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Short Note

Resonance Curves Obtained in the Vibration of Fe–3%Si Reeds

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A series of amplitude-vs-driving-frequency measurements were performed for the forced vibration of Fe–3%Si reeds. With an increase in the magnitude of the driving force, the resonance frequency tended to shift to the lower side, similarly to soft-spring-type resonance. For sufficiently large driving force, however, it was found that the resonance curve became skewed and the resonance frequency began to shift to the higher side, similarly to hard-spring-type resonance.

KEYWORDS: Fe–3%Si, automodulation, internal friction, phase transformation, resonance curve

Polycrystalline Fe–3%Si with grains 2–3 mm in diameter was used as samples. They were formed into $55\times5\times0.36$ mm^3 reeds. Figure 1 shows a schematic diagram of the experimental setup used. The sample on which a small Sm–Co magnet was attached was vibrated through the constant-gradient magnetic field produced by two Helmholtz coils. Illumination of the vibrating sample naturally caused an in-phase change in the amount of light reflected from the sample. This change was detected by a light sensor, the output of which could easily be converted to the change in vibration amplitude by calibration. The vibrating system was housed in a vacuum chamber ($\sim1\times10^{-3}$ Torr) to reduce the effect of air friction. The chamber was mounted on a viton damper to reduce external mechanical noise.

Figure 2 shows the resonance curves which we obtained in series. The curves from a to f are arranged in ascending order of the magnitude of the driving force employed during each measurement. One sees in curves a to c that the resonance frequency decreased with an increase in driving force. In curves d to f, however, one can see that the resonance frequency tended to increase. In addition, we observed abrupt drops of vibration amplitude in the course of these measurements, as indicated by the arrows in the corresponding curves.

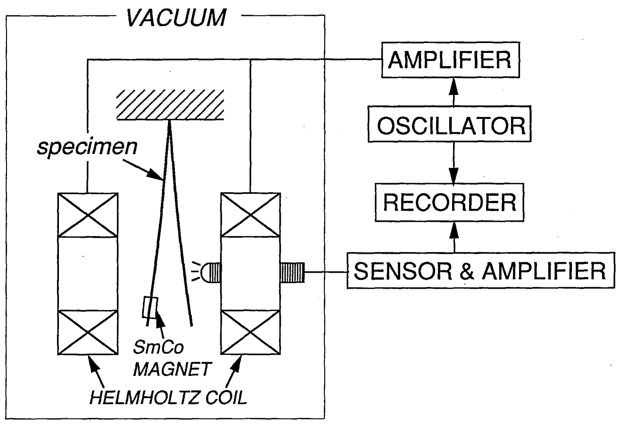

Fig. 1. Schematic diagram of the experimental setup.

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All of the data in Fig. 2 were obtained by increasing the driving frequency. After the amplitude drop, we decreased the driving frequency from the higher to the lower side. This yielded the curve shown in Fig. 3(a), where unfilled squares and filled triangles represent data obtained in the course of increasing and decreasing frequencies, respectively. By repeating measurements many times, we confirmed the reproducibility of the cycle C–A–B–C in Fig. 3(a).

To interpret this result, we presume that the resonance characteristics of a Fe–3%Si specimen, subjected to a high driving force, should in reality be expressed by a skewed curve such as C′A′D′B′ in Fig. 3(b). This means that the vibration amplitude is not univalued but trivalued in the frequency range between D′ and B′, although the values on the line A′D′ cannot actually be observed because of some instability (not yet clarified). That the resonance curve tends to be skewed is suggested from a careful examination of curve d in Fig. 2. In our view, when the driving frequency decreases to point D′ after the drop from A′ to B′, the vibration amplitude must jump to point E′ (or C′). However, points D′ and E′ (or C′) are located too closely to be separated within the accuracy of the present measurement, and hence they appear as a single point as C in Fig. 3(a).

Asymmetric resonance curves have been reported for the vibration of zinc and other metals.[1,2)] To explain the

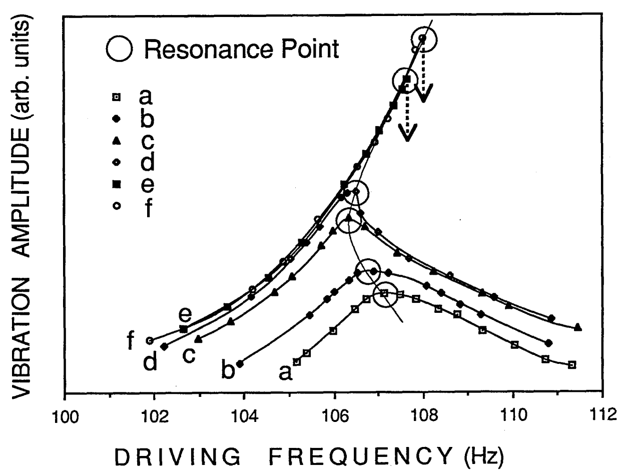

Fig. 2. Resonance curves in the vibration of an Fe–3%Si reed. The driving strength was progressively greater from a to f.

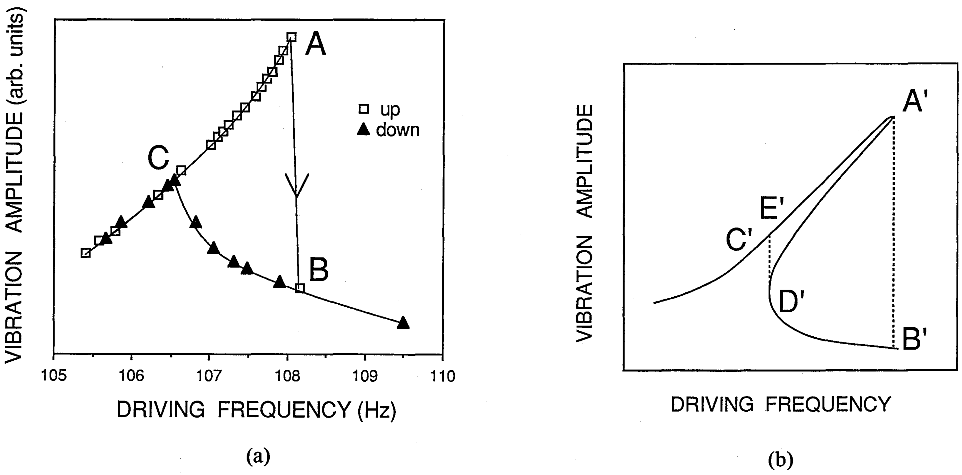

Fig. 3. (a) Resonance curve of an Fe-3%Si reed forced to vibrate highly. (b) Explanatory resonance curve for the curve of (a).

nonlinear behavior of this phenomenon, Wuttig and Suzuki,[3,4] Aning *et al.*,[5] and Suzuki and Wuttig[6] took phase transformation of metals into consideration. The resonance curves observed in the present study are not only "asymmetric" but "skewed". It should again be emphasized that, when the driving force increased to a certain level, the resonance frequency began to increase with the strength of force applied. We consider that this resonance behavior should be ascribed to some nonlinear mechanism inherent to Fe–3%Si. The mechanism is now under study.

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