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SQUEAL NOISE ELIMINATION ON RAILWAY WHEELS WITH RING

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1. INTRODUCTION

A railway wheel and a disk brake with a ring snapped into a circumferential groove on the wheel or the disk are used [1],[2]. Although using a stainless ring in railway wheels decreases the occurrence of squeals, the precise reason for elimination of squeals has been unknown. In our previous paper [3], damping properties were studied numerically using a simple model which consisted of a disk with a ring. In this paper, the frictional experiments to verify the effect of the elimination of squeal of a disk with a ring were conducted using the same simple experimental apparatus as a numerical model.

2. NUMERICAL RESULTS

In our previous paper [3], the damping property of a wheel or a disk with a ring was investigated by using a model such as the one shown in Fig.1. The ring is parallel to the disk, clamped at inner radius r_i and free at outer radius r_o. The ring is connected by springs (the complex spring constant per unit length k^*) to the circumference of the disk at a distance of the ring radius, a, from the center of the disk. Furthermore, let $K^*=k^*ar_o^2/D=K(1+0.1i)$ be the nondimensional spring constant, where D is the flexural stiffness of the disk. The relation between spring constant K and loss factors η is shown in Fig.2 for c=2, 3, 4 mm, (3-0) and (4-0) modes, with (n-s), n: the number of nodal diameters of the disk, s: the number of nodal circles, c: the radius of the cross section of the ring. In this figure, ξ is the ratio of the natural frequency of the ring to that of the disk. This figure reveals that the maximum loss factors are obtained at a certain spring constant which increases for higher modes. As the value of ξ approaches 1, loss factors are reduced.

3. EXPERIMENTAL PROCEDURE AND RESULTS

Figure 3 shows a schematic experimental apparatus. One side of a squared steel rod (1.6 cm in length of the side and 60 cm in rod length) was pressed against the circumference of a stationary disk (S45C, 5 cm in inner diameter, 30 cm in outer diameter and 0.7 cm in thickness) with a ring under different contact loads. Three kinds of test rings (14 cm in ring radius and 2, 3, 4 mm in radius of the cross section of the ring) were used. The contact load was applied to the rod by the weights. A squeal occurred when the rod was moved in the axial direction of the disk. The ring was connected to the disk with two methods as shown in Fig.4: it was bonded with a synthetic resin glue to the disk, and it was tightened at 24 points of the disk with bolts. The loss factor at each mode was determined from the decay of amplitude in the axial acceleration by an impulsive excitation. Sound pressure levels were measured by a 1/2" microphone placed at a distance of 20 cm from the frictional surface.

Squeals of (4-0) and (3-0) modes occurred when the rod was rubbed at its center and at 4 cm from its center, respectively.[4] In Fig.5, time histories and frequency spectra for sound pressures are shown in the presence of squeals of (3-0) and (4-0) modes. It can be seen that their spectra are characterized by the presence of many harmonics of squeal frequencies. Figure 6 shows the number of squeal occurrences for both (3-0) and (4-0) modes under different contact loads when nuts tightened to the ring were loosened in two steps. In this figure, the number of squeal occurrences is also shown for the disk without a ring. The number of the squeal occurrence is expressed as a percentage of the number of squeal occurrences during fifty frictional experiments. Figure 7 plots loss factors for each case. In this figure, decaying time histories by an impulsive excitation are also shown. From Figs.6 and 7, it should be noted for squeals of (3-0) and (4-0) modes that if the ring was completely tightened to the disk with bolts, squeal frequently occurs because of low loss factors, and for the slightly tightened ring, squeal hardly occurs owing to high loss factors. Further, the number of squeal occurrences decreases with increasing contact load. Also squeal hardly occurs if the loss factor is greater than about $2x10^{-3}$. Comparison between experimental and numerical results suggests that when the ring was completely tightened to the disk, the spring constant K becomes larger, and K decreases with loosening bolts. Therefore, it is expected that the spring constant K for the slightly tightened ring takes the value where loss factor is at a maximum.

Next, for the ring bonded with a synthetic resin glue, we examined squeal occurrence and loss factor when the radius of the cross section of the ring c varied 2, 3 and 4 mm. These squeal occurrences and loss factors are shown in Figs.8 and 9. In these experiments, the loss factor is significantly high. Therefore, significant high loss factors do not give rise to squeal with the exception of a little squeal occurrence of (4-0) mode whose loss factor is slightly lower than that of the (3-0) mode for c=3 and 4 mm.

4. CONCLUSIONS

The following conclusions were drawn from the frictional experiments of the rod and the disk with a ring. If the ring is completely tightened to the disk with bolts, squeal frequently occurs in a frequency for a disk without the ring. However, when the ring is slightly tightened to the disk with bolts, or it is bonded with a synthetic resin glue to the disk, squeal hardly occurs because of high loss factors. There seems to be an optimum spring constant between the rod and the disk for the elimination of squeal.

References
[1] P.J.Remington, Journal of Sound and Vib., 116(2) 339-353 (1985)
[2] Product Catalogue for "Noise-Proof Wheels," Sumitomo Metal Co., Ltd.
[3] M.Nakai and M.Yokoi, Proceedings of Inter-noise 95, 151-154(1995)
[4] M.Nakai et al., Bulletin of JSME, 27(224), 301-308(1984)

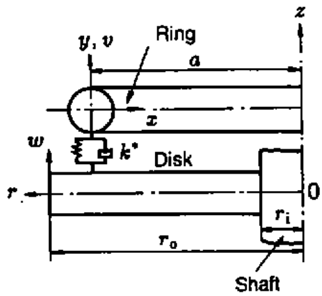

Fig.1 A model of a disk with a ring

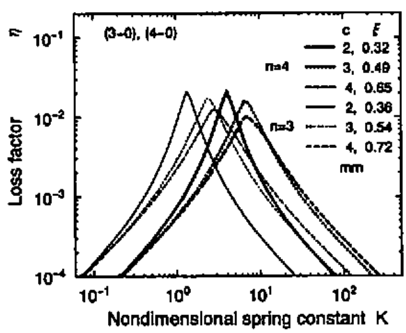

Fig.2 Relation between K and η for (3-0) and (4-0) modes

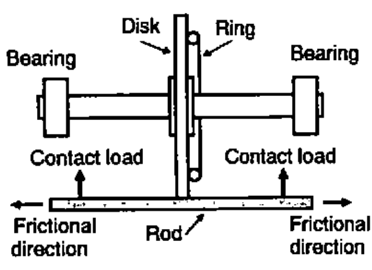

Fig.3 Schematic of an experimental apparatus

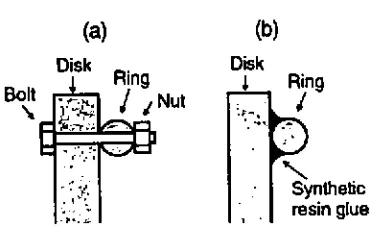

Fig.4 Two methods to connect the ring to the disk

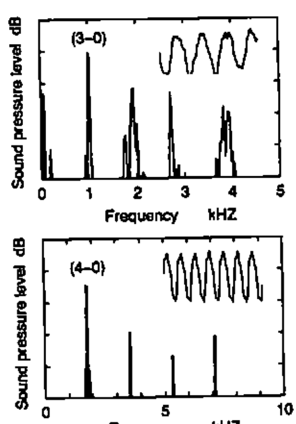

Fig.5 Time histories and frequency spectra of squeals

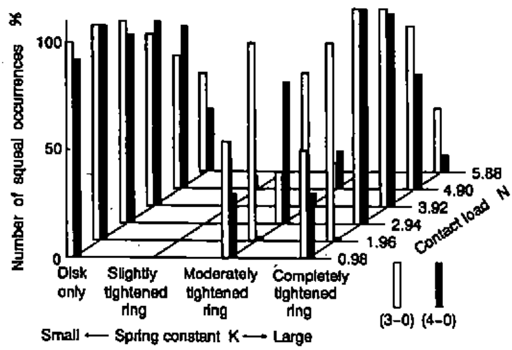

Fig.6 Number of squeal occurrences for (3-0) and (4-0) modes when the ring was tightened to the disk with bolts

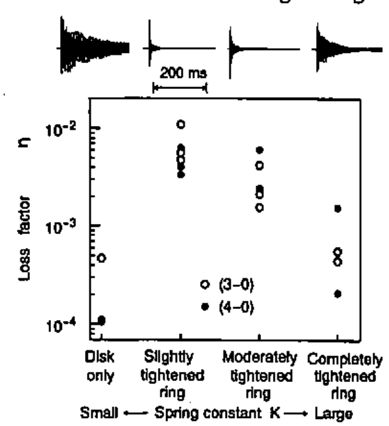

Fig.7 Loss factors and decaying time histories for tightened ring with bolts

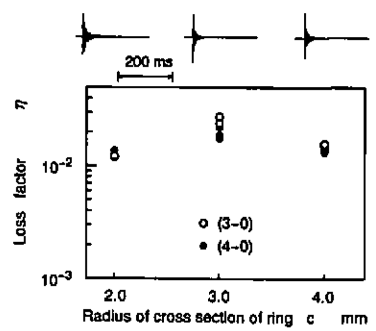

Fig.9 Loss factors and decaying time histories for bonded ring

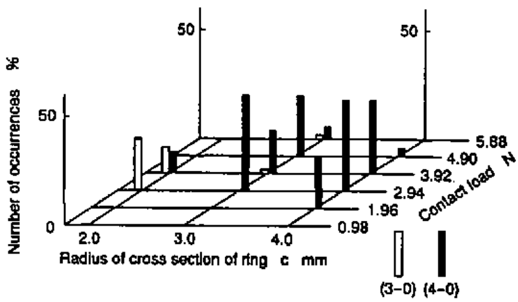

Fig.8 Number of squeal occurrences for (3-0) and (4-0) modes when the ring was bonded with synthetic resin glue to the disk