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The Measurement for Performance Parameter of Automobile Braking System with Electronic Vacuum Booster

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Abstract

This paper measures the performance parameter of the automobile braking system with Electronic Vacuum Booster (EVB) through real vehicle experiment. According to the data collected from the experiment, the performance parameters of EVBs in different cars are not the same. The performance parameters of the EVB in both test cars can be separated into three parts. For example, when the desired braking intension, in other words the input signal of electronic vacuum booster, is less than 7, the braking effect is not obvious; when the desired braking intension is between 7~40, the relationship between the desired braking intension and the acceleration is found to be linear variation; when the desired braking intension is greater than 40, the wheels will be locked and the acceleration is constant. Then we get the performance parameter of automobile braking system with electronic vacuum booster through linear regression. The results can be used for automatic brake control.

Keyword: Braking system; Electronic Vacuum Booster; Performance parameter; Acceleration; Braking intension

1. Introduction

With the development of wireless communication technology and intelligent vehicle technology, the cooperative vehicle infrastructure systems are becoming hot research areas. Car to car collaboration is the important part of cooperative vehicle infrastructure systems (Zhang et al., 2012). As the subsystem of cooperative vehicle infrastructure systems, car-to-car collaborative control emphasizes on the key technology of conflict resolution, vehicle active control and safety warning (Hou, D.Z., 2004). Vehicle active control includes vehicle active brake control. To realize the vehicle active brake control, the vehicle has to be installed with the electronic vacuum booster (Wang et al., 2011).

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EVB devices are increasingly being used now in cars. It is based on the general vacuum booster of the vehicle, and has two functions. One is to take the place of driver to actively adjust the brake pressure without driver action. This is employed in driving assistance systems, such as ACC (adaptive cruise control), S&G (stop & go) and CAS (collision avoidance system). Another is to automatically increase the brake pressure for emergency braking to ensure safety (Zhang et al., 2010).

In order to implement the automatic brake control, the performance parameter of the EVB has to be calculated. By sending the desired braking acceleration to the EVB when the vehicle is conflicting with other vehicles, the EVB will actively adjust the brake pressure to achieve the desired acceleration to avoid conflict of vehicles (Li, S.F., 2009) (shown as Fig.1). The relationship between the desired braking acceleration and the braking intension is needed, which is the performance parameter of the EVB.

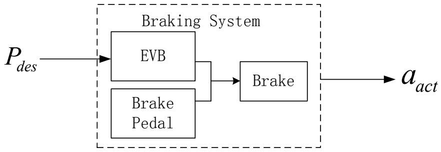


Fig.1. the relationship between P_{des} and a_{act}

In Fig.1, P_{des} is the desired braking intension, which is the input signal, and a_{act} is the actual acceleration, which is the output signal.

This paper measures the performance parameter of automobile braking system with electronic vacuum booster via real vehicle experiment.

2. Method

2.1 Experiment method

As shown in Fig.1, EVB adjusts brake pressure to achieve the desired acceleration. In order to get the desired acceleration, we need to know the relationship between braking intension, the input signal of electronic vacuum booster, and the acceleration of vehicles. In our experiment, different braking intension is sent to the EVB and the actual acceleration will be measured after the braking system adjusts the brake pressure. The relationship between the desired braking intension and the actual acceleration can be obtained. Then calculating the inverse function can get the relationship between the desired acceleration and the actual braking intension, and the inverse function can be used to describe the performance of the EVB.

For the purpose of measuring whether speed has an influence on the relationship between the braking intension and the acceleration, the experiment is conducted under different speeds.

The method to get performance parameter by experiment is as follows: Let the test car run with the different speeds, then give the different brake intension signals to the CAN bus of test car. The EVB will get the signals and implement automatic control. At the same time GPS measures the speed, and the IMU measures the crosswise and axial acceleration of the car. According to the relationship of the brake intension signal, the acceleration and the speed, the performance parameter of the EVB can be obtained.

2.2 Data acquisition

This experiment is to get the relationship between the vehicle acceleration and the brake intension signal. The actual values of the acceleration and brake intension signal of test car have to be measured. The experimental facilities are as follows: two test cars with electronic vacuum boosters, IMU (Inertial Measurement Unit), GPS and IPC (Industrial Personal Computer). The data acquired by the equipment are as follows: the input brake intension signal (that is the desired braking intension, whose theoretical value is between 0~100, while corresponding with the brake pressure from 0 to 10MPa), the crosswise and axial acceleration of the IMU, and speed of the test car.

This paper selects 32 different desired braking intensions based on experience from many experiments. The specific steps are as follows:

(1) Conduct the experiment at every desired braking intension 5 times respectively.

(2) Send the brake intension signal to the EVB when the speed achieves to 60km/h and let the signal last for 3~5 seconds. The data are recorded at the same time.

(3) Send the brake intension signal to the EVB again when the test car has slowed down, and repeat the same work until the speed approach to zero.

Data collection is carried out for two cars, getting 16188 and 4579 groups of data respectively.

2.3 Data processing

The installation position between the IMU and the test car's center of gravity has some deviation (shown as Fig.2). The data acquired by the IMU is not the test car's crosswise and axial acceleration. While it is the IMU's (a_y & a_x), we have to calculate the crosswise and axial acceleration of the test car (a_Y & a_X).

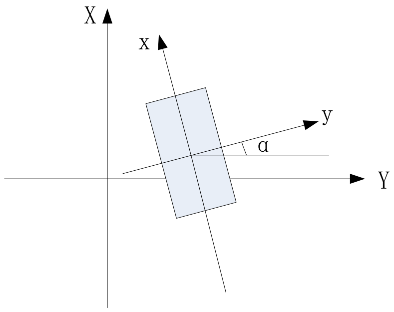
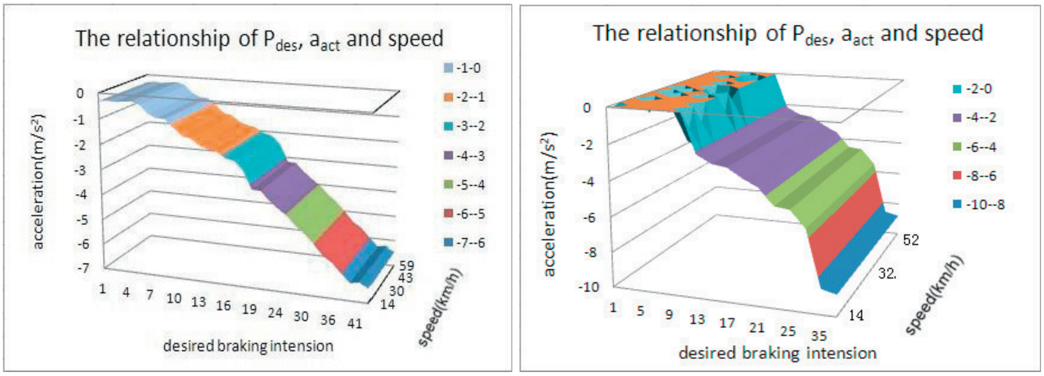


Fig.2. the installation deviation angle of IMU

In Fig.2, α is the deviation angle between the IMU and the test car. The acceleration of the test car can be got by the following formula:

$$\begin{cases} a_X = a_x \cos\alpha + a_y \sin\alpha \\ a_Y = a_y \cos\alpha - a_x \sin\alpha \end{cases} \quad (1)$$

In order to analyze the variation tendency of the acceleration and whether speed has any influence on the acceleration, the time-dependent curve of acceleration and the speed-dependent curve of acceleration have been made. At the same time the relationship of the desired braking intension, the actual acceleration and the speed has been made (shown as Fig.3).

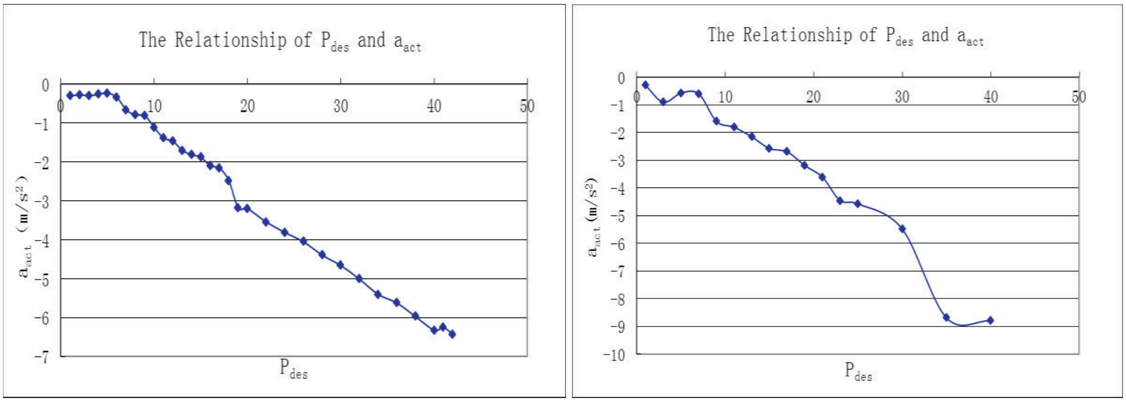


(a) (b)

Fig.3. the relationship of P_{des}, a_{act} and speed

(a) the first car; (b) the second car

The Fig.3 shows that the speed almost has no influence on the relationship between the acceleration and the desired braking intension. So the graph of the relationship between the desired braking intension and the acceleration can be got. The acceleration is the average of the accelerations at every desired braking intension (shown as Fig.4).



(a) (b)

Fig.4. the relationship of P_{des} and a_{act}

(a) the first car; (b) the second car

Fig.4 shows that the relationship between the desired braking intension and the acceleration of the two cars are not the same.

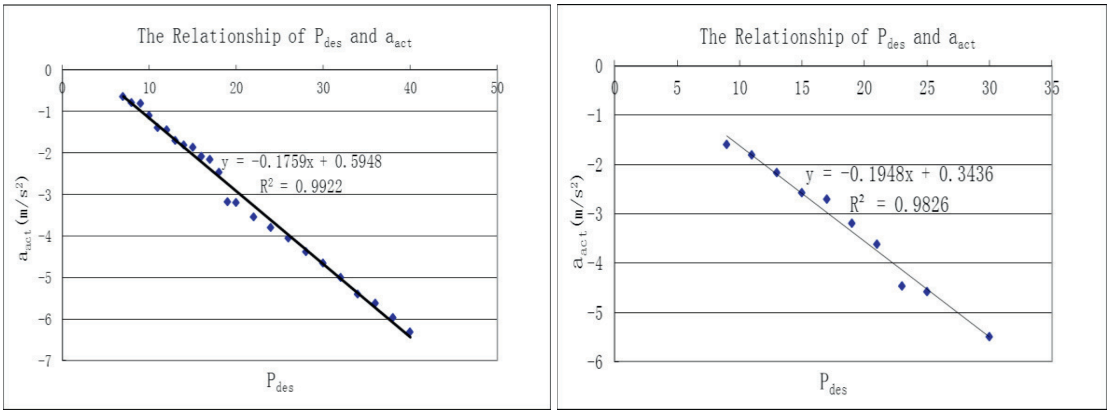
For the first car, when the desired braking intension is less than 7, the braking effect is not obvious; when the desired braking intension is between 7~40, the relationship between the desired braking intension and the acceleration presents to be linear variation; when the desired braking intension is greater than 40, the variation of the acceleration is not obvious, almost present to be a horizontal line.

For the second car, when the desired braking intension is less than 9, the variation of the acceleration has fluctuations; when the desired braking intension is between 9~35, the relationship of the desired braking intension and the acceleration presents to be linear variation; when the desired braking intension is greater than 35, the variation of the acceleration is not obvious.

The above analysis shows that the relationship between the desired braking intension and the acceleration of the two cars are not the same. Both relationships can be separated into 3 parts.

The first part: when the desired braking intension is less than 7 or 9, the braking effect is not obvious. The results present to be a horizontal line.

The second part: when the desired braking intension is between 7~40 or 9~35, the relationship between the desired braking intension and the acceleration presents to be linear variation.



(a) (b)

Fig.5. the relationship of P_{des} and a_{act} (linear part)

(a) the first car; (b) the second car

Fig.5(a) shows that for the first car when the desired braking intension is between 7~40, the relationship between the desired braking intension and the acceleration can be regressed by linear model. The linear equation is as:

$$y = \begin{cases} -0.66, & 0 < x < 7 \\ -0.1759x + 0.5948, & 7 \le x < 40 \\ -6.32, & x \ge 40 \end{cases} \tag{2}$$

where x represents the braking signal and y represents the acceleration. The regression coefficient is 0.9922. The multinomial is as:

$$y = \begin{cases} -0.66, & 0 < x < 7 \\ 0.0008x^2 - 0.2131x + 0.9396, & 7 \le x < 40 \\ -6.32, & x \ge 40 \end{cases} \tag{3}$$

Where x represents the braking signal and y represents the acceleration. The regression coefficient is 0.9938. The both regression coefficients are close to each other. Due to the convenience of calculation, we choose the linear equation (2) to describe the relationship between the desired braking intension and the acceleration for the first car.

Fig.5 (b) shows that for the second car when the desired braking intension is between 9~35, the relationship between the desired braking intension and the acceleration also can be regressed by linear model. The linear equation is as:

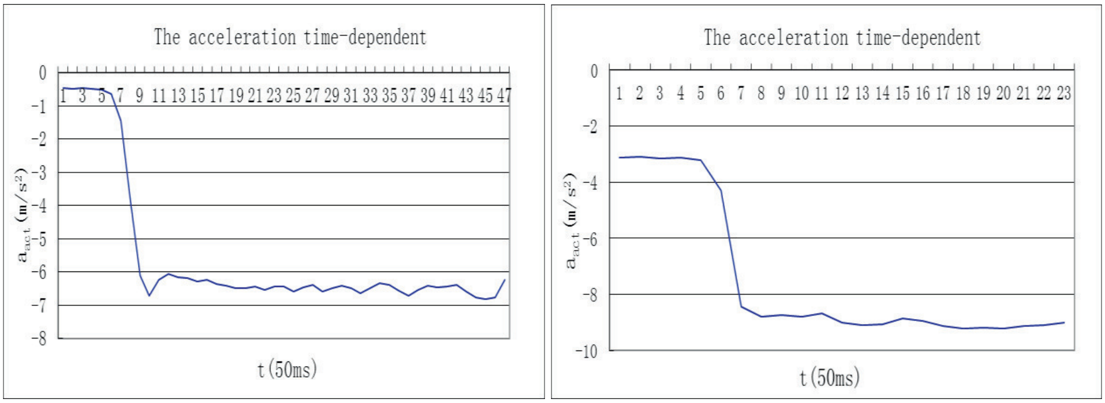
$$y = \begin{cases} -1.60, & 0 < x < 9 \\ -0.1948x + 0.3436, & 9 \le x < 35 \\ -8.70, & x \ge 35 \end{cases} \quad (4)$$

Where x represents the braking signal and y represents the acceleration. The regression coefficient is 0.9826. The multinomial is as:

$$y = \begin{cases} -1.60, & 0 < x < 9 \\ -0.0014x^2 - 0.1395x - 0.127, & 9 \le x < 35 \\ -8.70, & x \ge 35 \end{cases} \quad (5)$$

Where x represents the braking signal and y represents the acceleration. The regression coefficient is 0.9848. The both regression coefficients are close to each other. We choose the linear equation (4) to describe the relationship between the desired braking intension and the acceleration for the second car.

The third part: when the desired braking intension is greater than 40 or 35, the variation of the acceleration is not obvious. It means that the wheels are locked.



(a) (b)

Fig.6. the acceleration time-dependent

(a) the first car; (b) the second car

Fig.6 (a) shows the acceleration time-dependent of the first car when the desired braking intension is 40. The stable value is -6.32m/s^2, the delay time is 0.45s, the rise time is 0.15s.

Fig.6 (b) shows the acceleration time-dependent of the second car when the desired braking intension is 35, the stable value is -8.70m/s^2, the delay time is 0.30s, and the rise time is 0.08s.

3. Results and analysis

The data acquisition and processing give the result that the relationship between the desired braking intension and the acceleration can be separated into 3 parts. For example, for the first car, the first part: when the desired braking intension is less than 7, the braking effect is not obvious. The result almost presents to be a horizontal line. The second part: when the desired braking intension is between 7~40, the relationship of the desired braking intension and the acceleration presents to be linear variation. From the linear equation matched by the two cars, (2) and (4), the performance parameter of the EVB can be got by calculating their inverse functions. The third part: when the desired braking intension is greater than 40, the acceleration is constant. It means that the wheels are locked. According to the above calculation, the EVBs' performance parameters of the two test cars are as follows:

$$x = \begin{cases} 0, & -0.66m/s^2 < y < 0 \\ -5.5956y + 3.615, & -6.32m/s^2 < y \le -0.66m/s^2 \\ 40, & y \le -6.32m/s^2 \end{cases} \tag{6}$$

$$x = \begin{cases} 0, & -1.60m/s^2 < y < 0 \\ -5.0442y + 2.0526, & -8.70m/s^2 < y \le -1.60m/s^2 \\ 35, & y \le -8.70m/s^2 \end{cases} \tag{7}$$

Where x represents the braking signal and y represents the acceleration.

The results show that the performance parameters of the different cars' EVB are not the same. So the performance parameters of the EVB installed in the different cars have to be measured respectively. At the same time, the relationship between the desired braking intension and the acceleration is not a simple linear relation, but we can use linear model to describe different segments.

According to the relationship of the desired braking intension and the acceleration, deducing the inverse function can easily get the relationship of the desired acceleration and the braking intension, and the inverse function can be used to describe the performance of the EVB. When the vehicle is conflicting with other vehicles, the safety acceleration will be sent to the EVB by programming with the performance parameter. The braking system will actively adjust the brake pressure until the speed slow down and avoid the conflict.

4. Conclusions

This paper introduces a method to measure the performance parameter of automobile braking system with electronic vacuum booster via real vehicle experiment. The conclusions are as follows:

(1) The speed has no influence on the relationship between the desired braking intension and the acceleration.

(2) The performance parameters of the different cars' EVB are not the same, so the performance parameters have to be measured respectively.

(3) The performance parameters of the both test cars' EVB can be separated into 3 parts: For the first car, when the desired braking intension is less than 7, the braking effect is not obvious. The result almost presents to be a horizontal line; when the desired braking intension is between 7~40, the relationship between the desired braking intension and the acceleration presents to be linear variation; when the desired braking intension is greater than 40, the wheels are locked, the acceleration is constant. For the second car, when the desired braking intension is less than 9, the braking effect is not obvious. The result has some fluctuation; when the desired braking intension is between 9~35, the relationship between the desired braking intension and the acceleration

presents to be linear variation; when the desired braking intension is greater than 35, the wheels are locked, the acceleration is constant. The EVBs' performance parameters of the two test cars are as formula (6) and (7).

The performance parameter gained by the real vehicle experiment can be used to realize automatic brake control.

Acknowledgements

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