The Theoretical Analysis of Test Result's Errors for the Roller Type Automobile Brake Tester

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Abstract: The main testing parameter of the roller brake tester is the braking force. Actually, there are some differences in results even if the same vehicle is tested on the same tester. So it will bring trouble to evaluate the braking performance accurately. Based on force analysis, the mathematical model of the roller opposite force type automobile brake tester is built in this article. And then the factors of influencing braking force value will be analyzed by theoretical calculations Taking the instance of the Jianghuai light truck and using the mathematical model analyze influencing factors for testing results and calculate error value.The results showed that adhesion cofficients of between testing wheels and rollers and between non-testing wheels and floor, structure of the roller brake testor have an influece on testing results of braking force and structure of the roller brake testor is the least. The theoretical analysis provide references for comparison test among testing equipments of the braking performance.

Key words: Roller brake tester, Mathematical model, Adhesion coefficient, Braking force, Error

1 Introduction

Automobile braking performance is one of the most important factors in vehicle safety performances[1][2].It is also a key indicator and an essential inspection item of vehicle safety performance test. Currently, the automobile braking performance is tested mostly through the roller opposite force type brake tester according to GB7258-2004 named "Safety specifications for power-driven vehicles operating on roads" However, the same car in different tester for the braking performance test, the results often not consistent, even contrary. So that, it can't evaluate the vehicle's braking performance whether reached the national standards.

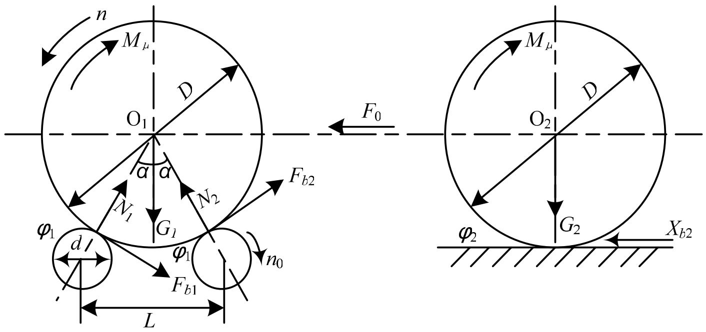
Based on the above situation, it is necessary to approach the influencing factors of testing results for the parameters of the testers, and establish its mathematical model of automobile testing on the roller brake tester. Thus, it can analyze the relationship of the vehicle testing results from different testers, and it can obtained more consistent evaluations of the vehicle's braking performance.

2 Mathematical model of automobile testing on the roller brake tester

According to the braking test of automobile on the roller tester, the force analysis is processed in two ways: force analysis of front wheels test and rears wheel test. So the mathematics theoretical models are built individually. When analyzing, it is assumed that the center of front and rear wheels is located in the same level. And the influences caused by rolling resistance and resilient wheels on force-measuring system are ignored.

2.1 Mathematical model of front wheels braking test[3]

When the automobile's front wheels brake, the force analysis of the roller brake tester is as shown in Figure 1.



D----wheel diameter(mm); d----roller diameter(mm); α----formed angle;

G_1, G_2----load of the front wheels and rear wheels(N);

N_1、N_2----normal force of the front and rear rollers to front wheels(N);

F_{b1}、F_{b2}----tangential force of the front and rear rollers to front wheels(N);

φ_1----adhesion coefficient between testing wheels and rollers;

φ_2----adhesion coefficient between non-testing wheels and floor;

X_{b2}----horizontal reaction force of floor to rear wheels(N)

Fig.1 The force analysis of front wheels braking test on the roller tester

According to the principle of mechanical equilibrium, relations can be built as below:

$$\sum F_X = 0 \quad F_{b1}\cos\alpha + F_{b2}\cos\alpha + N_1\sin\alpha - N_2\sin\alpha - F_0 = 0 \tag{1}$$

$$\sum F_Y = 0 \quad -F_{b1}\sin\alpha + F_{b2}\sin\alpha + N_1\cos\alpha + N_2\cos\alpha - G_1 = 0 \tag{2}$$

With the increasing of F_{b1} when the front wheels brake force is being tested, if the front wheels don't slip backwards, the maximum value of F_{b1} and F_{b2} will be: $F_{b1\max} = N_1 \cdot \varphi_1$ and $F_{b2\max} = N_2 \cdot \varphi_1$. Meanwhile, $F_0 = X_{b2\max} = G_2 \cdot \varphi_2$. So Eq.1 and Eq.2 can be written as:

$$N_1 = \frac{G_2\varphi_2(\varphi_1\sin\alpha + \cos\alpha) - G_1(\varphi_1\cos\alpha - \sin\alpha)}{(1+\varphi_1^{\,2})\sin 2\alpha} \tag{3}$$

$$N_2 = \frac{G_2\varphi_2(\varphi_1\sin\alpha - \cos\alpha) + G_1(\varphi_1\cos\alpha + \sin\alpha)}{(1+\varphi_1^{\,2})\sin 2\alpha} \tag{4}$$

Under the premise of no moving backwards, the vehicle's front wheels maximum brake force should be:

$$F_{bf\max} = F_{b1\max} + F_{b2\max} = (N_1 + N_2)\varphi_1 = \frac{G_2\varphi_1^{\,2}\varphi_2 + G_1\varphi_1}{(1+\varphi_1^{\,2})\cos\alpha} \tag{5}$$

According to Eq.3, if $\varphi_2 = \dfrac{G_1(\varphi_1\cos\alpha - \sin\alpha)}{G_2(\varphi_1\sin\alpha + \cos\alpha)}$ then $N_1 = 0$, the tested wheels will leave the roller and move backwards. Meanwhile we can get:

$$N_2 = \frac{G_1}{\varphi_1 \sin\alpha + \cos\alpha} \tag{6}$$

If the tested wheels are locked after leaving the roller tester, the maximum brake force of the front wheels is:

$$F'_{bf\max} = N_2 \cdot \varphi_1 = \frac{G_1 \varphi_1}{\varphi_1 \sin\alpha + \cos\alpha} \tag{7}$$

2.2 Mathematical model of rear wheel braking test

When the vehicle's rear wheels brake force is tested, the force analysis of the roller brake tester is as shown in Fig.2.

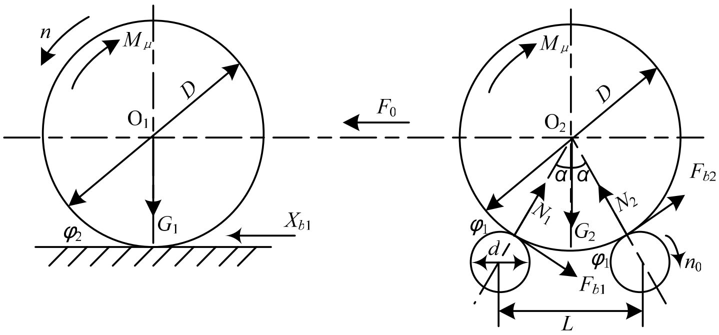


Fig.2 The force analysis of rear wheel braking test on the roller brake tester

Similarly, according to the principle of mechanical equilibrium, relations can be built as below:

$$\sum F_X = 0 \quad N_1 \sin\alpha + F_{b1} \cos\alpha + F_{b2} \cos\alpha - F_0 - N_2 \sin\alpha = 0 \tag{8}$$

$$\sum F_Y = 0 \quad N_1 \cos\alpha + N_2 \cos\alpha + F_{b2} \sin\alpha - F_{b1} \sin\alpha - G_2 = 0 \tag{9}$$

If the rear wheels don't slip backwards, have $F_{b1\max} = N_1 \cdot \varphi_1$, $F_{b2\max} = N_2 \cdot \varphi_1$ and $F_0 = X_{b\max} = G_1 \cdot \varphi_2$. So it can be gotten that:

$$N_1 = \frac{G_1 \varphi_2 (\varphi_1 \sin\alpha + \cos\alpha) - G_2 (\varphi_1 \cos\alpha - \sin\alpha)}{(1 + \varphi_1^2) \sin 2\alpha} \tag{10}$$

$$N_2 = \frac{G_1 \varphi_2 (\varphi_1 \sin\alpha - \cos\alpha) + G_2 (\varphi_1 \cos\alpha + \sin\alpha)}{(1 + \varphi_1^2) \sin 2\alpha} \tag{11}$$

The maximum brake force of the rear wheels is

$$F_{br\max} = \frac{G_1 \varphi_1^2 \varphi_2 + G_2 \varphi_1}{(1 + \varphi_1^2) \cos\alpha} \tag{12}$$

According to Eq.10, it can be known that $N_1 = 0$ when $\varphi_2 = \dfrac{G_2 (\varphi_1 \cos\alpha - \sin\alpha)}{G_1 (\varphi_1 \sin\alpha + \cos\alpha)}$, then

$$N_2 = \frac{G_2}{\varphi_1 \sin\alpha + \cos\alpha} \tag{13}$$

If the tested wheels locked after leaving the roller tester, the maximum brake force of the rear wheels is:

$$F'_{br\max} = N_2 \cdot \varphi_1 = \frac{G_2\varphi_1}{\varphi_1 \sin\alpha + \cos\alpha} \tag{14}$$

3 Analysis on influencing factors of testing results[4] [5]

3.1 The adhesion coefficient between testing wheels and rollers

According to GB/T13564-2005 "the roller opposite force type automobile brake tester", if vehicle is lighter than 3 tons, the roller tester's diameter should be 245 mm and the center distance should be 430 mm. Take a light truck HFC1061KS for example, its tires model type is 7.50-16, and the individual weight of front and rear axles are 1716 kg and 1412 kg. Considering the actual testing situation, let $\varphi_1 = 0.6 \sim 0.95$ and $\varphi_2 = 0.7$. Substituting them in Eq.5, the calculation results are shown in Fig.3 as below.

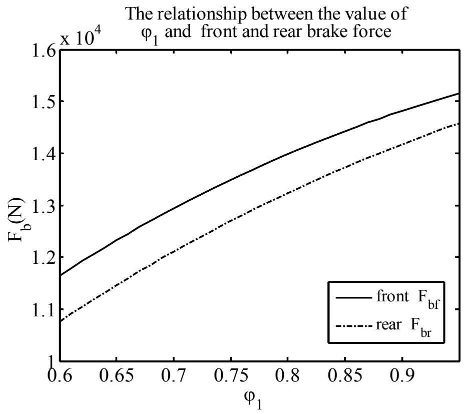


Fig.3 The relation curves of the front and rear wheel braking forces with the increase of φ_1

From Fig.3, it can obviously tell that the difference of braking force between $\varphi_1 = 0.6$ and $\varphi_1 = 0.95$ is up to about 4000 N, which reflects that the braking performance is affected by φ_1. Because the rollers may be worn more or less after a long use, the value of φ_1 will decrease. Regarding the front and rear brake force when $\varphi_1 = 0.75$ as reference values, some comparisons are made as Tab.1 between $\varphi_1 = 0.65$ and $\varphi_1 = 0.75$.

Tabel 1 The comparison of the front and rear brake force between $\varphi_1 = 0.65$ and $\varphi_1 = 0.75$

	$\varphi_1 = 0.65$	$\varphi_1 = 0.75$	Relative error δ
Front F_{bf}	12324 N	13488 N	8.63%
Rear F_{br}	11458 N	12695 N	9.75%

It can be concluded that with the increase of adhesion coefficient between wheels and rollers, the braking force test capability of front and rear wheels will significantly increase as well. Hence, a good value of φ_1 which must be ensured through a number of ways is a basic premise for braking force test.

3.2 The adhesion coefficient between non-testing wheels and floor

Similarly, taking the light truck and the same tester as an example, the front and rear braking force will be calculated. According to GB7258-2004, the value of φ_1 should not be less than 0.75. So it is taken as 0.75 on the calculation. Considering the actual testing situation, φ_2 is taken between 0.4 and 0.8. The results are calculated and shown in Fig.4.

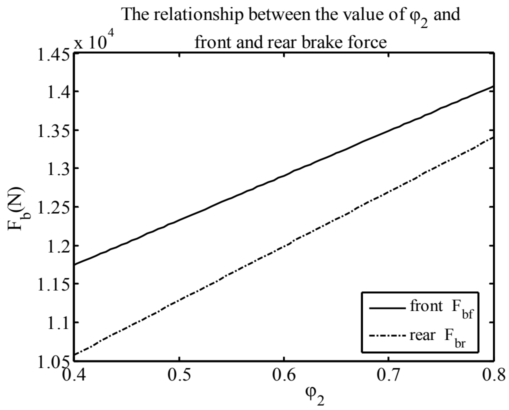


Fig.4 The relation of the front and rear brake force with the increase of φ_2

From Fig.4, we can tell that the test result differs when we take different values of the adhesion coefficient between non-testing wheels and floor. Furthermore there is a proportional relationship between the value of φ_2 and braking force. The difference of braking forces between $\varphi_2 = 0.4$ and $\varphi_2 = 0.8$ is up to about 2000 N, which has a great impact on the evaluation of braking performance. In test stations, if the ground cannot be cleaned up or maintained in time, it will lead to the decrease of adhesion coefficient, and then affect the evaluation on braking performance. For example, the adhesion coefficient of terrazzo floor is less than 0.6. Regarding the front and rear brake force when $\varphi_2 = 0.7$ as reference values, some comparisons are given as Tab.2 between $\varphi_2 = 0.7$ and $\varphi_2 = 0.6$.

Tabel 2 The comparison of the front and rear brake force between $\varphi_2 = 0.6$ and $\varphi_2 = 0.7$

	$\varphi_2 = 0.6$	$\varphi_2 = 0.7$	Relative error δ
Front F_{bf}	12906 N	13487 N	4.31%
Rear F_{br}	11988 N	12694 N	5.56%

By the Eq.6, Eq.7, Eq.13 and Eq.14, it is known that when the φ_2 takes a particular data ($N_1 = 0$) the testing braking force is minimum. It means the vehicle is slipping on the tester. That may be one reason why the vehicle with good brake performance cannot pass the test. So in the actual test, it is specified that the adhesion coefficient between non-test wheels and ground cannot be less than 0.7.

3.3 Structural factors of the roller brake tester

After investigation we found that the sizes of testers which are being used in different test institutions have differences, although GB/T13564-2005 has made provisions for the standard of tester. According to the force analysis in Fig.1 and Fig.2, it can be known that the formed angle α is related to the wheel diameter D, the roller diameter d and the roller center distance L. Supposing that D is a constant value (taking the light truck as an example), we can discuss the relationship between the formed angle α and braking force through combining with the actual parameters of different testers. The formed angle α is proportional to the front and rear braking force, as shown in Fig.5.

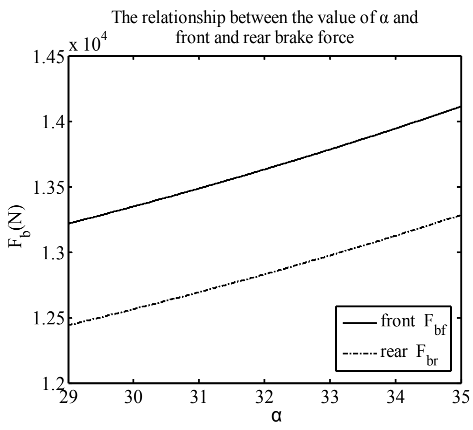


Fig.5 The braking force of front and rear wheels with the change of the formed angle α

Also taking the light truck as an example, applying relevant parameters of three different testers and combining Eq.5 with Eq.12, the braking force of front and rear wheels are shown as below:

Table 3 The front and rear brake force of JAC light truck on the different testers

Type	d(mm)	L(mm)	α(°)	F_{bf}(N)	F_{br}(N)
1	200	390	29.6	13293.9	12512.7
2	240	470	34.5	14027.5	13203.2
3	245	430	31.0	13487.0	12694.4

In Tab.3 the data of Type 3 is the ruled data in GB/T13564-2005. If taking them as reference values, the relative errors are -1.43% in Type 1 and 4.01% in Type 2.

From Fig.5 and Tab.3, the conclusion is made: when the same vehicle is tested in different testers, the formed angles are different due to the different structures. It causes the errors in test results. Therefore, the structure of the brake tester can be an impact for the braking force test as well.

4 Conclusions

By taking a light truck as an example, the mathematical model is established through force analysis. Combining the specific parameters of tester, the test results of braking force can be theoretically analyzed and calculated by the model. The conclusions can be made as below:

1. The testing results are affected by the adhesion coefficient between the tested wheels and rollers, by the adhesion coefficient between non-tested wheels and ground, and by the structure of the brake roller tester. Among them, the structure of brake tester contributes relatively less affection to the braking force.

2. Due to the difference of the structure of testers in different places, it makes some differences in braking force test results. They belong to structural errors and are unavoidable in the testing process. From Tab.3 and Fig.5 we can see that the formed angle has less influence in test results. It indicates that doing comparative tests of different test devices is feasible and the test results are comparable.

3. To reduce the test errors resulting from the structure of the testing equipment, the formed angles α can be modified through the mathematical model if they are too large or too small.

Acknowledgement

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