



# The effect of short glass fiber dispersion on the friction and vibration of brake friction materials



Jae Hyun Gweon, Byung Soo Joo, Ho Jang\*

Department of Materials Science and Engineering, Korea University, 02841 Seoul, South Korea

## ARTICLE INFO

### Article history:

Received 28 December 2015

Received in revised form

25 April 2016

Accepted 6 May 2016

Available online 13 May 2016

### Keywords:

Brakes

Friction material

Glass fiber

Stick-slip

Friction mechanism

Contact stiffness

## ABSTRACT

Friction and vibration of brake friction materials containing short glass fibers were investigated to examine the effect of fiber dispersion on friction instability. The friction material specimens with chopped or milled glass fibers were prepared and the friction and wear characteristics were measured using a one-fifth-scale brake dynamometer and a Krauss-type tester. The results showed that the milled glass fibers, which were evenly dispersed in the friction material, produced a smoother sliding surface with higher contact stiffness. On the other hand, the chopped glass fibers promoted a rough surface due to the existence of the primary contact plateaus caused by fiber bundles. The friction material with milled glass fibers exhibited a higher coefficient of friction, high wear rate, and larger oscillation amplitudes during stick-slip experiments, which was attributed to the higher static friction due to the smooth surface. The friction materials with milled glass fibers, therefore, can have a higher propensity for friction-induced vibration during brake applications. This is contrary to the conventional assumption, which favors good dispersion of the short fibers within composite materials. This study also indicated that the static coefficient of friction could be more important than the contact stiffness as a trigger for friction-induced vibrations.

© 2016 Elsevier B.V. All rights reserved.

## 1. Introduction

The application of glass fibers for friction materials dates back to the early development of woven friction materials using continuous fibers. On the other hand, short glass fibers were mainly used to replace asbestos fibers when they were banned for health reasons. Two different types of short fibers, chopped and milled, are commonly used for dry mixing and molding, and have been used as a substitute for asbestos and to improve mechanical properties and heat resistance [1,2]. In general, short glass fibers are 2–6 mm in length and several tens of microns in diameter. Other fibrous materials have also been used to substitute asbestos fibers and enhance braking performance under various conditions. Some examples include aramid fibers [3,4], metal fibers [5,6], ceramic whiskers [7,8], carbon fibers [9–11], natural fibers [11], and ceramic fibers [12,13]. These fiber materials are often blended with short glass fibers showing improved properties compared to monolithic fibers [14,15].

The effects of short glass fibers on the tribological properties of friction composites have been studied by various research groups. Bahadur et al. [16] studied friction and wear properties and found

that the glass fibers in polyester composites improved wear resistance and mechanical properties. They found no correlation between the mechanical properties and the friction coefficient. Gopal et al. [17] proposed that the wear rates and friction coefficients at different temperatures were closely related to the formation and destruction of friction films on the surface of the material, which were determined by the thermal degradation of the matrix and the pull-out of glass fibers. Kim et al. [2] investigated the effect of chopped glass fibers on friction-induced oscillation and wear of brake friction materials containing 0, 5, or 10% glass fiber. They suggested that the propensity for friction-induced vibration was higher when the friction material had a higher glass fiber content.

Despite promising material properties, there have been several concerns about the use of short glass fibers in the production of commercial brake friction materials, which has limited their wider application. One of the major concerns is poor wear resistance due to the brittleness of the glass fibers, which degrades the reinforcing capability with a subsequent decrease in the friction coefficient at high temperatures [11,18]. Another important issue when using glass fibers is high noise generation, which has been ascribed to the aggressiveness of the abrasive wear debris from the brittle glass fibers [19]. Kim et al. [2] also proposed that chopped glass fibers increase friction-induced vibration due to an increase in contact stiffness of the friction material surface due to the

\* Corresponding author.

E-mail address: [hojang@korea.ac.kr](mailto:hojang@korea.ac.kr) (H. Jang).

presence of larger plateaus near the short glass fiber bundles. To reduce the disadvantages of excessive high temperature wear and high noise generation, glass fibers are often blended with other fibers [20], while short glass fibers are also used as abrasives to control the friction coefficient of friction materials [21]. The specific mechanisms producing brake noise when using friction materials containing short glass fibers are still unclear. The behavior of the short glass fibers on the sliding surface needs further investigation in order to elucidate the critical mechanism behind the friction-induced noise and vibrations during braking.

In this study, the friction and wear characteristics of brake friction materials prepared with short glass fibers were investigated to understand the relationship between the dispersion of the fibers in the matrix and the friction instability. In particular, we focused on the change in the stick–slip behavior (which is closely related to friction-induced noise and vibration) for friction materials with different glass fiber dispersion. This study complements our previous work where we compared the friction characteristics as a function of the glass fibers concentration and focused on the effect of fiber dispersion on the friction characteristics [2].

## 2. Experiments

The friction materials used in this study were based on the formulation shown in Table 1., identical to that used in our previous study [2]. This was a simplified version of a full formulation [1], containing only six ingredients to minimize unclear interactions among ingredients. Two different types of glass fibers, chopped and milled, were used (E-glass, Owens Corning), as shown in Fig. 1. The chopped glass fibers were composed of hundreds of short glass fibers while the milled fibers were dispersed by milling. The fibers were 5–6 mm in length and 8–10  $\mu\text{m}$  in diameter.

Fabrication of the friction material specimens was undertaken by mixing, pre-forming, hot-pressing and then post-curing [22]. The size of the friction material samples after fabrication was

$45 \times 18 \times 6$  mm. The distribution of the glass fibers on the friction material surface is shown in Fig. 2. It can be seen that the chopped fiber bundles were embedded in the friction material while the milled glass fibers were evenly dispersed on the surface. The surface hardness on the Rockwell hardness scale S was 108 and 115 for the friction materials with chopped and milled fibers, respectively. Gray cast-iron discs, 142 mm in diameter and 8 mm in thickness, were used as a counter part for the tribotests. The microstructure of the iron discs showed typical A-type graphite flakes. Contact stiffness of the friction material specimen was measured employing a zirconia hemisphere (radius=2 mm) that maintained contact area during compression tests using a universal testing machine (3367, Instron, USA). The surface morphology of the friction material was measured using a laser confocal microscope (VK-8710, Keyence) before and after the sliding tests.

The friction and wear tests were performed using a one-fifth-scale brake dynamometer. The friction material was burnished to ensure a uniform contact with the disc surface and to stabilize the friction level. Low speed tests were carried out at a sliding velocity of 0.1–30 mm/s and a pressure of 1–6 kgf/cm<sup>2</sup>. The absolute humidity was maintained at approximately 5.9–7.7 g/m<sup>3</sup>, which is equivalent to 23–30% relative humidity. The wear tests were carried out using a Krauss-type tribometer. The detailed test procedure employed in this study is shown in Tables 2 and 3.

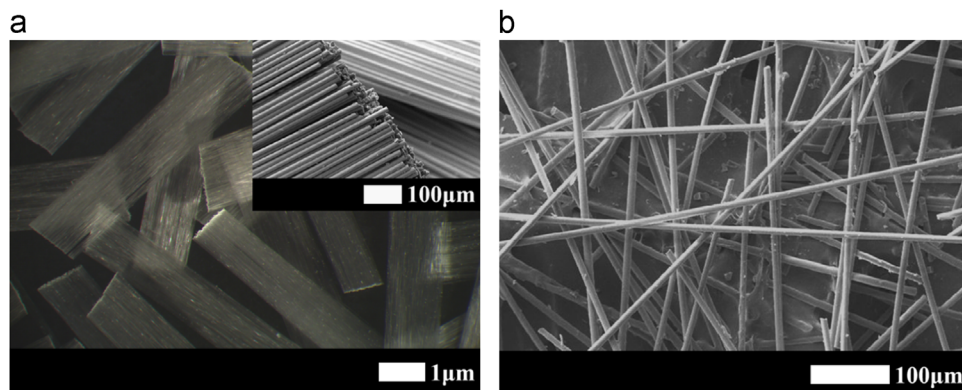
## 3. Results and discussions

### 3.1. Friction and wear

The friction coefficient and wear rate were examined initially to investigate the effect of the dispersion of the fibers in the friction material. Fig. 3 shows the change of the friction coefficient during burnishing. The coefficient of friction rapidly increased up to the 10th stop and became consistent afterward, indicating that the friction material surface was already well burnished after a relatively short time. The friction coefficient at the 50th stop was considered as the kinetic friction coefficient in this study, although the coefficient of friction could be further changed when the braking conditions, such as applied pressure, sliding velocity, temperature, and humidity, were changed. The friction coefficient of the specimens with milled fibers was higher than that for samples with chopped fibers. To find possible causes for the difference in the friction coefficient of the two types of sample, the sliding surfaces were examined using confocal microscopy after burnishing. The images of the surface morphologies presented in Fig. 4 show that the friction material with the milled fibers is smoother than that with the chopped fibers. This was confirmed by roughness parameters calculated from the same areas.

**Table 1**  
The composition of the friction material specimens used in this study.

| Ingredient                   | Vol% |
|------------------------------|------|
| Glass fiber(chopped, milled) | 10   |
| ZrSiO <sub>4</sub>           | 5    |
| Graphite                     | 10   |
| Aramid fiber                 | 5    |
| Phenolic resin               | 40   |
| Barite                       | 30   |



**Fig. 1.** Morphology of the short glass fibers (a) chopped and (b) milled.

Download English Version:

<https://daneshyari.com/en/article/616855>

Download Persian Version:

<https://daneshyari.com/article/616855>

[Daneshyari.com](https://daneshyari.com)