Study on Resistance Setting Method for Chassis Dynamometer Test of Hybrid Electric Bus

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***Abstract*—Comparison of running resistance generated from on-road coasting tests and recommended calculation was analyzed in this paper. Using coefficient and multipoint setting methods, chassis dynamometer tests of Hybrid Electric Bus (HEB) were carried out to simulate on-road running resistance according to coasting test data. Test results show that the average relative error between coasting test results and computational resistance is larger than 9%, so road coasting test can not be replaced by any other calculating methods. The maximum relative error between coasting test resistance and simulated results is less than 3%.**

Keywords- HEB; running resistance; chassis dynamometer; setting

I. INTRODUCTION

The auxiliary power unit is added to power train system of HEB and the actual engine working status are optimized, so that traditional engine bench test is no longer applied to HEB and new test must be carried out from the aspect of complete vehicle [1]. Current complete vehicle test mainly consists of road test and chassis dynamometer test. The controllability and repeatability of road tests are easily changed by variable factors, such as road conditions, environment. By controlling variable factors, chassis dynamometer test accurately simulate vehicles on-road running resistance [2-3]. Based on this prerequisite, vehicle fuel consumption and emission performance are researched on the chassis dynamometer. However, with the application of braking energy recovery systems, increasing regenerative braking force will lead HEB running resistance to become more complex when vehicles slow down. Therefore, it is important for the study of fuel consumption and emission performance to accurately simulate road running resistance. At present, major automotive regulation systems (the United States, Europe and Japan) have released a series of chassis dynamometer test procedures about HEB, and China also issued chassis dynamometer test procedures about HEB fuel consumption in 2005.

II. ANALYSIS

Vehicle on-road running resistance includes several separate components such as air resistance, rolling resistance, acceleration resistance and driveline friction resistance [4]. These resistances can be expressed as a linear or quadratic function with respect to vehicle speed, so on-road running resistance can be modeled as a quadratic function with respect to vehicle speed [5-6]. It is very important to obtain the precise coefficients of quadratic function. Using different calculation methods, different coefficients are acquired. The equation of running resistance expressed by employing road load coefficients (A, B and C) is as follows:

$$F=A+BV+CV^2$$

After installation on the chassis dynamometer, an unloaded coastdown is run to acquire mechanical loss of testing system, which includes rolling loss between tires and roller, friction loss in the driveline and chassis dynamometer. Based on the same analysis, mechanical loss of testing system also can be expressed as a quadratic function with regard to vehicle speed. The equation of mechanical loss expressed by utilizing loss coefficients (a, b and c) is as follows:

$$F_{Tloss}=a+bV+cV^2$$

Therefore, the resistance of power absorption unit (PAU) can be approximately set on the chassis dynamometer and the equation is as follows:

$$F_{PAU}=(A-a)+(B-b)V+(C-c)V^2$$

III. TESTING SYSTEM AND PROGRAM

A. Testing system

Test vehicle is a heavy-duty Hybrid Electric Bus. As shown in the TABLE Ⅰ and TABLE Ⅱ, main parameters and test environment are illuminated in detail.

TABLE I. VEHICLE PARAMETERS

Items	Parameters
vehicle mass at time of test	15630 kg
vehicle curb mass	11600 kg

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maximum loading mass	17800 kg
overall width	2250 mm
overall height	2400 mm
area of front projection	4.725 m^2
coefficient of air resistance	0.65

TABLE II. TEST ENVIRONMENT

Items	Parameters
atmospheric temperature	33 ^0C
atmospheric pressure	100.9kPa
atmospheric density	1.148758 Ngs^2gm^{-4}

B. Testing program

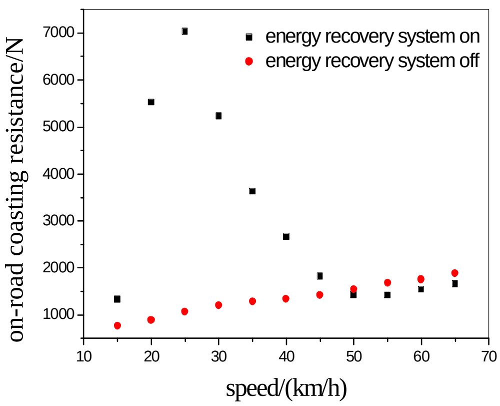
Before starting coasting test, the braking energy recovery system should be shielded because of the character of HEB performance. In order to establish load curves generated from road load coefficients and loss coefficients, 5km/h coasting speed interval is set up following from 70km/h to 15km/h and time△T from $V_2=V_i+\triangle V$ to $V_1=V_i-\triangle V$（△V =5km/h） is recorded as coasting time at the speed of V_i [7]. Repeat the above testing program and make the statistical accuracy of coasting time less than 5%. Finally, load curves and coefficients will be obtained by fitting data points（V_i, F_i）. Vehicle on-road running resistance or mechanical loss at the speed of V_i are as follows:

$$F_i = M\frac{2\Delta V}{\Delta T}\times\frac{1}{3.6}$$

IV. TESTING RESULT

A. The impact of braking energy recovery system

Fig.1 illustrates the working effect of braking energy recovery system while running a coastdown on the road.



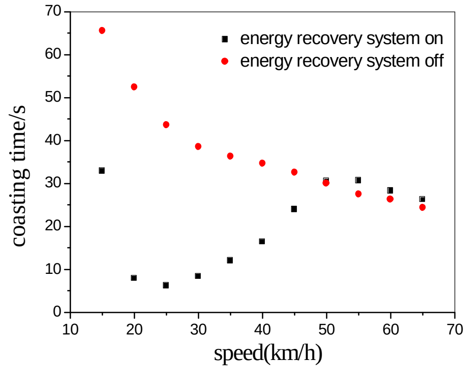


Figure 1. The impact of braking energy recovery system

In high-speed stage, coasting resistance and time are basically similar without reference to recovery system working status. With the increasing deceleration, recovery system gets to work. Coasting resistance increases sharply and coasting time reduces significantly, especially in the range of 20km/h-45km/h. It will make vehicle running resistance more complex. In order to accurately simulate on-road running resistance, braking energy recovery system must be shielded.

B. The comparison of different resistance calculation methods

As indicated in the TABLE Ⅲ, different coefficients are acquired by different resistance calculating methods.

TABLE III. LOAD COEFFICIENTS

calculation Methods/load coefficients	coasting test	theoretical calculation	standard calculation
A	562.352	628.013	958.263
B	18.735	3.9213	0
C	0.0247	0.1452	0.1501

Fig.2 to Fig.4 respectively compares resistance calculated from on-road coasting test and other computational methods. TABLE Ⅳ enumerates fitting equations about different methods.

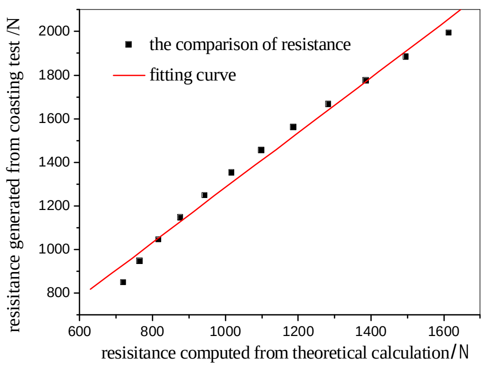


Figure 2. Comparison of resistance generated from on-road coasting test and theoretical calculation

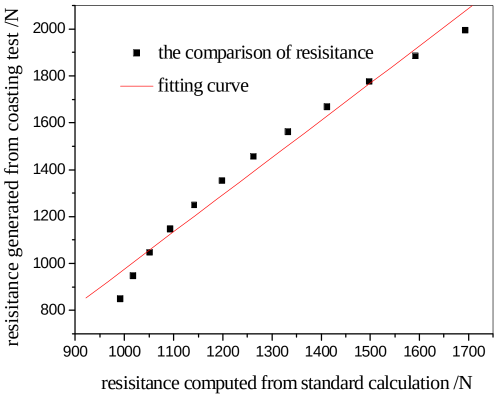


Figure 3. Comparison of resistance generated from on-road coasting test and standard calculation

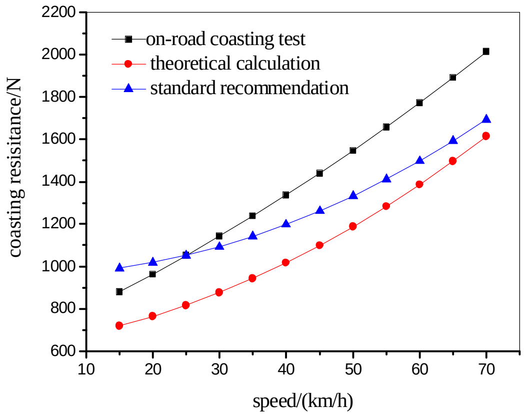


Figure 4. Comparison of resistance generated from different calculation methods

Fitting curves have a good correlation (correlation coefficient is approximately equal to 1), but proportionality coefficient is larger than 1 and absolute value of intercept is far greater than 0. It suggests that the average relative error between on-road test results and any other computational resistance is larger than 9% and even larger. The main reason is that automotive transmission resistance is not considered in the theoretical calculation method, and standard calculation is just a compromise by analyzing a great of test data. Therefore, HEB on-road coasting test can not be replaced by other calculation methods.

TABLE IV. FITTING EQUATIONS AMONG DIFFERENT CALCULATION METHODS

Fitting curve	Liner equation	Correlation coefficient
Coasting test and theoretical calculation	Y=1.26086X+23.402	R^2=0.9863
Coasting test and standard calculation	Y=1.58748X-611.909	R^2=0.9747

C. The simulant resistance of chassis dynamometer

Fig.5 shows on-road coasting resistance and mechanical loss of testing system. Fitting equation is illustrated in the TABLE Ⅴ.

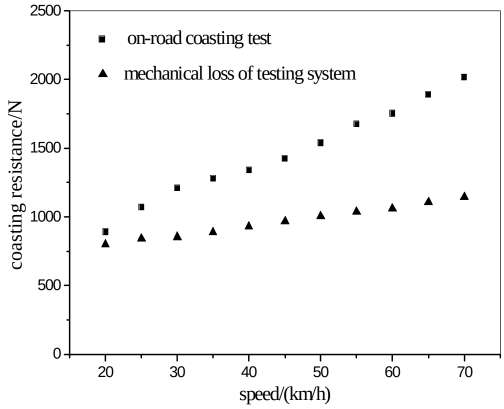


Figure 5. Test resistance

At present, there are two methods to set PAU resistance on the chassis dynamometer. Fig.6 respectively describes PAU resistance obtained from multi-point and coefficient setting method [8].

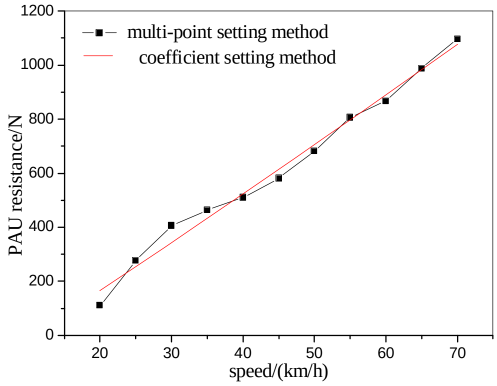


Figure 6. PAU setting resistance

Contrast between on-road coasting resistance and simulated results generated from multi-point and coefficient setting method on the chassis dynamometer is illustrated in the Fig.7. Fitting equation of simulated resistance, which is acquired by adopting coefficient setting method, is shown in the TABLE Ⅴ.

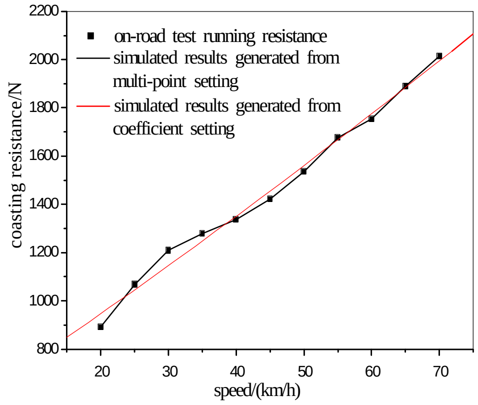


Figure 7. The simulant resistance of chassis dynamometer

It suggests that the maximum relative error between on-road test coasting resistance and simulated results on the chassis dynamometer is less than 3%. In other words, the on-road running resistance of HEB can be accurately reproduced on the chassis dynamometer.

TABLE V. MECHANICAL LOSS AND SIMULATED RESISTANCE ON THE CHASSIS DYNAMOMETER

Fitting curves generated from coefficient setting	Fitting equations	correlation coefficient
Mechanical losses	F_{Tloss}=681.11+5.67V+0.013V^2	R^2=0.9975
Simulated resistance	F=562.35+18.375V+0.0247V^2	R^2=0.9909

V. CONCLUSION

1) HEB on-road resistance is obtained by running coasting test, which is not be replaced by other calculation methods.

2) Using multi-point and coefficient setting method, on-road running resistance can be accurately reproduced on the chassis dynamometer.

3) It is not sure that homologous series HEB can utilize the same load coefficient directly, which meets chassis dynamometer test requirement, so we need to do more research in this aspect.

REFERENCES

[1] Yu Wei, Qin Kongjian. Status-quo and Trend of test methods for Emissions and Fuel Economy of Heavy Duty Vehicles [C]. Beijing: China Machine Press, 2009, 761~765.

[2] Ma Jie, Zhou Hua and Lu Hongyu. The Effect of Dynamometer Resistance Setting on the Test Result of Vehicle Exhaust Emission[J]. Automotive Engineering, 2006, 9: 873-876.

[3] Fang Maodong. Measurement of Road Running Resistance for Light-duty Vehicles and Its Setting on the Dynamomete [J]. Automobile Technology, 1996(2):22~27.

[4] Yu Zhisheng. Automotive Theory [M].Beijing: China Machuine Press,2006.

[5] Han Xiukun, Gao Liping and Qiu Qunlin. Calibration Method and Accuracy Analysis of Chassis Dynamometer[J]. Automotive Engineering, 2004, 5:623-625.

[6] Han Zongqi, Li Liang. A method of Determining Coasting Resistance Coefficient [J].Automotive Engineering, 2002, 4: 364-366.

[7] Ministry of Environmental Protection of the People’s Republic of China .GB18352.3-2005 Limits and Measurement Methods for Emissions From light-duty Vehicles(Ⅲ 、 Ⅳ) [S]. Beijing: China Environmental Science Press, 2005.

[8] Fang Maodong. A Study on the setting of Chassis Dynamometer for Automotive Emission Test. [J] Automotive Engineering, 1996, 2:114-119.