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FRICTIONAL NOISE IN SLIDING CONTACT OF ALUMINA CERAMICS

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1. INTRODUCTION

Alumina is promising for a wear resistant material at high temperatures because of its high hardness and high chemical stability. Frictional noise of high sound pressure level, which is called "squeal", sometimes generates during the sliding of alumina pair. This paper describes the frictional noise in the sliding contact of alumina pair at elevated temperatures.

2. EXPERIMENTAL PROCEDURE

Frictional tests of plate-on-plate type were conducted in laboratory air with a dry friction test rig, as shown in Fig.1, using a couple consisting of the same material. The test section of wear test rig is schematically shown in Fig.2. Each specimen was mounted in a stainless steel holder which was heated by high-frequency induction coils to the required temperature. Figure 3 illustrates the specimen geometry. An annular specimen was rotated on a square specimen under the constant load. Wear surface regions were examined by SEM. The friction tests were conducted at the heating stage from room temperature to 800℃ and at the cooling stage from 800 to 300℃. Sound pressure levels were measured by a 1/2" microphone placed at a distance of 10 cm from the friction surface.

3. EXPERIMENTAL RESULTS AND DISCUSSION

Figure 4 shows coefficient of friction at room temperature and 1000℃ where the sliding velocity varied from 0.05m/s to 0.3 m/s under a normal contact pressure of 0.4 MPa. This reveals that the coefficient of friction at 1000℃ is smaller than that at room temperature and is nearly constant for various sliding velocities. Hereafter experiments were hence performed at the sliding velocity of 0.2 m/s.

Figure 5 plots sound pressure levels measured at different temperatures. When the temperature increases from 170 to 600℃, a squeal of high sound pressure level, around 100 dB, continuously occurs. However, at a temperature above 600℃, the sound pressure level abruptly decreases, and the squeal disappears. During the decrease in temperature from 800℃, the squeal begins to occur again at 600℃. At the temperatures lower than 350℃, the sound pressure level decreases and the squeal disappears.

Figure 6 shows sound frequency spectra and time histories in the presence of the squeal at both heating and cooling stages. Time histories exhibit sinusoidal waveforms with changing amplitudes, and they are dominated by many harmonic components. The relationship between the squeal frequency and the test temperature is shown in Fig.7. Squeal frequency is approximately 1800 Hz, except for cases from 450 to 350 ℃ in the cooling stage where the frequency is 2500Hz. The Young's modulus of the alumina ceramics simply decreases with increasing temperature. However, the squeal frequency does not change depending on the temperature. This implies that the squeal frequency is not related to the natural frequency of alumina specimen itself, but to that of the coupled system which consists of the alumina specimens and the rotational axis. The coefficient of friction, which should be responsible for squealing occurrence, is shown for various temperatures in Fig.8. It is 0.8–0.9 up to 500℃. As the temperature further increases, it decreases to 0.6 at 600℃. There is no significant difference in the coefficient of friction between the cooling and the heating stages. Comparison between Figs. 5 and 8 suggests that squealing sound ceases when the coefficient of friction decreases to 0.6. Figure 9 represents characteristics of specific wear loss of alumina for various temperatures. The specific wear loss significantly decreases. Therefore, the reduction in wear loss may be related to the squeal suppression.

Figure 10 presents SEM micrographs of the friction surface and its cross section of the alumina specimens. The friction surface is very smooth at 1000℃ and the surface layer of very fine grains (0.1μm) is observed. The thickness of the surface layer is several to 10 μm. It has been considered that the surface layer is formed by dynamic recrystallization associated with the plastic deformation of the friction surface region [1]. At room temperature, a thin surface layer is also observed. However, the contact between the layer and the bulk surface is not tight and brittle transgranular fracture features are observed. At 600 ℃, the friction surface exhibits some mixture of brittle and plastic features.

The hardness measurement of the friction surface demonstrates that the surface layer exhibits very low hardness, i.e. very low deformation resistance at high temperatures. The surface layer with low deformation resistance would allow shear stress release resulting in low wear loss and also low coefficient of friction. The transition from elastic to plastic contact is observed at a temperature around 600℃. It is therefore reasonable to assume that this transition is directly related to the squeal halt around 600 ℃.

At lower temperatures, no plastic deformation is observed at the surface [1]. An elastic contact dominates at the frictional surface and thus the vibration would be more easily excited. However, squealing does not occur around room temperature. SEM observations suggest that a thin layer of wear debris particles is observed at the friction surfaces. Those particles may prevent the elastic contact of the bulk surfaces, suppressing the squeal occurrence.

4.CONCLUSIONS

From the frictional tests of alumina pair at high temperature, the following results were drawn. Squeal occurs when the coefficient of friction was more than 0.6. No squeal occurs above 600℃ because of the coefficient of friction less than 0.6. The squeal frequency is approximately independent of the temperature. The squeal may occur by the coupled vibration of the frictional system including the alumina specimens but not by the vibration of the alumina pair itself.

Reference

[1] T. Senda et al., J. Am. Ceram .Soc., 78 [11] 3018-24 (1995).

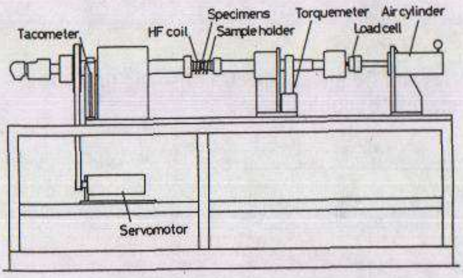

Fig.1 Experimental apparatus

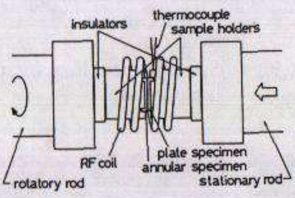

Fig.2 Schematic of the test section of wear test rig

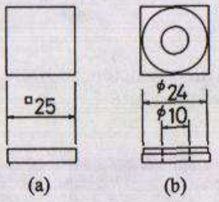

Fig.3 Specimen geometry (a) plate specimen (b) annular specimen

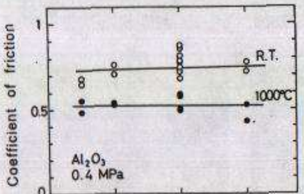

Fig.4 The coefficient of friction versus sliding speed

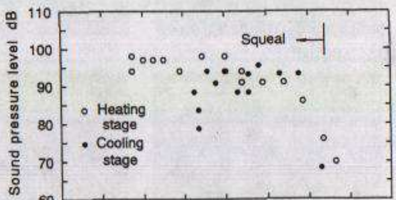

Fig.5 Sound pressure level versus temperature

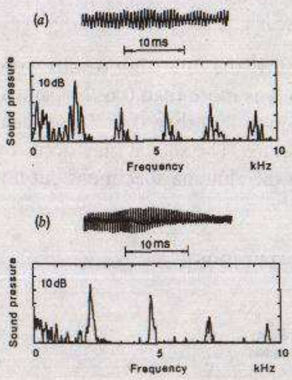

Fig.6 Time histories and frequency spectra of sound pressure
(a) heating stage (b) cooling stage

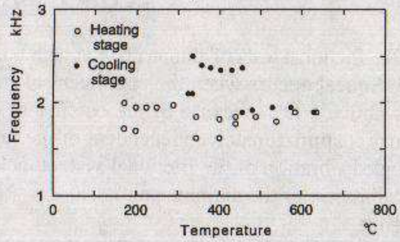

Fig.7 Squeal frequencies versus temperature

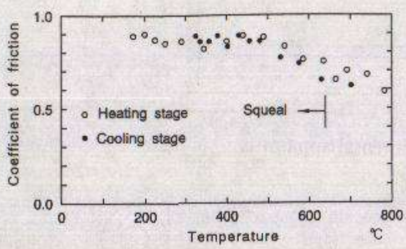

Fig.8 The coefficient of friction versus temperature

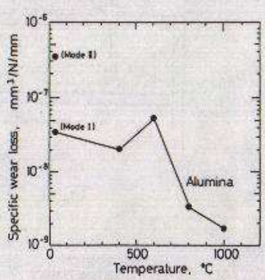

Fig.9 Specific wear loss versus temperature

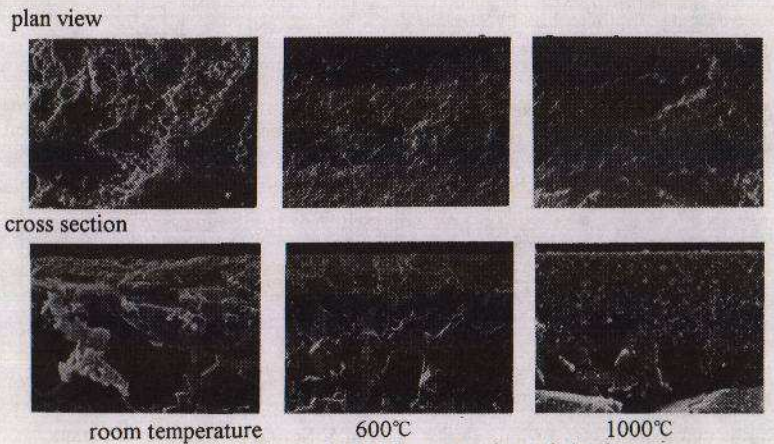

Fig.10 SEM of wear surface of alumina