

Effect of Phenolic Brake Piston Tribology on Brake Pedal Feel

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ABSTRACT

Phenolic brake pistons show excellent performance for weight saving, protection against vapor lock, noise reduction, no rust, and less seal scratch. Phenolic brake pistons have been successfully used since 1974. However there has been a complex system phenomenon related with the brake pedal feel.

Our recent study focused on the tribology of phenolic brake piston and its correlation to brake pedal feel. Several surface designs of phenolic brake pistons were created and evaluated using modified JASO C448 bench test station. Our testing found the friction force between a phenolic brake piston and the piston seal differs from that of a steel brake piston. Furthermore, we discovered the friction forces on a phenolic piston could be favorably altered by the surface design of the piston.

In this paper, we will propose how to improve brake pedal feel using a phenolic brake piston through designing the surface condition of the brake piston.

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INTRODUCTION

A phenolic brake piston contributes to automotive disc brake performance, weight saving, protection against vapor lock, noise reduction [1,2]. On the other hand, brake pedal feel is considered to be different from steel piston, especially for the passenger car which requires strict brake pedal feel. Brake pedal feel is one of the important characteristic that a driver can directly feel during braking. However it is very complicated phenomenon related with each brake system component parts. Regarding to brake pedal feel, Basch et al suggested the correlation of lining [3]. There is little information about brake pedal feel. Moreover, we have never seen a technical report for phenolic brake piston.

We suppose that there is a causal relation between brake pedal feel and surface tribology of brake piston. We investigate the difference of brake pedal feel between phenolic brake piston and steel brake piston related with surface tribology. We find the difference in friction coefficient between phenolic brake piston and steel brake piston using bench test station. It is reasonable to consider that surface tribology is influenced brake pedal feel because brake piston moves back and forth in the caliper cylinder. Surface observation and friction test results indicates the validity of our consideration.

We also study the potential of phenolic brake piston. Phenolic brake piston can be easily designed its shapes and surface by molding and processing. We have created several surface designs of phenolic brake pistons. In other words, we study tribology of phenolic brake piston. We consider that tribology of phenolic brake piston can be controlled. We believe that our study contributes for improvement of the brake pedal feel.

PHENOLIC BRAKE PISTON

Typical Manufacturing Process

Figure 1 shows a typical manufacturing process for the phenolic brake piston. Intermediate phenolic brake piston was formed through the molding process. Mold die surface was copied to the piston surface at this time. After that, circumference surface was grinded and boot groove was formed. In this paper, brake piston size was standardized outside diameter of 57mm.

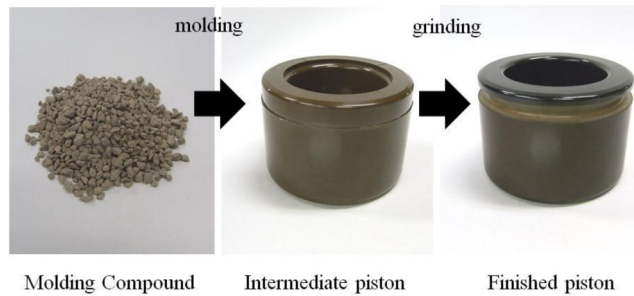


Figure 1. Typical manufacturing process for the phenolic brake piston

Surface Design of Phenolic Brake Piston

Several surface designs of phenolic brake pistons were created for further study. Created condition of each phenolic brake piston is shown in Table 1.

Table 1. Created condition of the phenolic brake piston

	Mold die surface	Brake piston surface
Phenolic A	polishing	grinded
Phenolic B	polishing	no grind
Phenolic C	honing	no grind

Phenolic A was a typical phenolic brake piston. Phenolic B and phenolic C were new designed phenolic brake piston. Figure 13 shows laser microscope image of them. Phenolic B was not observed any holes but a smooth surface and similar to steel. Phenolic C was observed unevenness surface without filler drop. Though both phenolic B and phenolic C were grind less piston, surface conditions were different.

EXPERIMENTAL

Bench Test

JASO C-448 standardizes some bench test procedures and refers to bench test station. We modified JASO C-448 bench test station. Figure 2 shows the appearance of bench test station. The experiment was carried out under the following conditions.

- Brake piston was set in a cylinder
- Apply pressure using air cylinder, 0.01MPa/sec
- Brake piston displacement = 2mm
- Displacement and pressure were recorded to data logger.

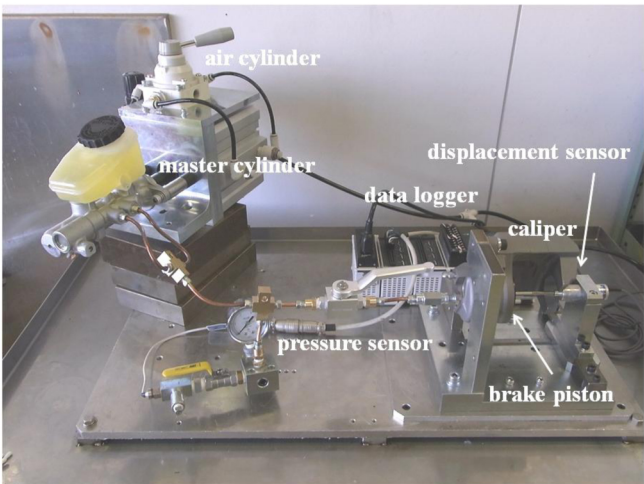


Figure 2. Modified JASO C448 bench test station

Friction Test

Dry condition test

Figure 3 shows the appearance of friction test station. Friction coefficient between a brake piston and piston seal under dry and lubricate condition was evaluated. The experiment was carried out under the following conditions.

- EPDM size = 3mm × 5mm, cut out from piston seal
- Friction displacement = 6mm
- Vertical load = 500gf, 1000gf, 1500gf, 2000gf
- Velocity = 0.5mm/sec, 1.5mm/sec, 3.0mm/sec, 5.0mm/sec
- Displacement and friction load was recorded to PC.

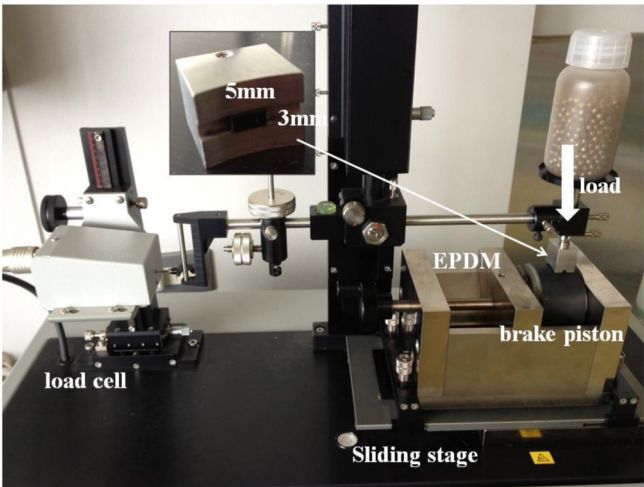


Figure 3. Friction test station

Lubricated condition test

We evaluated the influence of lubricant using same friction test station. Figure 4 shows the lubricated test method. Test procedure was following.

- Friction displacement = 18mm
- Vertical load = 1000gf,
- Velocity = 1.5mm/sec
- Lubricant was applied L = 3mm
- Other conditions were basically same as Dry test

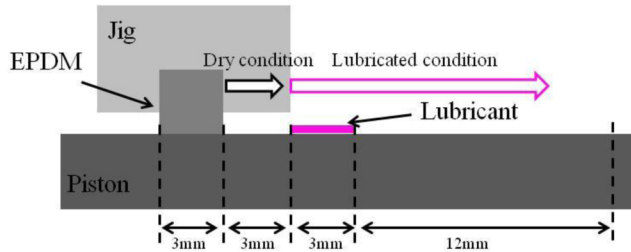


Figure 4. Lubricated test

RESULTS AND DISCUSSION

Phenolic Brake Piston and Steel Brake Piston Study

Bench test

Figure 5 shows bench test results for typical phenolic brake piston and steel brake piston. Brake fluid pressure level was equivalent to friction coefficient. There were some differences between phenolic A and steel. At first, dynamic friction coefficient of phenolic A was more than twice that of steel. Secondly, dynamic friction coefficient of phenolic A was growing while that of steel was stable. Thirdly roll back level was different because of the difference of the friction coefficient. We considered that those differences were caused by brake piston surface tribology.

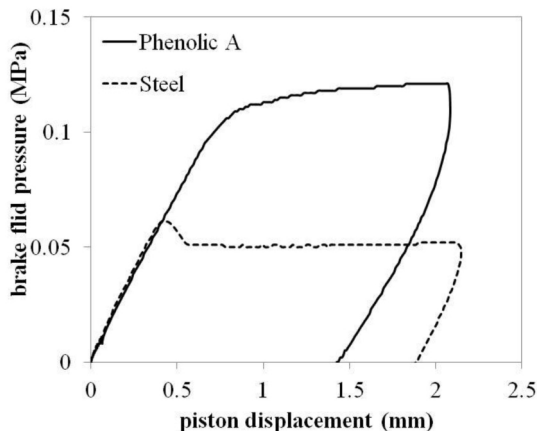


Figure 5. Bench test result

Surface observation

Figure 13 shows laser microscope image of phenolic A and steel surface. Typical phenolic brake piston surface was observed innumerable holes created by dropping out of the fillers during the grinding process. Steel was not observed any holes but a smooth surface. Note that surface condition was obviously different even though Ra level is same.

Friction test

Figure 14,15 shows friction coefficient under dry condition. Although we already discussed about bench test results, friction coefficient were almost same level under dry condition. Friction coefficient under dry condition depended on not material but load and velocity. Especially it tended to be higher under the low load or low velocity condition. Incidentally, a line was remained on phenolic A surface after the friction test and it was observed only for phenolic A surface. We confirmed it was caused by wear of EPDM by n=100 cyclic test.

Figure 16 shows the brake piston surface after n=100 cyclic test. There was a remarkable wear marks at the surface. It was not observed for steel brake piston. Figure 6 shows the transition of friction coefficient. Friction coefficient of phenolic A decreased gradually. It became almost 2/3 level after n=100 cyclic test.

Figure 17,18 shows the appearance after lubricated condition test. Lubricant remained on sliding surface of phenolic A. It seemed that phenolic A surface was familiar to lubricant. On the other hand, steel surface repelled lubricant.

Figure 7,8 shows transition of friction coefficient. Initial friction, 0 - 3mm, was dry condition. 3-6mm was lubricated transitional condition. 6-18mm was whole lubricated condition. Rate of friction coefficient decline of phenolic A was faster than steel. Though friction coefficient of phenolic A was saturated to 0.1, steel declined gradually. The difference in lubrication effect was observed in surface appearance and transition of friction coefficient.

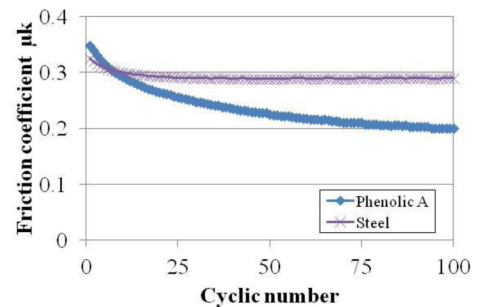


Figure 6. Transition of friction coefficient during n=100 cyclic test