# Braking Performance of Ceramic Coated Discs

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In this study, three kinds of brake discs including two coated brake discs and one steel disc were tested under the same experimental conditions on a reduced scale braking test bench. Plasma spray coating technique was used to coat ceramic powder on the discs. In the test, four commercial sintered brake pads were coupled with discs. Ceramic coated discs have shown good stability in friction coefficient at high speed and high energy braking conditions. However, ceramic coated discs caused more wear loss of pad mass than the steel disc. It was shown that thermal barrier effect in ceramic coated discs adjusted the thermal partition between pad and disc. Steel disc showed fluctuating friction coefficient at high speed but less wear loss of pad mass than ceramic coated discs.

**Keywords** : Ceramic coated disc, Friction coefficient, Mass wear loss, Thermal barrier effect

## 1. INTRODUCTION

For the speed up of the train and the reduction of maintenance costs, we need to develop new brake materials for high energy braking conditions with higher frictional performance and longer service life. When high-speed train is stopped from the high speed like 350km/h or more, high energy is dissipated on the friction surface of pad and disc. And disc and pad are under the high temperature and high braking pressure condition. So we need to develop new materials with stable frictional performance and higher wear resistance for the reduction of maintenance costs. Interesting alternatives are ceramic materials and carbon materials.[1] Ceramic materials are chosen for this study.

Ceramic coatings can endure high surface temperature.[2] Low thermal conductivity of ceramic materials shows thermal barrier effect. This effect decreases the proportion of heat transferred to the disc substrate and reduces the temperature rise of the disc substrate.[3-4] This also decreases the amount of plastic deformation, and metal seizure due to localized high flash temperature during high energy braking. In this way, the ceramic-coated brake disc leads to stable frictional performance and decreases the wear. However, high proportion of the heat transferred to the pad side and high hardness of disc surface let the pad be under the severe conditions. Therefore, we should examine the associated phenomena between coated disc and pad.

In this study, three kinds of brake discs including two coated brake discs and one steel disc were tested under the same experimental conditions on a reduced scale braking test bench. Braking test bench was specially designed for stop and hold braking tests.

## 2. EXPERIMENTAL RESULTS

### 2.1 Thermal behavior

Fig. 1 shows the temperature evolutions of three different discs and pad C under hold braking conditions. Temperature difference between pad and Zirconia coating disc is larger than that between pad and steel disc. This results from the thermal barrier effects of zirconia coating. Thermal barrier effect of ceramic materials results from low conductivity caused by the porosity of materials. In the case of Zirconia disc, much portions of heat is transferred to the pad, so the pad temperature is very high. However in the case of steel disc, pad temperature is low and even lower than disc temperature. This means that more portion of dissipated energy is transferred to the steel disc compared with the case of the ceramic-coated disc

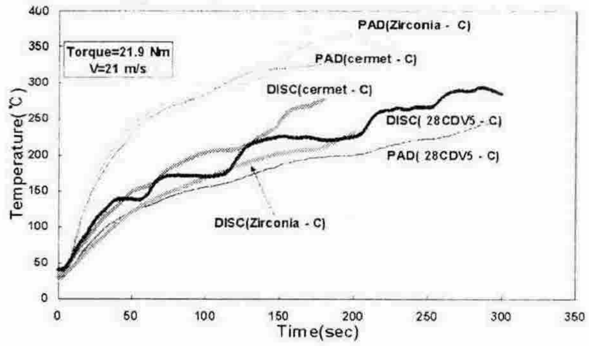


**Fig. 1** Temperature evolution of the discs and the pads during hold braking test

### 2.2 Friction coefficients

Fig.2 and Fig.3 show friction coefficient evolution during hold braking test, which was performed for 3 to 5 minutes for the simulation of high energy dissipated braking conditions for ceramic-coated disc and steel disc. Ceramic-coated discs show apparently stable friction coefficient at high energy braking conditions. Steel disc had shown fluctuating friction coefficient. But in couple with pad C the fluctuation is changing with small amplitude about the constant mean value of 0.4, and with pad B fluctuation is very small and gradually increases with time. Steel-pad D couple shows unstable result and the test was stopped at 130sec.

### 2.3 High-speed stop braking test

Fig.4 shows the results of high speed stop braking tests. Cermet disc and pad B couple shows most stable friction coefficients. But pad mass wear is larger than any other couples as shown in Fig.5. In the beginning, friction coefficient is high as shown in Fig.4 and then decreasing to the stable value during the braking and rising again at the end of the test. Evolution of friction coefficient seems to result from the reason that the surface layer made of wear debris causes the decreasing of friction coefficient, and transformation of surface layer and wear debris cause the rising of friction coefficient at the end of the braking. Rooster tailing phenomena is larger in steel disc than cermet disc.

### 2.4 Pad mass wear

The pad mass wear per dissipated energy was measured after each braking step shown, and the total pad mass wear per energy is shown in Fig.5 for all tested couples.

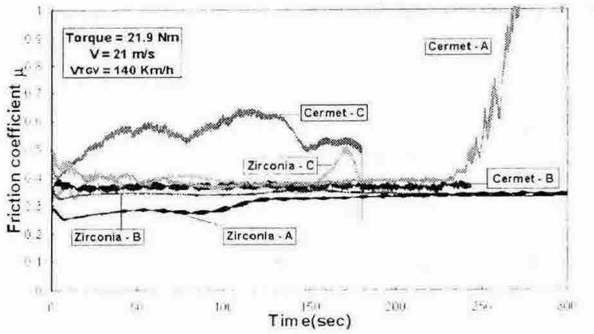


**Fig. 2** Friction coefficient evolution during the hold braking test with ceramic coated discs

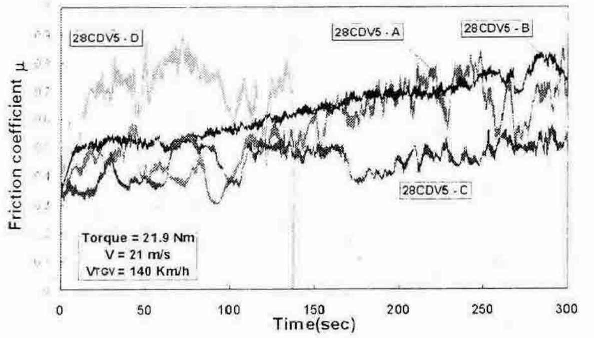


**Fig. 3** Friction coefficient evolution during the hold braking test with 28CDV5 discs

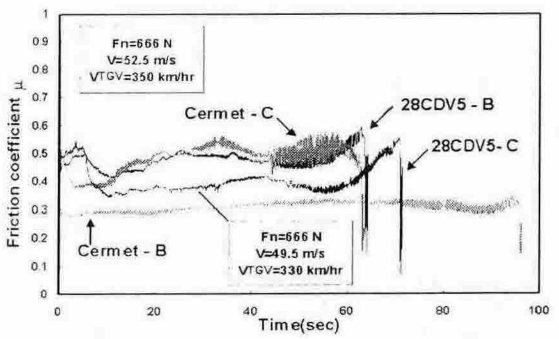


**Fig. 4** Friction coefficient evolution during the stop braking test

The pad mass wear coupled with small disc show the result of the smallest wear in steel disc. The friction couples with larger disc show similar tendency in pad mass wear, but 1.5 times larger than couples with small disc. This is because the result with larger disc includes the test under high normal pressure and high-speed conditions. Cermet disc coupled with pad B show stable friction coefficient but larger pad mass wear. This is because cermet-coated disc with metallic ingredients, which have high hardness, cause the wear of the pad surface before oxidized friction surface was made on the disc surface and keep the surface under uniform conditions.

Mass wear of pad A was smaller than that of other pads. But thick hard layer of about 1mm thickness was formed on pad surface and locally detached from the pad surface. Severe transformation of pad surface like surface layer detaching cause great change in friction coefficient and unstable friction coefficient as shown in Fig.2 Pad D show larger pad mass wear than any other pads as shown in Fig.5 and show unstable friction coefficient as shown in Fig.3.

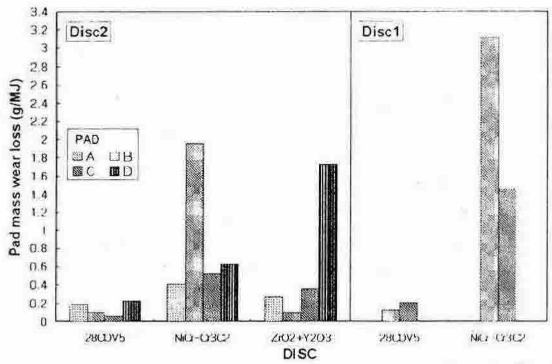


**Fig. 5** Pad mass wear loss of the braking pairs after finishing all braking test steps

Pads used in this study are composed of Cu as main component and Fe, graphite, silica, $Al_2O_3$ as friction control elements. All particles are mixed uniformly but the particle sizes are different in each pad. Pad A has bigger graphite particles than other pads. Pad C and B composed of small particles show stable friction coefficient and more healthy surface state after testing

## 3. CONCLUSIONS

The following results are drawn through the test.

- Ceramic coated discs had shown good stability in friction coefficient at high speed and high energy braking conditions. But Ceramic coated discs caused more pad mass wear loss than the steel disc.
- Zirconia disc showed the bigger thermal barrier effect and more stable friction coefficient at high energy braking conditions than cermet disc. Cermet disc showed stable friction coefficient under nearly all conditions but caused larger pad mass wear than zirconia disc.
- It was shown that thermal barrier effect in ceramic-coated discs adjusted the thermal partition between pad and disc.
- Steel disc had shown fluctuating friction coefficient at high speed and high energy braking conditions, but less pad mass wear loss than ceramic coated discs.

In the future, we need to develop new pad materials for ceramic discs to maintain longer service life of pad. Also we should examine the durability of ceramic coating to assure service life and reliability through endurance test.

## 4. REFERENCES

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