Abstract: The technology of braking performance evaluation has been generally developed with technology of speed improvement of railroad 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 systems. In this paper, we tried to test braking friction materials (disc brake and block brake) for the high speed rotation which is in a current use commercially, and its results will be introduced by means of arranging of a braking performance test evaluation technology on braking friction materials of railway vehicle using the high speed dynamometer (400 [km/h]-grade).

Key-Words: Brake Dynamometer, Railway Vehicle, Friction Coefficients, Disc Brake, Block Brake

1 Introduction

The technology of braking performance evaluation has been generally developed with technology of speed improvement of railroad vehicle. Nowadays, test procedure and evaluation standard from technology of test evaluation on single braking parts to controlling of the braking system, running testing of integration performance and its evaluation technology are systematically established.

The test evaluation technology has also been developed with study for localization development of braking parts in the domestic market. The test evaluation techniques has accumulated with full scaled dynamometer that its level is below 200 [km/h] in the performance testing fields of friction materials, KRS(Korean Railway Standards) presents about coefficient of friction, abrasion, and so on as a test evaluation standard.

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.

Fig.1 The 400 [km/h] grade high-speed brake performance tester

Recently, high-speed braking performance tester, which is top speed 400 [km/h]-grade is introduced. And then it became able to perform the test of developed braking parts in KRRI (Korea Railroad Research Institute). Therefore we tried to test braking friction materials (disc brake and block...
brake) for the high speed rotation which is in a current use commercially, and its results will be introduced by means of arranging of a braking performance test evaluation technology on braking friction materials of railway vehicle using the high speed dynamometer (400 [km/h]-grade).

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 in various initial braking speed condition when the block brake is applied. The main conclusions are then summarized in section 5.

2 Overviews of the Brake Performance Tester

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.

Table 1. Main performance of the brake dynamometer

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. drive power</td>
<td>397kW (540HP)</td>
</tr>
<tr>
<td>Max. drive torque</td>
<td>2,527Nm</td>
</tr>
<tr>
<td>Max. drive speed</td>
<td>2,500rpm (400km/h)</td>
</tr>
<tr>
<td>Max. brake torque</td>
<td>25,000Nm</td>
</tr>
<tr>
<td>Pressure Brake</td>
<td>6,000 N x 2</td>
</tr>
<tr>
<td>Flywheel Inertia</td>
<td>Max./Min. 1900kg·m²/400kg·m²</td>
</tr>
<tr>
<td>Diameter of the test wheel</td>
<td>Φ700~1120mm</td>
</tr>
<tr>
<td>Acceleration time</td>
<td>(0~1500rpm) 2 min. 30 sec</td>
</tr>
</tbody>
</table>

Fig. 2 Brake performance dynamometer for high speed train

3 Performance Test of Block Break

3.1 The Test Outline and Material

This test refers to friction material test about braking shoe (wheel-thread brake block) which is being applied in domestic KTX, it is an important procedure of braking shoe performance and safety evaluation. Braking tests were conducted on the basis of UIC Code (UIC541-4“Brakes-Brakes with composition brake blocks”) and shape of braking shoe was shown in the Fig.3.

The material of braking shoe used in this test is composed of organic composition and major properties include 2.6 [g/cm³] in density 0.92 [kJ/kgK] in specific heat capacity.
3.2 Test Method

The test for measuring the friction coefficient was carried out with reference to UIC 541-4 provisions, tests were conducted after obtaining more than 80% friction surface of braking shoe through adequate pre-test (bedding) prior to the test.

We executed the test in accordance with various initial speed of braking respectively in order to grasp the characteristics of high-speed braking system. The test executed in order of 80, 120, 160, 200 [km/h] under air pressure force 16.6 [kN]. And in condition of air pressure force 5.9 [kN], the test also executed in turns of 80, 120, 160, 200, 250, 300 [km/h].

The actual braking tests as shown in Fig.4. Thermal band on the wheel thread is formed like this figure.

4  Test Results

4.1 Average Coefficient of Friction

The average coefficient of friction each initial speed of braking is shown in the table 3. The average coefficient of friction means the average value of the friction coefficient during braking; we found that higher initial braking velocity gets lower average coefficient of friction.

<table>
<thead>
<tr>
<th>No.</th>
<th>Speed (km/h)</th>
<th>Test Result ($\mu$)</th>
<th>Max Temp (°C)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>80</td>
<td>0.311</td>
<td>60.3</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>120</td>
<td>0.323</td>
<td>98.1</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>160</td>
<td>0.299</td>
<td>123.8</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>200</td>
<td>0.261</td>
<td>232.6</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>80</td>
<td>0.307</td>
<td>74.7</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>120</td>
<td>0.337</td>
<td>90.6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>160</td>
<td>0.384</td>
<td>221.5</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>200</td>
<td>0.351</td>
<td>281.0</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>250</td>
<td>0.308</td>
<td>210.5</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>300</td>
<td>0.293</td>
<td>977.0</td>
<td></td>
</tr>
</tbody>
</table>

The instantaneous coefficient of friction, which $\mu_a$ 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

$$\mu_a = \frac{F_t}{F_b} \quad (1)$$

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

$$\mu_m = \frac{1}{S_2} \int_0^{S_2} \mu_a ds \quad (2)$$

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Fig.3  The shape of brake shoe

Fig.4  The shape of braking test and thermal band observed on the wheel when it is on braking
4.2 The Instantaneous Coefficient of Friction
In general, friction coefficients were obtained ranging from 0.261 to 0.323 in 80-200 [km/h] speed in the condition of air pressure force 16.6 [kN].

Friction coefficients were obtained ranging from 0.293 to 0.384 in the condition of air pressure force 5.9 [kN] (the air pressure force is lower than above condition), we can get the result that high friction coefficient was obtained in the condition of low air pressure force.

Fig.5 The change on instantaneous coefficient of friction in braking initial speed 80 [km/h] (air pressure force 16.6 [kN])

Fig.6 The change on instantaneous coefficient of friction in braking initial speed 120 [km/h] (air pressure force 16.6 [kN])

Fig.7 The change on instantaneous coefficient of friction in braking initial speed 160 [km/h] (air pressure force 16.6 [kN])

Fig.8 The change on instantaneous coefficient of friction in braking initial speed 200 [km/h] (air pressure force 16.6 [kN])

Fig.9 The change on instantaneous coefficient of friction in braking initial speed 80 [km/h] (air pressure force 5.9 [kN])

Fig.10 The change on instantaneous coefficient of friction in braking initial speed 120 [km/h] (air pressure force 5.9 [kN])

Fig.11 The change on instantaneous coefficient of friction in braking initial speed 160 [km/h] (air pressure force 5.9 [kN])
Fig. 12 The change on instantaneous coefficient of friction in braking initial speed 200 [km/h] (air pressure force 5.9 [kN])

Fig. 13 The change on instantaneous coefficient of friction in braking initial speed 250 [km/h] (air pressure force 5.9 [kN])

Fig. 14 The change on instantaneous coefficient of friction in braking initial speed 300 [km/h] (air pressure force 5.9 [kN])

The instantaneous coefficient of friction each braking initial velocity was obtained from data analysis of braking characteristics, detailed results were shown in from Fig.5 to Fig.14.

5 Conclusion
In this paper, measurement test of coefficient of friction was introduced about braking shoe for development of performance test technology using 350 [km/h]-grade high-speed braking performance tester. And test standard of braking friction material using high-speed tester was summarized.

Also, braking characteristics of friction material on the top speed 300 [km/h] were considered, average and instantaneous coefficient of friction was obtained.

It is possible to secure performance test technology for conducting performance test of the future new braking based on the result of this study. It have been identified that can be utilized not only evaluation on friction characteristics of braking friction materials but also braking disk or development of wheel.

References: