Thermal Analysis of the Disc Brake Test using the High-Speed Camera

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Abstract: - The technology of braking performance evaluation has been generally developed with technology of speed improvement of railroad vehicles. And brake dynamometer is designed to simulate the brake characteristic of the high speed train, analyze the experimental object, and also is used to develop and test the brake systems. In this paper, we tried to analyze the brake disc thermal characteristics using the high-speed camera for the high-speed disc surface during the braking, and its results will be introduced by means of a braking performance test evaluation technology on braking system of the railway vehicles.

Key-Words: High-Speed Camera, Thermal Analysis, Brake Dynamometer, Railway Vehicle, Brake Disc

1 Introduction

The technology of braking performance evaluation has been generally developed with technology of speed improvement of railroad vehicle. Nowadays, technology of the test and evaluation from single braking parts to running testing of integration performance is systematically established.

The test evaluation techniques have 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 torque of the shaft is measured with contact or noncontact method. 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.

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).

In this paper, we tried to analyze the brake disc characteristic using the high-speed camera for the high speed rotation which is in a current use commercially, and its results will be introduced by means of a braking performance test evaluation technology on braking system of the railway vehicles using the high-speed camera.

This paper is organized as follows. Section 2 overviews a brake dynamometer and the experiment environment for the disc brake. Section 3 shows the experiment results in various braking speed condition when the disc brake is applied using the high-speed camera. The main conclusions are then summarized in section 4.

2 Overviews of the Brake Performance Tester

2.1 Brake dynamometer

A dynamometer consists of the following main elements.

◆ The drive-train consists of the following elements: motor, interchangeable flywheels and brake disc.

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The flywheels and brake disc is matched to the parts 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, 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, disc-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

(a) high-speed brake performance tester

(b) A part of disc brake

Fig.1 Brake performance dynamometer for the high speed train

Table 1 shows the main features of the brake dynamometer.

Table 1. Main features of the brake dynamometer

Max. drive power	397kW(540HP)
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	Max./Min. 1900kg•㎡/400kg•㎡
Diameter of the test wheel	Φ700~1120mm
Acceleration time	(0~1500rpm) 2 min. 30 sec

2.2 Disc brake test

This experiment is as a test for the brake disc pads, refers to a test to assess the safety by verifying the performance of the brake pad tests were conducted with reference to UIC specification (UIC541-3 “Brakes-Disc brakes and their application-General conditions for the approval of brake pads”), braking pad is applied to the current KTX as the pad and the shape of the pad is shown in the Fig. 2.

Material is composed of sintered metal, heat capacity and thermal conductivity is respectively 600 [J kg ℃], 25 [W m ℃].

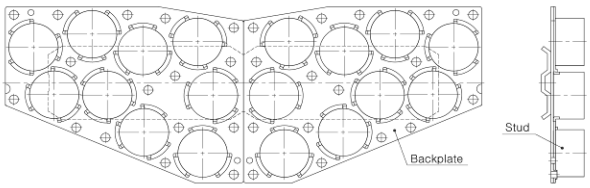

Fig.2 The shape of the brake pad for the disc brake

The test for measuring the friction coefficient was carried out with reference to UIC 541-3 provisions, tests were conducted after obtaining more than 80% friction surface of braking pad through adequate pre-test (bedding) prior to the main test. The test was performed in braking initial temperature as 60 ° C [6].

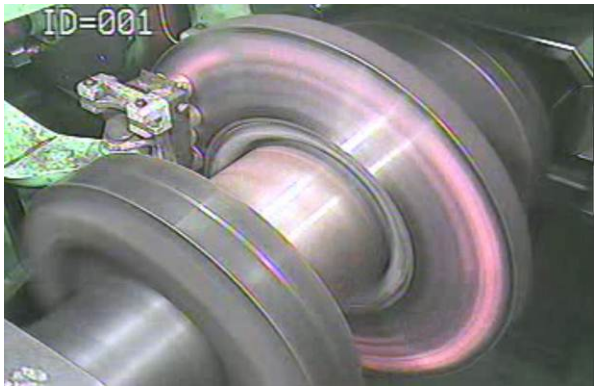

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Fig.3 The shape of hot spot is observed when the brake system is applied, thermal band is observed when testing of braking disc

We executed the test in accordance with an initial speed in 320 [km/h] in order to analyze the temperature characteristics of high-speed braking system. Air pressure force in 22.5 [kN] for the braking cylinder is used during the braking test.

The actual braking tests look like this Fig. 3, thermal band in the disc surface is formed like this figure and the surface morphology of speculated as the formation of hot spots was observed after braking stopping.

3 Experimental Results

3.1 Disc brake test results

The actual braking test results are shown in the Fig. 4. Due to the use of the encoder 1024 pole, speed output at the high-speed (1,846 [rpm]) rotation is affected by noise. It seems the output waveform is distorted by mutually influence. Therefore, in order to remove the effects of noise, the number of encoder's pole should be reduced (about 360 pole) or noise shielding devices should be installed.

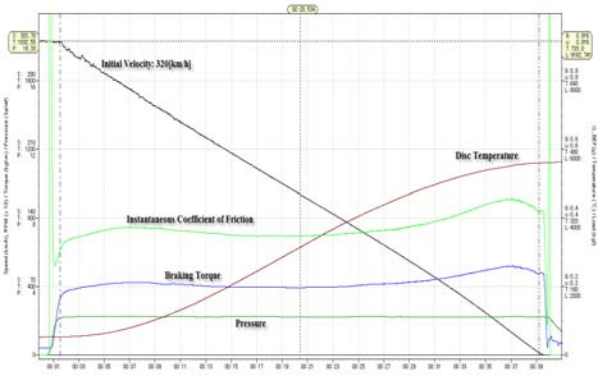
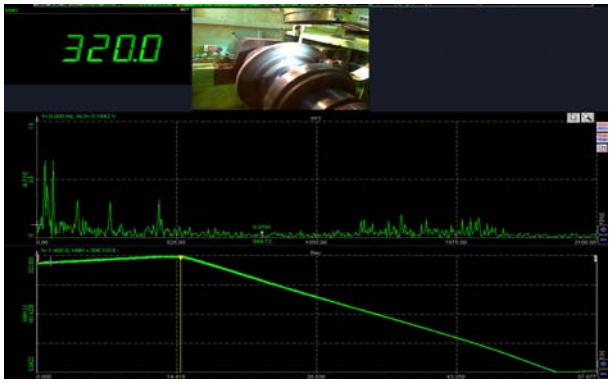


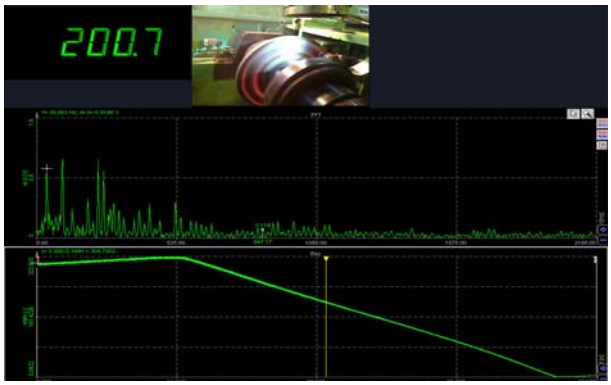
Fig. 4 Brake disc test results in initial speed braking 320 [km/h] with the brake force 22.5 [kN]

The process of initial speed braking from 320 [km/h] to stop are shown in Fig. 4, measured instantaneous coefficient of friction, braking torque at that time, braking force (i.e. 22.5 [kN]), and the temperature of the disc surface are shown.

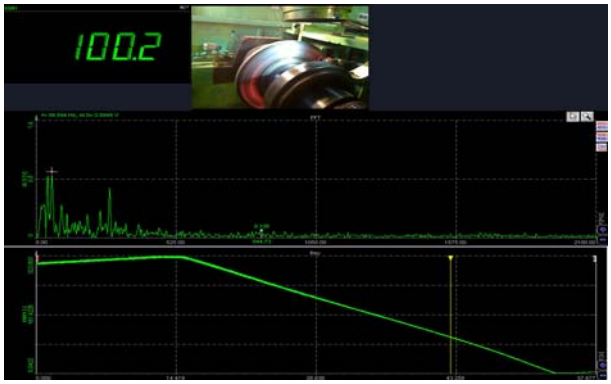
For the analysis of this phenomenon during braking in the initial speed in 320 [km/h], the following DAQ data which are speed, brake noise, and its frequency analysis are acquired. The signals for analysing the brake sound of the disc brake using a high performance microphone is measured, and the frequency analysis is performed.



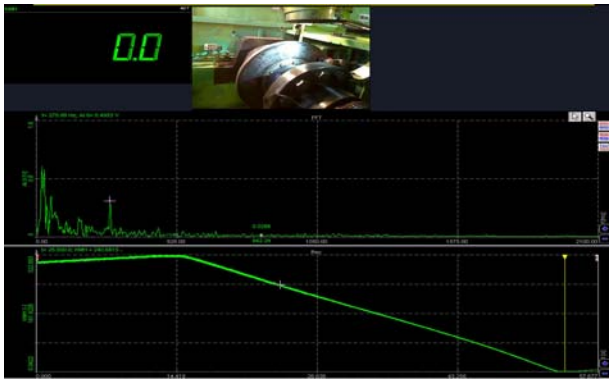
(a) DAQ data in braking velocity 320[km/h]



(b) DAQ data in braking velocity 200[km/h]



(c) DAQ data in braking velocity 100[km/h]



(d) DAQ data in braking velocity 0[km/h]

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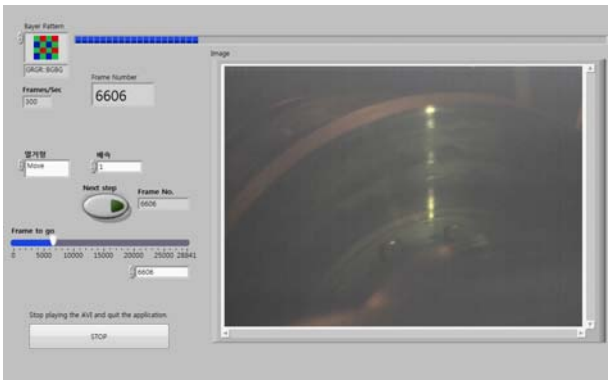
Fig. 5 DAQ data: speed, brake noise, and its frequency analysis

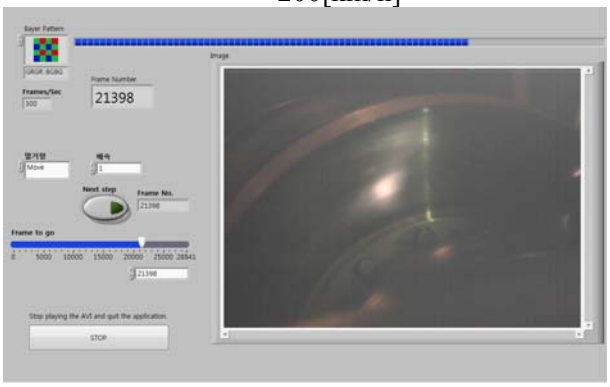
3.2 Thermal analysis of disc braking by using high-speed camera

Disc brake test was performed in the maximum initial speed braking 320 [km/h]. For the thermal analysis of disc braking during stopping, the following series of figures represent the still images for disc thermal characteristics of the high-speed camera. The exposure time of the high-speed camera is setting as 100 [μs], the image size is fixed as the 640x480 pixel, and the shutter speed is synchronized at 500 [frame/s] speed.

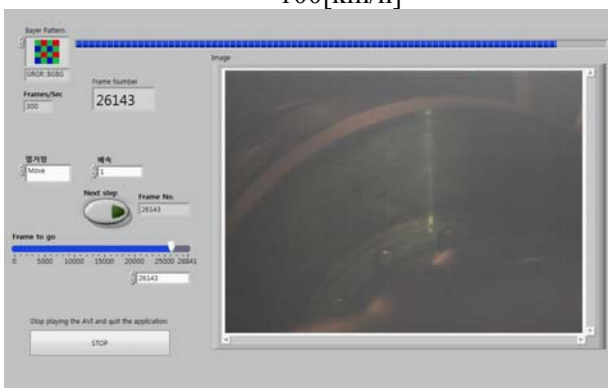


(a) Still image analysis in braking velocity 320[km/h]

(b) Still image analysis in braking velocity 200[km/h]



(c) Still image analysis in braking velocity 100[km/h]

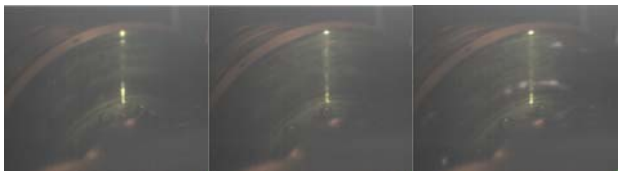


(d) Still image analysis in braking velocity 0[km/h]

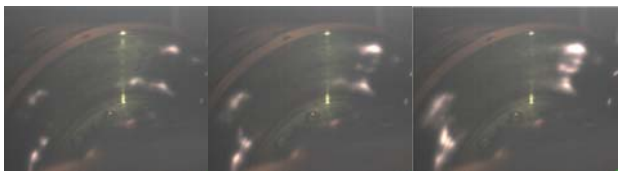
Fig. 6 Analyzing of the still image according

Below 16 figures are shown the still images for surface of the disc from initial speed (first measuring point is 300 [km/h]) to stop with 40 seconds section at the same location during braking time. From the still images, we could find thermal characteristic of the surface of the disc. The scattered distribution of thermal moves gradually to a point and be destroyed after that.

(a) 0 [sec] (b) 2.5 [sec] (c) 5 [sec]



(d) 7.5 [sec] (e) 10 [sec] (f) 12.5 [sec]



(g) 15 [sec] (h) 17.5 [sec] (i) 20 [sec]

(j) 22.5 [sec] (k) 25 [sec] (l) 27.5 [sec]

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(m) 30 [sec] (n) 32.5 [sec] (o) 35 [sec]

(p) 37.5 [sec]

Fig. 7 Thermal analysis of brake disc (braking force is 2.2.5[kN]) by high-speed camera at the same location

4 Conclusion

In this paper, during the braking test, the DAQ data which are speed, brake noise, and its frequency analysis are acquired, the signals for analysing the brake sound of the disc brake using a high performance microphone is measured, and the frequency analysis is performed. Further, disc brake test was performed by using high-speed camera for analyzing the thermal characteristic of the surface of the disc.

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