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The Effects of Ni Addition in Cu Base Sintered Friction Material-Microstructure and Tribological Behavior

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Abstract—The effects of Ni contents in Cu base sintered friction material were studied. The contents of Ni were increased up to 9 wt% in the Cu-Sn matrix. The microstructure and tribological behavior of the friction material were examined. Pin on disk type of constant speed friction test rig were used to measure the friction and the wear rates. The results show that Ni addition increased the friction coefficients and decreased the wear rates of the materials. Relations between microhardness of the matrix and friction properties have been discussed. In addition optimum Ni content is recommended through the analysis of wear debris.

Key words : Cu base, Matrix, Ni content, Microstructure, Tribological behavior

1. Introduction

Sintered friction materials have been widely used for heavy duty brake systems such as aircrafts and high speed trains [1,2]. They have high heat conductivity and high heat resistance. Also they have less deterioration of materials by heat while in use. The matrix of sintered friction material can be classified into two groups, Cu base or Fe base respectively. Since Cu is suited to Fe, Cu base friction material is often used for the brake system, which has an Fe base counter part. The basic structure of sintered friction material is the combination of matrix, friction modifier, and lubricant. The matrix must have an appropriate mechanical strength to hold the friction modifier and lubricant in itself as well as good property for heat radiation. Friction modifier, which is scattered in the matrix, keeps a stable friction coefficient, increases wear resistance, and reduces oxide or deposit layer. Solid lubricant such as graphite, lead or etc. lies in the interface and reduces direct intermetallic contact.

Usually a combination of several of these constituents comprises the sintered brake pads in the system. Unfortunately, the inclusion of a constituent to gain one property often causes other undesirable effects. The main focus of this study is to evaluate the role of Ni on the matrix strengthening and tribological properties in the sintered friction materials. For those purposes Ni was added into the reference matrix as a matrix intensifier. Their microstructures were examined and the friction and wear under unlubricated conditions have been investigated.

2. Experimental

2-1. Test specimens

Four types of Cu-Sn base sintered specimens were prepared as shown in Table 1. Specimen A is the reference friction material without any content of Ni. The contents of Ni were increased up to 9 wt% from specimen B to D. Ni has good properties as an intensifier of Cu base matrix. It can make complete solid solution with copper and can increase the strength of matrix [3]. Each specimen was compacted 3 cm×3 cm×8 cm. With a pressure of 3 tons per square centimeter, at room temperature, the mixed powder was molded. Sintering was carried out in H_2-atmosphere with 1.8 tons per square centimeter at 250°C for 15 minutes and then soaked for 2 hours at 810°C. The microhardness of each speci-

Table 1. Formulation of specimens

	Ni	Sn	Fe	lubricant	Cu
A	0	6	9.5	14	Bal.
B	3	6	7	14	
C	6	6	7	14	
D	9	6	7	14	

men was measured by microhardness tester with 100 g load. For the analysis of microstructure the specimens were etched by 3% nital solution.

2-2. Test rig and procedures

As schematically illustrated in Fig. 1 the pin on disk type of constant speed test rig was used for the measurements of the friction coefficients and the wear rates. The normal load was 716 N and sliding speed was 16 m/s. The friction coefficients were determined by the average after 1000 revolutions. But the data before 330 revolutions were not collected to get steady state friction coefficients. Even the tests were conducted at room temperature, the bulk temperature of the specimens rose about 200°C within 300 revolutions. The bulk temperature measurements were made by a Chromel-Alumel thermocouple. The thermocouple was inserted through the back of the friction pad to the inside of the friction surface up to 2 mm. For the elevated temperature test, the disk was heated until the bulk temperature of specimens reached 280°C by a heater

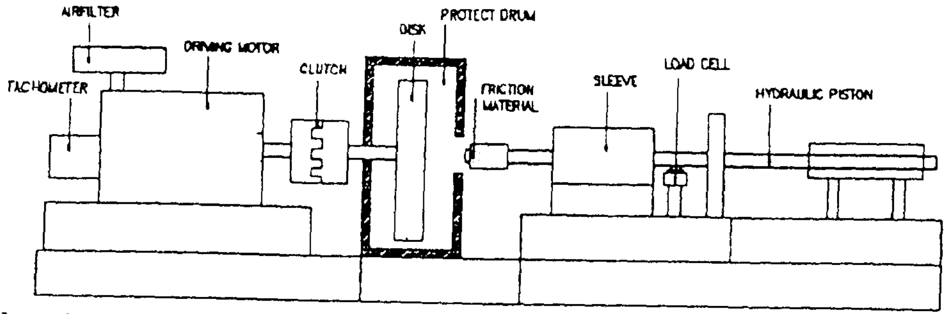

Fig. 1. Schematic diagram of friction test rig.

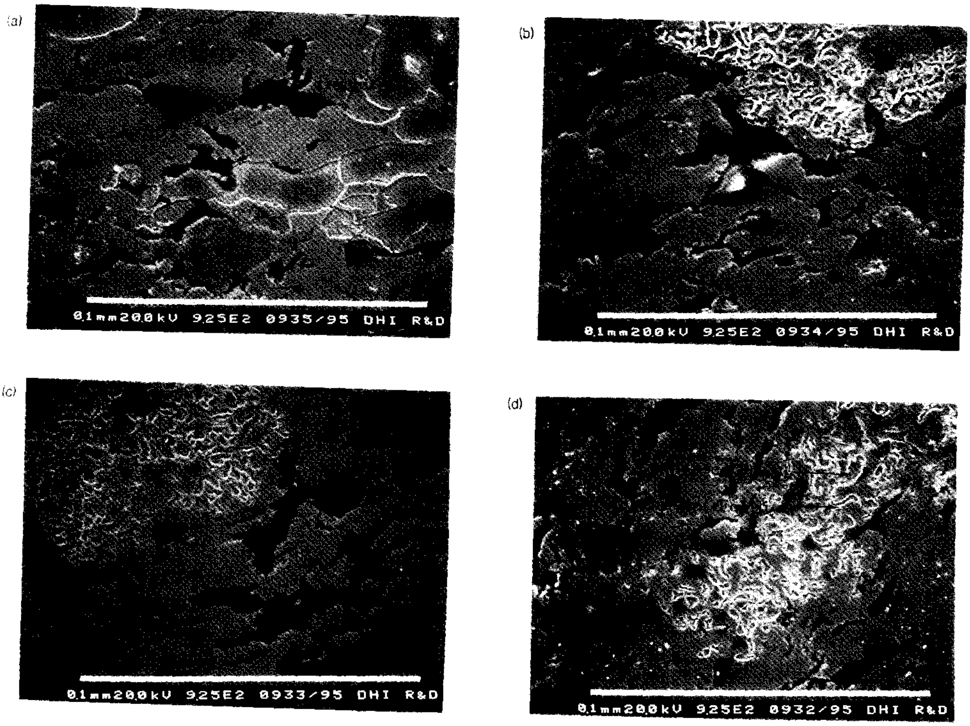

Fig. 2. Microstructures of specimens.
(a) 0 wt% (b) 3 wt% (c) 6 wt% (d) 9wt% of Ni Addition

which was attached to the disk. The plotted results were the averages of three measurements. While the wear rates were measured after 5 cycles of experiments for each specimen. Each cycle of experiment was 1000 revolutions and 2 minutes rest for cooling down the disk. All tests were carried out in dry condition.

3. Experimental results and discussions

3-1. Microstructure

Besides the usual technological testing procedures for measurement of friction and wear, the metallography is an essential expedient for judging quality and uniformity of sintered friction materials. The micrographs in Fig. 2 show typical microstructure of each sintered specimen which contained 0 wt%(a), 3 wt%(b), 6 wt%(c), and 9 wt%(d) of Ni. Table 2 shows the results of quantitative EDX analysis on α-bronze matrix of each specimen. As shown in Fig. 2 and Table 2, Ni was possibly solved into α-bronze and formed the Cu-Sn-Ni solid solution. Especially this solid solution increased the strength and the hardness of matrix considerably by solid solution hardening. This result increased the microhardness of matrix from 88 HrR to 130 HrR as plotted in Fig. 3. Consequently Ni added skeleton held the solid lubricants and friction modifiers firmly so that the tribological behaviors of friction material were improved. While some of the contents of Ni diffused to Fe and changed the morphologies of Fe particles as shown in Fig. 2. From Fe morphologies, collapsed and protrudent parts were observed. The results of quantitative EDX analysis of the parts are shown in Table 3. It was found that Ni was analyzed out more on the protrudent parts than on the collapsed parts. These prudent parts, which seem to be a metallic compound [3], increased the hardness of the friction material. Thereby the hard intermetallic phases were preserved in the matrix and influenced favorably the coefficient of friction and the wear resistance.

Table 2. Quantative analysis of Ni content in matrix by EDX

specimen	A	B	C	D
Content	0	1.88	5.13	8.15

Table 3. EDX analysis of Fe-Ni phase

Component	Fe	Ni	Cu	etc.
Prudent Part	71.9	13.0	9.4	5.9
Collapsed Part	89.7	3.0	3.0	4.3

3-2. Friction and wear test

Fig. 4 shows the mean friction coefficients with the contents of Ni and temperatures from constant sliding speed tests. As the content of Ni increases the friction coefficient increases. However, the friction coefficients at room temperature tests reach constant value after 3 wt% of Ni content. The wear rate decreases as the content of Ni increases as shown in Fig. 5. The increase of the friction coefficients and the decrease of wear rates are believed to result from matrix strengthening and hardening [4] as shown in Fig. 3.

On the other hand, it is found that low friction, but high wear, occurred at elevated temperature from Fig. 4 and Fig. 5. It is possibly due to the frictional heat. The frictional heat softened the contacting asperities on the surface so that the wear rate increased [5].

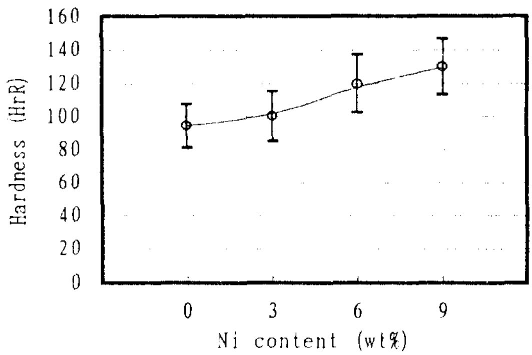

Fig. 3. Microhardness of matrix versus Ni content.

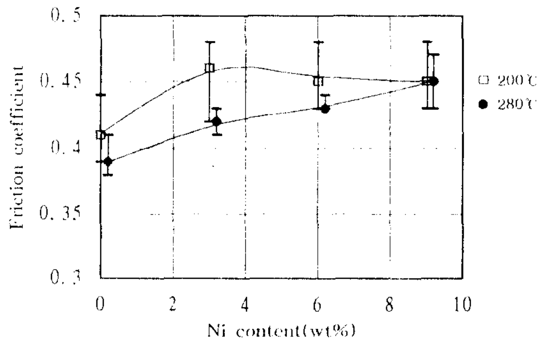

Fig. 4. Friction coefficient versus Ni content.

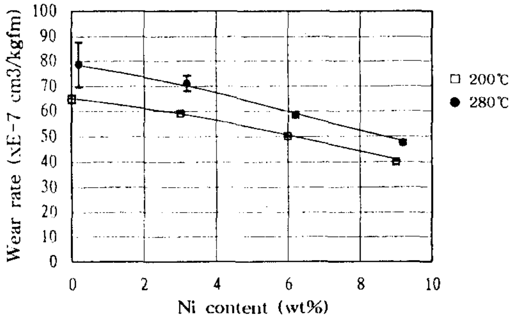

Fig. 5. Wear rate versus Ni content.

The friction material is required to provide stable and repeatable high friction with low wear rate for the good durability. In addition it has to show kindness to the mating surface of the friction pair. In present study a forged steel disk was used as a counter part. During the test wear debris were collected and analysed by SOAP. Since the content of Fe in each specimen is almost same as shown in Table 1, relative evaluation of kindness to the disk is possible with Fe particles contained in the collected debris. As the amount of Ni increases, the Fe particle increases about 2 times [6]. This result means that the Ni added friction materials attacked the counterpart disk. Therefore the optimum contents of Ni can be determined by considering the friction coefficient, wear rate, and the kindness to the disk. In this experimental range, 4 wt% of Ni addition in the sintered friction material is recommendable.

4. Conclusions

The effects of the contents of Ni in Cu base sintered friction material have been studied through the tribo-test and metallography analysis. By raising the Ni content, the microhardness of matrix increased by the solid solution hardening and the Fe-Ni hard phases. Resultantly the tribological properties of the friction material were improved. The optimum content of Ni can be determined with the friction coefficient and wear rate as well as wear debris analysis so that 4 wt% of Ni addition is recommendable in present experiment range. In addition the microstructure of Fe-Ni hard phases will be studied further.

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