions may appear during data collection process, which will affect the authenticity of data [4]. Removing or correcting the abnormal data can improve the accuracy of the data. Wavelet decomposing and reconstruction are used to denoise the original data. The noise signal can be described as:

$$S(x)= \mathrm{f}(x) + n_1(x) * n_2(x) \tag{1}$$

As shown in Fig. 2, the wavelet decomposition and reconstruction method have a good effect, and it can improve the signal-noise ratio (SNR) effectively.

4.2. Threshold Selection for Kinematics Sequences

The kinematics sequences refer to the process of a car state changed from one idle to the next. A kinematics sequence typically includes acceleration state, deceleration state, uniform state, and idle state. Electric vehicle have no idle state, so the kinematics sequences are divided according to vehicle speed. According to the analysis of experimental data, the static threshold is set to 2 km/h and the acceleration threshold is 0.15 $\mathrm{m/s^2}$.

4.3. Selecting Characteristic Parameters

Generally, kinestate is described by kinematic feature parameters, and the kinematics sequences with the same characteristic parameters are classified as a class [5]. In this paper, the selected 15 characteristic parameters include travel time, uniform time, acceleration time, deceleration time, idle time, running distance, maximum speed, average speed, running speed, speed standard deviation, maximum acceleration, average acceleration of the acceleration period, maximum deceleration, average deceleration of the deceleration period, and acceleration standard deviation. The contribution rate of each component is calculated by PCA, as shown in Table 2. The first 3 principal components with variance greater than 1 are selected for FCM clustering analysis. The first 3 principal component parameters include information such as running distance, maximum speed, running speed, speed standard deviation, travel time, acceleration time, deceleration time, idle time, and uniform time. These parameters can reflect the overall operation characteristics of the vehicle [6].

Table 2. Total Variance Explained

Component	Total	% of variance	Cumulative %
1	7.4517	49.68	49.68
2	3.9747	26.50	76.18
3	1.3126	8.75	84.93
...	...	...	...
15	0.0027	0	1

4.4. Cluster Analysis Based on FCM

In this paper, 1124 kinematics sequences are analyzed by FCM clustering. And all kinematics sequences are divided into 3 classes, namely, congested driving cycle, stable-flow driving cycle, and unimpeded driving cycle. Fig. 3 shows the clustering results.

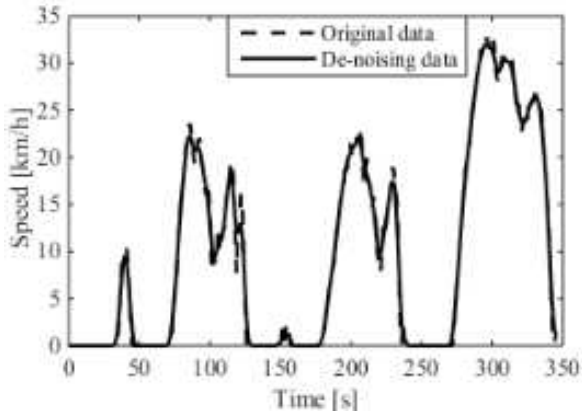

Fig. 2. Data comparison before and after denoising

5. Construction and Analysis of Driving Cycle

5.1. Constructing the Driving Cycle in Xi'an

According to the proportion of kinematics sequences of different driving cycles in FCM clustering results, the sequences corresponding to the nearest point in the cluster center are selected to construct the driving cycle. According to the number of kinematic fragments of 1:1:2 ratio, the overall driving cycle in Xi'an was constructed by selecting suitable kinematic fragments in congested driving cycle, stable-flow driving cycle and unimpeded driving cycle. as shown in Fig. 4. The total running time is 657s,

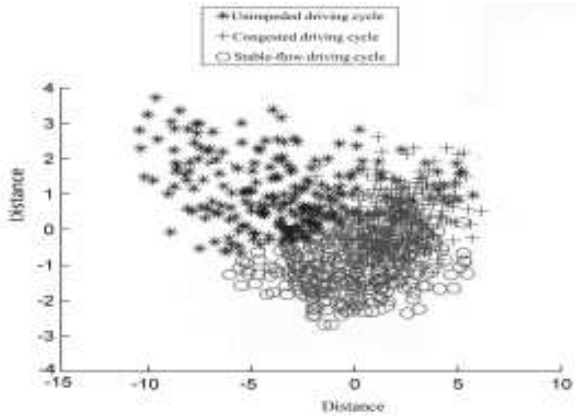

Fig. 3. Results of FCM clustering

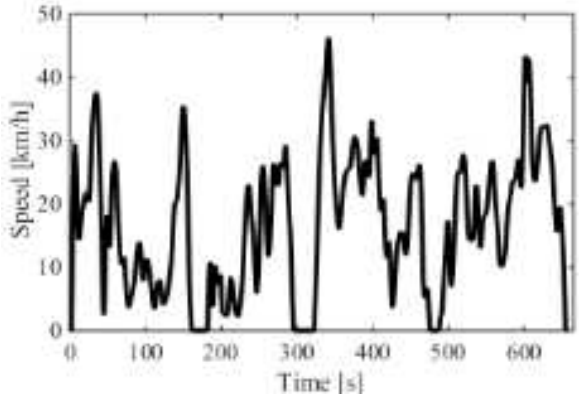

Fig. 4. Overall driving cycle of xi'an

5.2. Comparison and Analysis of Urban Driving Cycle in Xi'an

In order to verify the rationality and authenticity of Xi'an driving cycle established in this paper, according to the national standard GB/T 18386-2005 "the test method for electric vehicle energy and driving range", BYD E6 pure electric vehicle driving cycle test was taken on rotary drum test bench. The differences between actual driving range of vehicle and the driving range of Xi'an driving cycle are shown in Table 3.

Table 3. Comparison of the test results of driving range

Pilot projects	Driving range
CYC-XA bench test	299.01
NEDC bench test	256.27
Actual road test	287.29

Through comparing the driving range of CYC-XA bench test, NEDC bench test, and actual road test, the difference between the driving range of CYC-XA and the actual driving range is 11.72 km, and the relative error is 3.91%; the difference between NEDC and actual driving range is 42.74 km, and the relative error is 14.29%. By contrast, there is a little differences between electric vehicle driving range and the measured driving range in actual road test. And compared with NEDC, CYC-XA is more close to the true traffic conditions of Xi'an. Therefore, the driving cycle established in this paper is able to truly reflect the overall traffic characteristic of Xi'an, and the driving cycle has high authenticity.

6. Conclusion

In this paper, a typical large and medium-sized city of Xi'an was selected as the research object, and the construction method of electric vehicle driving cycle was studied. The characteristics of urban driving cycle in Xi'an was compared with other typical driving cycles. The results showed that the driving cycle established in this paper is able to truly reflect the overall traffic characteristic of Xi'an, and the driving cycle has high authenticity.

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Received November 16, 2016