Analysis of Drive Cycles and Its Application in the Design of Electric Bus

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Abstract

The analysis of drive cycle is the basis of vehicular real-control during design and the application of electric vehicles. Beijing will hold the Olympic Games in 2008 and there will be about 1000 electric buses made full use of at that time. The requirements of the electric buses' design according to tested data of two kinds of drive cycles will be analyzed in the paper. And it dictates that the entire considerations of different drive cycles are very important for current electric buses' design and their different requirements of energy and power, which is necessary for E-bus design and the realization of efficient real-time control.

Keywords

analysis of drive cycle, electric bus, design, drive cycle

1. BACKGROUND

Analysis of vehicular drive cycle includes analytical calculation of characteristic drive modes and of typical drive cycle. We can know the vehicle's driving requirements from drive cycle, and then we can acquire minimum demands for each assembly's performance and some dynamic individualities of the drivetrain.

Nowadays, a batch of electric city buses have been made into use in Beijing's public transportation. In next two years, experts will trace these buses and obtain their vital data in many aspects, for instance, acceleration performance, economic performance and reliability. Comparing these real test data to the results stemming from analysis of drive cycle and calculation of simulated models, we can appraise electric buses' usage circumstances and analyze the factors which influence their performances.

In this paper, we mainly show two kinds of drive cycles and introduce the application of analysis methodology.

2. INTRODUCTION OF TYPICAL DRIVE CYCLES

Running in Beijing's urban areas, buses have to meet certain special requirements such as the max velocity (80km/h, lasting time excels 30 minutes), the grade ability (20% @ 5km/h), and the accelerating time (55 seconds for a shifting process from 0 to 80km/h). Through the calculation of these characteristic drive modes, we can get general requirements for the vehicle's drivetrain parts such as rated power and rated torque.

However, as an electric vehicle, we should consider its drive cycle, to obtain satisfactory range between charges as to related drive cycle, and to know peculiar detailed requirements for energy storage and key parts of the bus.

2.1 Establishment of the drive cycle

The drive cycle is a speed-changing course. Its essential parameters, for example, the average speed, driving periodicity, and so on, are identical or quite similar to the actual traffic condition. In order to gain the drive cycle, large numbers of the velocity change courses must be measured and recorded, the typical drive cycle then can be summarized from those original data according to certain criterions.

To evaluate the vehicle's drive model and establish drive cycle, we should analyze the models of velocity value and use certain essential parameters.

The models of velocity value includes idle speed model, acceleration model, deceleration model, uniform speed model, driving periodicity and extended driving periodicity. And those important parameters are : v_1: the average speed of the whole driving course (km/h); v_2: the average technical speed (which is calculated including the parking time of obeying the traffic regulations, but without the passengers getting on or off the bus time); a: the average acceleration (m/s^2); d: the average deceleration (m/s^2); T: extended driving periodicity (s); P_i: temporal percentage of the idle speed model; P_a: temporal percentage of the acceleration model; P_d: temporal percentage of the deceleration model; P_c: temporal percentage of the uniform speed model.

The measuring roads are selected all in Beijing's urban areas. We consider the average speed as the basis on the route's selection, and in the meantime consider the route's distribution on varieties of roads, the passenger flow volume, the passenger origin, the degree of traffic jam, the temporal traffic change and so on. In a word, the selections must reflect the whole condition of the

public traffic's routes in the urban areas of Beijing.

The total idea of getting the drive cycle is that the essential parameters, which can represent the actual driving characteristics, are abstracted from a great deal of actual driving data. Using those parameters, the drive cycle's curve can be formed. According to the differences of final decided way and dominating purpose, the drive cycle can be sorted into the calculative one and the statistical one.

2.2 Two drive cycles for research

Selecting two parameters, average speed and driving periodicity, as the basis on the drive cycle's confirmation, we can get the calculative drive cycle by the mathematical processing. The drive cycle is shown as Figure 1. We call it city-4 drive cycle temporarily. It can be said that the city-4 drive cycle represents the public traffic's condition in Beijing.

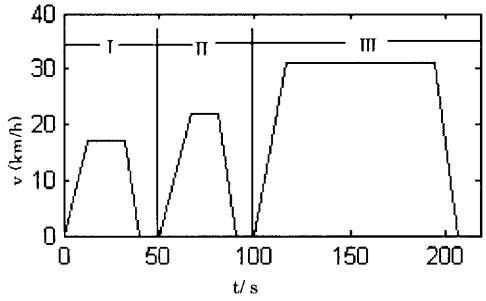


Fig. 1 Calculative drive cycle: City-4

According to different temporal sectors or area sections, we assemble different practical statistic, and then we can acquire another cycle, statistical drive cycle. It is shown in Figure 2. We call it typical city bus drive cycle. For the purpose of analysis and research, we use these two kinds of drive cycles. The comparison between their parameters is shown in the Table 1.

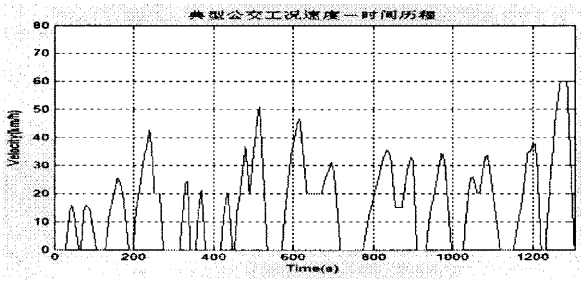


Fig. 2 Statistical drive cycle: Typical city bus drive cycle

Table 1 Comparison between two drive cycles

Drive cycle	Driving periodicity (s)					Velocity (km/h)		Acceleration (m/s^2)	
	Total	Idle speed	Acc*	Uniform speed	Dec*	Max	Average	Max	Min
Typical city bus drive cycle	1304	461	510	84	333	60	16.01	0.83	-0.99
City-4 drive cycle	220	32	46	114	28	31	18.15	0.51	-0.72

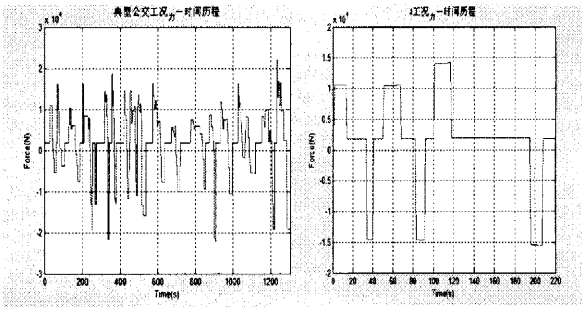
Notes: * Acc-accelerating Dec-decelerating

3. ANALYSIS OF DRIVE CYCLES

As to a certain bus, its parameters are known. We can establish simulated model or compile calculative programs to acquire the requirements of driving force, power, energy and of other things we need. The referenced prototype in this paper is BFC6110-EV, which is now coming into business application.

3.1 Analysis of driving force

During the driving periodicity, the force which would impel a bus similar to BFC6110-EV is illustrated in Figure 3. The figure above is drawn individually for each drive cycle.

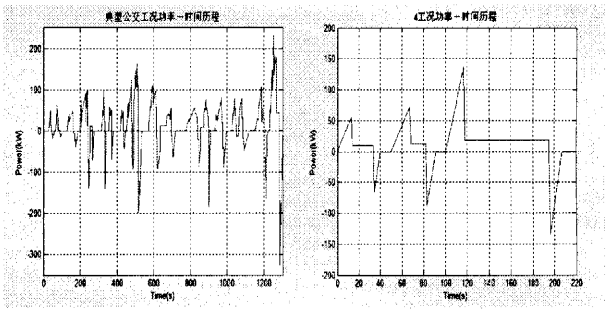


(a) Typical city bus drive cycle (b) City-4 drive cycle

Fig. 3 Driving force needed for two drive cycles

3.2 Analysis of power

The comparison between two cycles' driving power needed is shown in Figure 4. The contrast between their force and power needed is shown in Table 2.



(a) Typical city bus drive cycle (b) City-4 drive cycle

Fig. 4 Driving power needed for two drive cycles

Table 2 Certain power and force data for two drive cycles

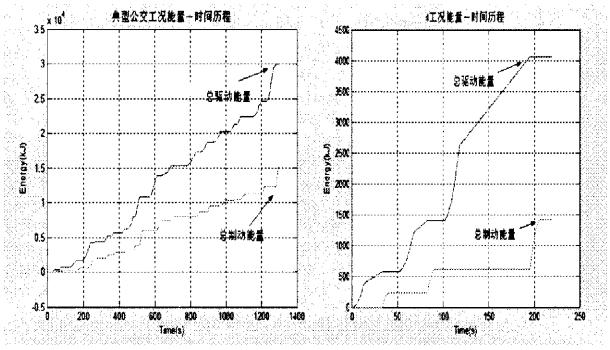
Drive cycle	Power (kW)		Force (N)	
	Max (driving) and lasting time	Min (braking) and lasting time	Maximum driving	Maximum braking
Typical city bus drive cycle	233.4 during 53s	-326.4 during 19s	21950	-22110
City-4 drive cycle	135.9 during 95s	-135.4 during 12s	14203	-15580

3.3 Analysis of energy

The comparison between two cycles' energy needed is shown in Figure 5.

As to the typical city bus drive cycle, the range of cycle is 5.800km. The energy needed for driving is totally about 30000kJ, and the braking energy is totally about 15500kJ. If the regenerative braking energy is entirely recycled, the energy which the bus needs is 14500kJ.

As to the city-4 drive cycle, the range of cycle is 1.109km. The energy needed for driving is totally about 4060.3kJ, and the braking energy is totally about 1420.7kJ. If the regenerative braking energy is entirely recycled, the energy which the bus needs is 2639.6kJ.

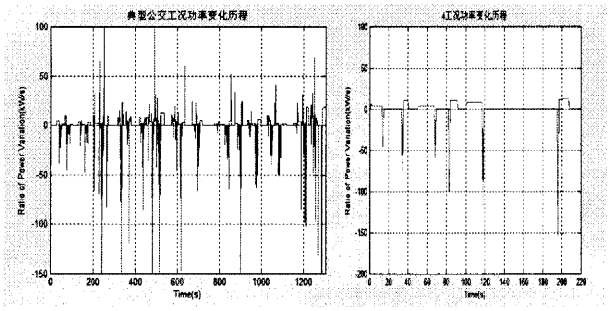


(a) Typical city bus drive cycle (b) City-4 drive cycle

Fig. 5 Energy needed for two drive cycles

3.4 Analysis of power variation

The Comparison between two cycles' power variation is shown in Figure 6.



(a) (b)

(a) Typical city bus drive cycle (The maximum ratio of variation is 137.6kW/s)

(b) City-4 drive cycle (The maximum ratio of variation is 12.1kW/s)

Fig. 6 Power variation for two drive cycles

3.5 Contrast analysis of requirements

Through the analysis of the two drive cycles mentioned above, we can acquire certain requirements for the electric buses' driving motor and other key parts. For example, as to typical city bus drive cycle, we need an electric motor whose maximum power excels 233kW (during 53 seconds), maximum input power is 326kW (as the generator, during 19 seconds), enduring ratio of power variation is 138kW/s. And as to city-4 drive cycle, we need an electric motor whose maximum power excels 136kW (during 95 seconds), maximum input power is 135kW (as the generator, during 12 seconds), enduring ratio of power variation is 12kW/s.

4. CONCLUSION

In this paper, we analysis basic design requirements for certain key parts of Beijing's electric bus by the two models of drive cycles. One is a statistical drive cycle, another is a calculative cycle.

With the methodology of analysis of drive cycle, we can propose certain requirements for drivetrain parts or electric energy subsystem during the overall vehicular design course, or make optimal configuration as to certain subsystem or overall driving system. And for the purpose of making the overall software of control system, we should apply the analysis of drive cycle rationally to adapt the driving system to the control strategy.

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