FRICIONAL AND WEAR PERFORMANCE OF CAST IRON COMPOSITES

T. MIYAUCHI, T. TSUJIMURA
Railway Technical Research Institute, 2-8-38 Hikari-cho Kokubunji-shi, Tokyo 185-8540, JAPAN; e-mail: toru@rtri.or.jp

T. TAKANASHI
Hokkaido Railway Company, Kita 11 Nishi 15 Chuo-ku Sapporo 060-8644 JAPAN

SUMMARY
Alloyed cast iron shoes, which contain alloying elements such as P, Ni and Mo, are used for rolling stock. Steadite precipitates when phosphorus is added in cast iron. The steadite phase has been investigated so far to a conclusion that the hard phase can improve the brake performance of cast iron shoes. In this study, SiC and PSZ ceramics were selected as artificially introduced hard phase materials. Then cast iron composites containing ceramic filters were prepared and subjected to frictional tests. Based on the examination that how the hard phase in cast iron affected frictional and wear performance, it was clarified that steadite and SiC as hard phases affected the frictional and wear performance, and increased the resistance to metal flow more effectively than PSZ.

Keywords: Cast iron, ceramic, composite, wear and friction

1 INTRODUCTION
Alloyed cast iron shoes, which contain alloying elements such as P, Ni and Mo, are used for rolling stock. Steadite precipitates when phosphorus is added in cast iron. The steadite phase has been investigated so far to a conclusion that the hard phase can improve the brake performance of cast iron shoes [1, 2]. This fact suggests that any artificially introduced hard phase in cast iron can also increase the ability of cast iron shoes. Following this idea, we applied ceramic materials as the substitute for the steadite phase in the cast iron and confirmed the improvement of brake performance by containing SiC ceramics between wheel and shoes during braking [3, 4]. We designed cast iron composites containing SiC filters and confirmed that they improved the brake performance with a full-scale brake tester. However, there are still some items to be investigated.

1. Damage of wheel steel caused by the attack of cast iron composites
2. Evaluation of the performance of PSZ as a substitute of SiC
3. Quantitative evaluation of the effect of ceramics

In this study, we performed frictional tests of cast iron composites containing SiC and PSZ ceramic filters with a small-scale frictional tester and investigated the items mentioned above. Steadite and ceramics have constituted hard phases. We discussed the effect of the hard phase on the frictional and wear performance of cast iron and cast iron composites.

2 EXPERIMENTS
Figures 1 and 2 give schematic views of specimens and the small-scale frictional tester used in this study. Two blocks were pressed to a disc which rotates at a steady speed in the tester. The disc diameter was 206 mm and the frictional area of the block was 30 x 30 mm. The disc is made of wheel steel. The sliding speed was set at 3, 6, 10, 14, 18, and 22 m/s. A 60 sec pressing test was repeated five times, at the pressure of 1 MPa. The test was repeated after the disc was cooled down below 333 K.

As shown in Table 1, two kinds of cast iron and four kinds of composites were used as block specimens. FC is cast iron and NHF is alloyed cast iron. Both are used for rolling stock at present in Japan. NHF contains P, Ni
and Mo as alloying elements with the P amount up to 2 mass %.

Regarding the composites specimens, two kinds of ceramic filters are contained in FC and NHF. One is made of SiC and another of ZrO₂. ZrO₂ used in this study is Partially Stabilized Zirconia (PSZ).

Steadite, SiC and PSZ constitute the hard phases in cast iron. To discuss the relationship between the ratio of hard phase and the performance, we observed micrographs of block specimens and measured the ratio of hard phase using image processing.

<table>
<thead>
<tr>
<th>Sign</th>
<th>Materials</th>
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<tbody>
<tr>
<td>FC</td>
<td>Cast iron (FC250)</td>
</tr>
<tr>
<td>FCS</td>
<td>Cast iron + SiC filter</td>
</tr>
<tr>
<td>FCZ</td>
<td>Cast iron + PSZ filter</td>
</tr>
<tr>
<td>NHF</td>
<td>Alloyed cast iron</td>
</tr>
<tr>
<td>NHFS</td>
<td>Alloyed cast iron + SiC filter</td>
</tr>
<tr>
<td>NHFZ</td>
<td>Alloyed cast iron + PSZ filter</td>
</tr>
</tbody>
</table>

Table 1: Block specimens

3 RESULTS

Figure 3 shows the mean frictional coefficient. The frictional coefficient of NHFS is the highest at all sliding speeds. The frictional coefficient, except that of NHFS, is almost the same at sliding speeds of 3 and 6 m/s. However, that of FC is the lowest at sliding speed over 10 m/s. NHF, FCS and FCZ show higher values of frictional coefficient than FC, which are similar to each other. This suggests that the frictional coefficient of FC can effectively be improved by using alloyed cast iron or by applying a ceramic filter.

Figure 4 shows the wear rate of the blocks. The specific wear rates of FCS, NHFZ and NHFS are remarkably low when compared with those of FC, FCZ and NHF at sliding speeds of 6 and 10 m/s.

Figure 5 shows the wear of disc. The wear of disc was negative at sliding speed of 3, 6 m/s because some parts of block specimens transferred to the disc. However, it was positive at sliding speed over 10 m/s. The wear of the disc of NHFS was the highest of all materials.

Figure 6 shows micrographs of specimens. Pearlite, steadite and graphite are observed in NHF. The amount of steadite is 14 % in area fraction in NHF. Both kinds of ceramic filters can form the stable composites in which no damage is found at the boundary between ceramics and metal area, and the ceramics occupy 20 % of the total area.

Table 2 shows the ratio of hard phase. There are no hard phases in FC. The ratio of hard phase in NHF is that of steadite, and the ratio of hard phase in FCS and FCZ is that of ceramics. The ratio of hard phase in NHFS and NHFZ was calculated as the sum of steadite and ceramics.
Table 2: Ratio of hard phase

<table>
<thead>
<tr>
<th></th>
<th>FC</th>
<th>NHF</th>
<th>FCS</th>
<th>NHFS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ratio of hard part, %</td>
<td>0</td>
<td>14</td>
<td>22</td>
<td>36</td>
</tr>
</tbody>
</table>

4 DISCUSSIONS

The experimental results show that the frictional and wear performance is affected by the addition of alloying elements in the cast iron or the composition of ceramics with the cast iron. It depends on the effect of hard phase in cast iron, such as steadite and ceramics. We investigated the effects of the ratio of hard phase on the frictional and wear performance. In the following Figures, the experimental results are reproduced for individual ceramics.

Figure 7 shows the relationship between the ratio of hard phase and the mean frictional coefficient of each kind of ceramic filter. In the Series SiC, the frictional coefficient does not change linearly with the amount of hard phase at sliding speed below 10 m/s, but a linear relationship is observed between the frictional coefficient and the amount of the hard phase at sliding speed over 14 m/s. In the Series PSZ on the other hand, the frictional coefficient doesn’t increase when compared with that of Series SiC at all sliding speeds even if the hard phase increases. These results show that the SiC filter increases the frictional coefficient more effectively than the PSZ filter.

Figure 8: Relationship between the ratio of hard phase and specific wear rate of blocks

Figure 9: Relationship between the ratio of hard phase and wear of disc
Figure 8 shows the relationship between the hard phase and the specific wear rate of blocks. In the Series SiC, the specific wear rate of block decreases at sliding speeds of 6 and 10 m/s when the hard phase increases. In the Series PSZ on the other hand, the specific wear rate of blocks doesn’t decrease even if the hard phase increases. In particular, it is the highest when the hard phase (FCZ) accounts for 22 % at sliding speeds of 6 and 10 m/s. These observations suggest that the SiC filter decreases the specific wear rate of blocks at the speed of 6 and 10 m/s more effectively than the PSZ filter.

The specific wear rate of blocks doesn’t change when the hard phase increases at sliding speed over 14 m/s. The block surface is melted by friction at the sliding speed over 14 m/s, and the frictional mechanism becomes welding wear. Based on these results, it is considered that the effect of hard phase is small in the welding wear condition.

Figure 9 shows the relationship between the hard phase and the wear of disc. A difference is found about the wear of disc at the sliding speed over 14 m/s between the two Series, and the wear of disc becomes high when the hard phase increases. However, the wear of disc in Series SiC is larger than that in Series PSZ. This suggests that SiC increases the wear of disc more effectively than PSZ.

Figure 10 shows cross section micrographs of blocks after the frictional test. Metal flow is found near the surface in FC and FCZ, but not in other blocks. This suggests that the resistance to metal flow doesn’t increase even when PSZ is contained, but increases when steadite and SiC are contained in cast iron.

USAMI et al [5] performed frictional tests of SiC and PSZ pins with a steel disc at sliding speeds from 1 to 15 m/s. They obtained the results that the frictional coefficient of SiC pins is higher than that of PSZ; the wear of SiC pins is lower than that of PSZ; and the wear of steel disc with SiC pins is larger than that with PSZ. The results of this study are in good agreement with those of USAMI et al although we performed frictional tests of cast iron composites containing SiC and PSZ.

5 CONCLUSIONS

We performed frictional tests of cast iron and cast iron composites and discussed the effect of hard phase in cast iron. The conclusions are as follows.

1. The relationship between the ratio of hard phase in cast iron and the performance was made clear.
2. Steadite and SiC as hard phases affect the frictional and wear performance as hard phases more than PSZ.
3. Steadite and SiC as hard phases more effectively increase the resistance to metal flow than PSZ.

6 REFERENCES