

“Sticky” Lining – the Phenomena, Mechanism and Prevention

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ABSTRACT

An unique bonding mechanism was studied after several instances, where the linings stuck to the brake drums on transit buses, were reported. Evidences suggested that the linings were “glued” to the brake drums surface after wear debris (dust) was turned into “adhesive paste” through complicated thermal and chemical changes. Factors such as the friction materials, environment and service conditions, which could activate and deactivate the lining bonding, were observed and discussed. The prevention measures are proposed.

Key Words: Brake Drum, Brake Lining, Bonding, Wear Debris, High Temperature

INTRODUCTION

It is well known that the brake linings may stick to the brake drums/discs after the parking brakes are applied overnight. In mild situations, lining sticking generates noises that can be best described as “stick-slip” phenomena. In severe conditions, the bonding forces are sufficient to prevent the release of brake, creating hazardous driving conditions.

A number of sets of brake linings and drums in city transit applications were submitted for analysis when the linings became stuck on the drums after the buses were parked overnight with the parking brakes applied. The bonding forces were so tremendous that they “over-powered” the return springs and the torque passed to the wheels was insufficient to break up the bond and free up the wheel during the buses’ start-up the next day. An example of such lining-to-drum bonding is shown in Figures 1 and 2.

It was noted that all the brake lining and drums were returned from the big metropolitan areas in the bordering states/provinces between the US and Canada. The transit system of these cities has been notorious for their

severe duty cycles because of high passenger volumes, making frequent stops at the traffic lights, bus stops and other situations. Field service reports also indicated the lining-to-drum bonding mostly occurred after snowstorms when the ground was wet for prolonged period of time.



Figure 1. The residual lining was visible on the drum surface after the lining was broken free using external forces



Figure 2. This photo shows damages to the lining surface from lining-to-drum bonding

As part of the daily maintenance routine, the vehicles were washed using high-pressure alkaline soap solutions under the above-mentioned weather conditions. When they were parked overnight in the bus depots, a clamping pressure of ~75 PSI was applied to the parking brakes. Other conditions existed in the lining-to-drum interface typically include:

- Water from snow and rain
- Aqueous salts (snow melting agent)
- Road dust/dirt
- Debris (also called brake dust) from the naturally abrasive action of drum-lining contact

The drum material was gray cast iron, grade G3500, per SAE J431. The drums had hardness in the range of HB 207-229 and the microstructure consisted of a lamellar pearlite matrix. The graphite morphology was mainly type A and sized class 3-4. The linings were made of glass fiber filled phenolic thermoset with barium sulfide filler. The glass fibers were in the form of ¼ inch long chopped strands.

The investigation on the braking mechanics ruled out it was a contributing factor of the underlined issue.

DETERMING THE CONTRIBUTING FACTORS

After discussing with the service engineers and application engineers, the problem is defined as such:

Under the weather conditions that resulted in prolonged wet ground and after the parking brake was applied overnight, a mechanical or chemical bonding had developed between the brake lining and drum. The bonding sometimes was sufficient to overcome the brake return spring and the driving torque in the initial vehicle setup, and caused hazardous driving conditions in these situations.

As it can be drawn from the problem statement, critical elements for the lining-stick-to-drum phenomena to happen most likely include the following:

- Excessive moisture at the brake component interface
- Clamping force from the application of the parking brake
- The brake lining surface condition, e.g. the brake debris (dust) build-up
- The brake drum surface condition, e.g. rust
- Possibly alkaline soap solution used in daily maintenance routine that can be deposited to the braking surface
- Possibly road debris (dust) that can be accumulated on the lining surface

TEST PROCEDURE

Based on the above, a design of experiment (DOE) as outlined in Table 1 was carried out to determine the major contributing factors. A test setup as illustrated in Figure 3 was developed for ease of implementation while being relevant to the real application as much as possible.

As shown in Figure 3, drum blocks in the size of 50 mm by 50 mm (2" by 2") cut from the returned brake drums and lining blocks in the size of 36 mm by 36 mm (1.5" by 1.5") from the returned linings were used. The test samples were assembled according to schedule outlined in Table 1 and kept in air-conditioned laboratory environment overnight for about 16 hours.

The significances of the factors listed in Table 1 are explained in the following text:

- The use of 5% HCl acid was to remove the pre-existed rust on the brake drum surface
- The brush cleaning of lining would remove possible brake and road dust accumulated on the lining surface

Table 1. The DOE schedule and test results

Factors	Sample Groups						
	1	2	3	4	5	6	7
5% HCl Acid wash of drum?	No	Yes	No	No	No	No	No
Brush cleaning of lining?	No	No	Yes	No	No	Yes	No
Clamping?	Yes	Yes	Yes	No	Yes	Yes	Yes
Water or Soap?	Water	Water	Water	Water	Soap	Water	Neither
Road dust addition?	No	No	No	No	No	Yes	No
Bonding?	Yes	Yes	No	No	Yes	No	No
Percentage of samples with bonding developed	100	100	0	0	100	0	0
Average bonding forces, lbs	8.8	9.0	0	0	8.0	0	0

- Clamps (Figure 3) with 40 lbs clamping force rating were employed. Two clamps would yield about 80 lbs clamping force in an attempt to simulate the force applied to the parking brake
- De-ionized tap water and alkaline soap solution used in the customer application that experienced the most problems were used in this DOE
- Road dust was collected from the brake shoes of the returned brakes. The dust was made into paste by mixing it with water and applied to the DOE matrix
- The sample size was 5 for each of the group listed in Table 1.

Bonding was said to have developed in the test assembly, if after removing the clamps the assembly could be lifted by holding the lining block alone in the position as shown in Figure 3. To simulate the parking brake releasing efforts, the axial forces necessary to remove the lining block from the test assembly were subsequently measured. We did not measure the shear forces of the bonding although they could be much larger and related to the torque loads at the vehicle startup.



Figure 3. The test setup

TEST RESULTS

Samples from Group 1 were tested without any modifications and represented the closest condition to the real world situation. Not surprisingly, bonding was developed on all samples and the average bonding force was measured around 8.8 lbs.

Samples from Group 2 saw very little modification: only the drum blocks were acid washed to remove any possible rust/corrosion on the braking surface. As shown in Table 1, bonding was developed on all samples and the average bonding force was measured at 9.0 lbs, very similar to the samples in Group 1. This suggested that the pre-existed rust on the drum surface is not a contributing factor to the lining-to-drum bonding.

Samples in Group 3 were modified by brushing off the brake and/or road dust that was accumulated on the

lining surface. Everything else was the same as those in Group 1. Not a single bonding was observed from this group. This indicated that the brake and/or road dust was an integral part of the bonding between the brake lining and drum.

Samples in Group 4 were not modified. However, they were tested without the clamping force. No binding was developed, which suggested that clamping forces were needed in order for the binding to form.

In Group 5, alkaline soap solution was used in place of de-ionized tap water. There were no other modifications. Again, bonding was developed on all samples with an average force of 8.0 lbs. It seems either water or alkaline soap solution could be part of bond forming mechanism.

In Group 6, the lining was brush-cleaned and pasted with the road dust collected from the returned brake shoes. No bonding was observed, which seemed to suggest that road dust was unlikely a contributor.

Group 7 presented a dry condition where everything else was the same as Group 1. The result suggested that like clamping force, water or alkaline soap solution was an integral part of the bonding mechanism.

Additional tests were performed to examine if the drum material was a contributing factor. Bonding was observed from these tests conducted on other drum materials with the returned lining. It could be concluded that the drum material was highly unlikely to be a factor.

Bonding was observed among Groups 1, 2 and 5, where water and alkaline soap solution were part of bonding agent. In order to detect possible alkaline soap residue or other water-soluble surface contaminants, the returned linings' contact surfaces were removed and subjected to one hour of extraction with boiling de-ionized water (also called Soxhlet extraction). No alkaline components were recovered from this solution. Alkaline soap or road salts is apparently not a necessary component of the bonding mechanism.

The state of the used lining cure was examined via differential scanning calorimetry (DSC) and no "uncured lining" was observed. Although these returned linings had obviously been exposed to heat during service, there was no notable difference in the state or value of the linings' enthalpy values. The linings exhibited the expected specific gravity values when compared with their respective new linings.

BONDING MECHANISM

The DOE identified the contributing factors of the lining-to-brake bonding as the following:

- Brake debris accumulated on the lining surface
- Existence of water at the brake interface
- Clamping force