Development of a Pneumatic Floating Brake Caliper for High-Speed Rolling Stock

Yasushi KARINO
Senior Researcher, Brake Control, Vehicle Control Technology Division

The components of foundation brake rigging must have a simple and robust structure. The existing compact and lightweight hydraulic floating caliper that combines a floating mechanism and a direct-acting pressing (brake force actuation) mechanism with built-in hydraulic cylinders is used extensively by Shinkansen railways (Fig. 1). However, RTRI researchers are developing a pneumatic caliper that solely relies on pneumatic pressure. It will eliminate brake parts to the extent that it doesn't require a pneumatic/hydraulic pressure converter. To obtain the required pressing (brake) force with pneumatic pressure alone, however, large-size actuators and a mechanism to essentially double the pneumatic power have to be incorporated in the design.

A unique feature of the developed pneumatic floating caliper (Fig. 2) is the use of an oval diaphragm pressing mechanism to directly transmit the required pressing force using pneumatic pressure alone without using levers or wedges. The diaphragm is incorporated between the piston and cylinder to form an annular folded section. When compressed air is supplied to the diaphragm, it smoothly crawls (referred to as "rolling motion" in Fig. 3) like a caterpillar tread along the cylinder wall without sliding, thereby directly applying a pressing force proportional to the pneumatic pressure on the backside of the lining. Consequently, the caliper works as a brake force generating mechanism (Fig. 3).

The operating membrane of the diaphragm has a thickness as small as 1.3mm made of a silicon rubber coated structure of tenacious aramid fiber multiple ply ground fabric. The diaphragm can withstand a pressure of 3Mpa or approximately four times the assumed maximum control pressure of 720kPa. Although silicon rubber, which features high heat resistance, can be used continuously at 180°C, the flexibility of rubber products often changes depending on the ambient temperature. Brittleness can progress at extremely low temperature causing a loss of elasticity. Thus, it is conceivable that the function, performance and durability of silicon rubber can degrade at temperatures lower than room temperature. To address these potential concerns, we implemented a durability test (type test) and an environmental test. As a result, we found that no abnormalities occurred with the diaphragm after repeating the pressing motion 1.2 million times. This is equivalent to the number of duty cycles that normally occur over four periods of general repair and the test verified the durability is at least equivalent to that of conventional units in a room temperature environment. We also confirmed that the durability is equivalent to that of the conventional units when the operational environment is -20 to 80°C.

This was demonstrated in duty tests, implemented under the low- and high-temperature environments (-40 °C and 120°C), that were more severe than that for the conventional units. Brake operations were performed 150,000 times at each temperature environment, or 300,000 times in total to duplicate the duty cycle over one general inspection period.

In line with the design maximum brake performance to guarantee deceleration of 5.32km/h/s for a rolling stock weight of 50ton, the new pneumatic caliper achieved a stopping distance of 4,623m at a brake application initial speed of 360km/h in a life-size model emergency brake bench test (Figs.4 and 5). We also implemented emergency brake tests with the new caliper at lower speeds up to a braking initial speed of 320km/h. As shown in Fig. 5, the test verified that brake forces equivalent to or in excess of that obtained by conventional hydraulic floating calipers were achieved. The caliper remained intact as demonstrated in an inspection after the test when the caliper was disassembled.

The caliper is currently at the final stage of commercialization.

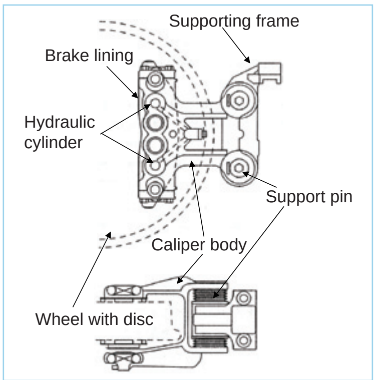

Fig. 1 Hydraulic floating caliper

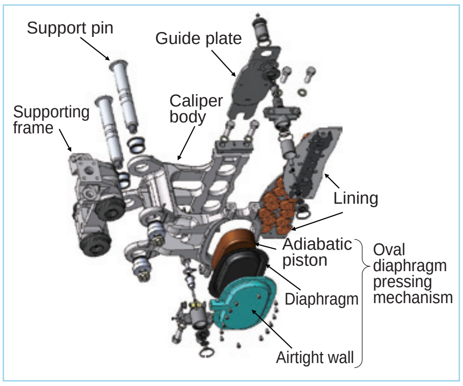

Fig. 2 Pneumatic floating caliper structure

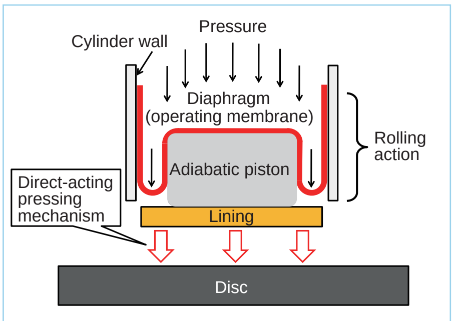

Fig. 3 Operating principle of the oval diaphragm pressing mechanism

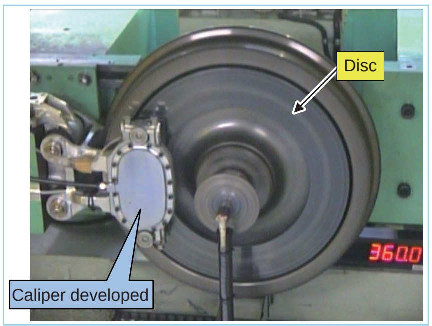

Fig. 4 Appearance of full-scale bench test

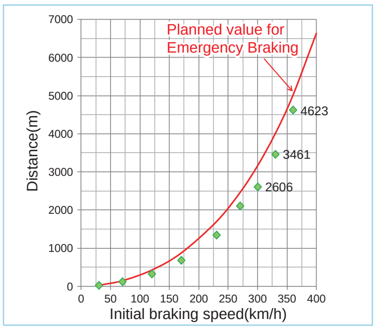

Fig. 5 Initial braking speed and stopping distance