Comparative Studies of the Tread Brake Dynamometer Between Dry and Wet Conditions

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Abstract: - This paper discuss comparative strudies of the tread brake dynamometer between dry and wet conditions. The brake dynamometers are widely used to evaluate the performance of brake systems and test the brake parts under various environments (weight, velocity, brake force, wet-dry conditions). In the process of the brake stops, the friction coefficients between dry and wet conditions must not deviate from each other by more than 15% under the same conditions. Experiments on the brake dynamometer for the high speed train are shown to illustrate the comparative studies of the tread brake dynamometer between dry and wet conditions with initial vehicle speed at 200 [km/h] considering the 920 [mm] wheel diameter.

Key-Words: - Tread Brake, Brake Dynamometer, Railway Vehicle, friction coefficients

1 Introduction

Dynamometer is a device for measuring the torque, force, or power available from a rotating shaft. The shaft speed is measured with a tachometer, while the turning force or torque of the shaft is measured with a scale or by another method. The first dynamometer was designed to measure the brake horsepower of a motor. This invention was the work of an engineer, Gaspard. He invented the Prony Brake Dynamometer in 1821 in Paris. Variations of this dynamometer are still in use today[1][2].

Brake dynamometer is designed to simulate the brake characteristic of the high speed train, and has a function of record the data which can be reproduced and help to analyze and compare the experimental object, and also is used to develop and test the brake system.

An example of such a dynamometer is shown in Figure 1. There are many variations to this basic format, because of the high speed rotation operation. There is an electric motor inserting and absorbing power, an inertia section, and a test section where the brake is mounted. Each size of vehicle will require different amounts of inertia. Since these disks are in discrete steps, there is often a compromise among the number of disks and wheels, the changeable inertia. Many test procedures specify how much inertia should be used based on vehicle weight and wheel load.

The test procedures performed on the brake dynamometers cover a wide range of operational conditions. They may simulate actual vehicle operations. For instance, in aircraft dynamometers it is typical to simulate actual operating conditions including taxing, take-offs, and landings. In passenger vehicle testing, standard procedures are often used which do not simulate typical vehicle operations, but instead, represent critical operational scenarios that test the limits of brake performance or elicit a specific type of performance characteristic.



Fig.1 Drawings of the brake performance dynamometer

The friction coefficients between dry and wet condition must not deviate from each other by more than 15% under the same conditions[7]. This paper contains the comparative studies of the tread brake dynamometer between dry and wet condition in initial vehicle speed at 200 [km/h] considering the 920 [mm] wheel diameter.

This paper is organized as follows. Section 2 overviews a brake dynamometer. Section 3 describes the experiment environment for the tread brake. Section 4 shows the experiment results which contain the comparison of dry and wet condition when the tread brake is applied. The main conclusions are then summarized in section 5.

2 Brake Dynamometer

A dynamometer consists of the following main elements.

• The drive-train consists of the following elements: motor, interchangeable flywheels and brake disk. The flywheels and brake disk is matched to the part number to be tested.

• The test bed consist of the following elements: caliper & adapter, power transfer axle, load bearing arm and load cell to calculate the breaking force.

In general, dynamometers are widely used to simulate the break performance of the railway vehicle. Brake dynamometer is designed to simulate the brake characteristic of the high speed train, and has a function of record the data which can be reproduced and help to analyze and compare the experimental object, and also is used to develop and test the brake system. The expected effect and practical scheme of the brake dynamometer are followings:

• Development of the brake, disk-pad, wheel and brake system of the high-speed & conventional train

• Test and performance evaluation of the brake system of the high-speed & conventional train with the international standard

• Performance and certification test of the brake system of the manufactured high speed train

Table 1 shows the main features of the brake dynamometer.

Max. drive power	397kW(540HP)
Max. unve power	<i>39/KW</i> (<i>3</i> 40111)

Max. drive torque	2,527Nm
Max. drive speed	2,500rpm(400km/h)
Max. brake torque	25,000Nm
Pressure Brake	6,000 N x 2
Flywheel Inertia	$\frac{Max./Min.}{1900 kg \cdot m^2/400 kg \cdot m^2}$
Diameter of the test wheel	Φ 700 ~ 1120mm
Acceleration time (0~1500rpm)	2 min. 30 sec



Fig.2 Brake performance dynamometer for high speed train

3 Experiments Environment

The friction coefficients between dry and wet condition must not deviate from each other by more than 15% under the same conditions according to the requirements of the UIC CODE 541-4. [7]

The instantaneous friction coefficient μ_a , which is determined in any moment of braking by the ratio of total braking force F_t to total contact force F_b , is calculated as

$$\mu_a = \frac{F_t}{F_b} \tag{1}$$

And the mean friction coefficient μ_m determined from reaching 95% of the nominal contact force F_b of the friction coefficient μ_m for the braking distance S_2 as Eq. (2).

$$\mu_m = \frac{1}{S_2} \int_{0}^{S_2} \mu_a ds$$
 (2)

Fig. 3 shows control desk screen to control and monitor the braking performance tester



Fig.3 Control desk screen for controlling and monitoring of the braking performance tester



Fig.4 Tread brake block of the braking performance tester

In the tread braking test, the initial test speed is set out at 200 [km/h] with composite tread brake blocks for the high speed train. And the same initial speed applies for testing the brake test at dry and wet condition.

Fig. 5 shows the surface of the wheel tread when it applied the braking process at initial speed of 200 [km/h]. We can observe the movement of the thermal band according to the speed variation.



(a) 180 [km/h]



(b) 170 [km/h] Fig.5 Trade breaking test at dry condition

For the tread braking test, we choose the inertia value as 800 $[kg \cdot m^2]$ because the UIC test program prescribed 4 [ton] (mass per brake disc) in case of the high speed train. And cylinder force is accomplished under 5.9 [KN].

4 Experiments

The two step tests were performed to compare braking performance under dry condition with that of wet condition.

4.1 Test Results of the Tread Brake

The experimental results including the speed curve, instantaneous friction coefficient, braking torque, and cylinder pressure from 200[km/h] to 0 [km/h] were obtained.



Fig.6 Measurement data with the dry condition at the initial brake speed 200 [km/h].

In the tread braking test of dry condition, braking distance was measured 1,213 [m] and braking time was gauged 45.7 [sec] during the braking test with cylinder pressure 22.6[kg/cm²] (i.e. cylinder force 5.9 [kN]).



Fig.7 Measurement data with the wet condition at the initial brake speed 200 [km/h].

In the braking test of wet condition, braking distance was measured 1,263 [m] and braking time was gauged 48.4 [sec] during the braking test with the same conditions.

4.2 Mutual Comparison between Dry and Wet Conditions

Two kinds of braking tests were performend and compared the results of the braking tests at a point of view of measured braking distance, braking time, braking torque, cylinder pressure, and friction coefficient.

Fig. 8 illustrates the mutual comparisons between dry and wet conditions, which are braking distance and braking time.



Fig.8 Mutual comparison between dry and wet: braking distance and braking time

Fig.8 indicates that the braking distance under wetting conditions has more long (50 [m]) because of decrement of the friction coefficient which is caused by in moisture.



Fig.9 Mutual comparison between dry and wet: braking torque

The difference of the braking torque under dry and wet conditions appear in Fig. 9. In wet brake stops, a higher braking torque which is average values 201.1 [kgf·m] is measured comparing with braking torque (190.9 [kgf·m])under dry brake stops.



Fig.10 Mutual comparison between dry and wet: pressure in brake cylinder

Fig. 10 shows the mutual comparison of pressure in brake cylinder between dry and wet conditions. In this case the same pressure in the brake cylinder is applied continuously during the braking operation.



Fig.11 Mutual comparison between dry and wet: friction coefficient

Fig. 11 illuminates the instantaneous friction coefficient μ_a and the mean friction coefficient

 μ_m comparisons between under dry and under wet conditions. The results tell us that the mean friction coefficient under wet conditions has changed within 15% against that of dry conditions because the approval deviation of the wet condition is calculated as 0.4071 (= 0.354*1.15). It is appropriate to verify the UIC CODE 541-4 requirements.

5 Conclusion

In this paper, we present a tread brake experiments on the dynamometer for high speed train in order to compare braking distance, braking time, and mean friction coefficient between dry and wet conditions in specific vehicle speed at 200 [km/h]. In the process of the brake stops, the friction coefficients between dry and wet conditions must not deviate from each other by more than 15% under the same conditions. As a test result we could verify the mean friction coefficient under wet conditions has changed within 15% against that of dry conditions.

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