# Analysis of Temperature Transition on Disc Brake using the High Speed Brake Dynamometer

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*Abstract:* - The technology of braking performance evaluation has been generally developed along with the improvement of the speed technology of railroad vehicles. Brake system of railway vehicles has a crucial role for the safety as well as riding quality of passengers. 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 temperature transition and/or thermal characteristics of the disc surface during braking using the high-speed camera system with a specially designed lighting system.

Key-Words: - Brake Dynamometer, Temperature Transition, Disc Brake, High Speed Camera

## **1** Introduction

Brake system of railway vehicles has a crucial role for the safety as well as riding quality of passengers. And 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[1].

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 [2]-[5]. 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 320 [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.

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.

# 2 Analysis of Temperature Transition on Railway Brake Disc

### 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. 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.

Fig. 1 shows the brake performance dynamometer for the high-speed train.



(a) shape of the brake dynmometer



(b) thread and disc brake parts Fig.1 The brake performance dynamometer for the high-speed train

Table I shows the main features of the brake dynamometer.

Table I Main	features	of the	brake	dynamometer
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Max. drive power	397(kW), 540(HP)			
Max. drive torque	2,527(Nm)			
Max. drive speed	2,500(r.p.m), 400(km/h)			
Max. brake torque	25,000(Nm)			
Pressure Brake	6,000 (N) x 2			
	Max./Min.			
Flywheel Inertia	$1900(kg \cdot m^2)/400(kg \cdot m^2)$			
Diameter of the test wheel	Ф700~1120(mm)			
Acceleration time	0~1500 (r.p.m)			

### **2.2 Experimental Environments**

The experiment devices for collecting thermal images using the high-speed camera are shown in the Fig. 2. The device is made up of three parts: the brake disc, the high-speed camera systems and the light systems.

2 (min.) 30 (sec)



(a) the experiment device made up of three parts: the brake disc, the light systems, and the high speed camera systems



(b) data acquisition and monitoring systems



(c) high-speed camera

Fig. 2 Real-time detection progress about the braking disc and the high-speed camera

Table II shows the main specification of the highspeed camera applied to braking experiment

Table II Main features of the high-speed camera

Model	Basler A504KC
Resolution	1280×1024

Sensor Type	Progressive Scan CMOS	
	(Color)	
Pixel Size	12×12(μm)	
Frame Rate at Full	500 (frame/s)	
Resolution		
Output Type	Camera Link (Full)	
Synchronization	External Trigger or Free	
	Run	
Housing Size	41.5×190×190(mm)	

Disc brake test was performed at the maximum initial braking speed as 320 (km/h). To observe the temperature transition and analyze the thermal characteristic of the disc surface during braking, the following series of freeze frame represent the still images for disc thermal characteristic of the high-speed camera. The exposure time of the high-speed camera is setting as 100 ( $\mu$ s), the image size is fixed as the 640x480 pixel, and the shutter speed is synchronized at 500 (frame/s) speed.

#### 2.3 Experimental Results

The actual braking test results for issuing the certifications are shown in the Fig. 3. As the velocity curve in Fig. 6 indicates, due to the use of the encoder 1024 (pole), speed output at the high-speed 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.



(a) instantaneous coefficient of friction



(b) disc braking results: speed, coefficient of friction, pressure, torque, temerature

Fig. 3 Brake disc test results in initial speed braking 320 [km/h] with the brake force 22.5 [kN]

For the analysis of this phenomenon during braking in the initial speed in 320 (km/h), the following DAQ data that are speed, brake noise, and its frequency analysis are acquired. The signals for analyzing the brake sound of the disc brake using a high performance microphone is measured, and the frequency analysis is performed. Data collected from DAQ at the speed point which is 320 (km/h), 300(km/h), 250(km/h), 150(km/h), 50(km/h) and 0(km/h), respectively, is appear in Fig. 4.



Fig. 4 General braking image of brake disc (braking force is 2.2.5[kN]) by the 30 [frame/s] camera

Below 12 figures in Fig. 5 are shown the still images for surface of the disc from initial speed (first measuring point is 320 (km/h)) to stop at the same location during the braking operation.



(k) 35 [s] or 37[km/h] (l) 37.5 [s] or 13[km/h] Fig. 5 Thermal analysis of brake disc (braking force is 2.2.5[kN]) by high-speed camera at the same location

Therefore we could find temperature transition or thermal characteristic of the surface of the disc. That is, the scattered distribution of thermal moves gradually to a point and is destroyed after that.

## 4 Conclusion

Disc brake test was performed by using high-speed camera for analyzing the thermal characteristic of the surface of the disc. It is possible to develop new disc brake material having the good performance for radiating thermal characteristic based on the results of this study. It have been identified that can be utilized not only evaluation on friction characteristics of braking friction materials but also braking disc or development of wheel.

The lightening in thermal image of the disc surface indicates the high temperature. Therefore we could find temperature transition or thermal characteristic of the surface of the disc. That is, the scattered distribution of thermal moves gradually to a point and be destroyed after that. And its results will be introduced by means of a braking performance test evaluation technology as well as brake parts development on braking system of the railway vehicles.

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