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Scattering of acoustic wedge modes

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Waves propagating along the edges of solid elastic wedges, i.e., acoustic wedge modes, 1,2, have been investigated on a large scale in recent years, both theoretically and experimentally (see, e.g., Refs. 3-9). This is due in large part to their remarkable properties, such as the strong concentration of energy near the edge, freedom from dispersion and diffraction losses, and in some cases a relatively low phase velocity. All this makes these waves very alluring for various applications, primarily in signal-processing devices.

All the existing papers on wedge modes have been devoted entirely to aspects of their propagation, possibly because of the structural complexity of these waves, which are tractable only by numerical methods for the most part. To the best of our knowledge, on the other hand, the scattering problem for wedge modes has been completely ignored to date. However, the need to investigate the corresponding problems does not leave any doubt. Such an investigation is necessary, first of all, in order to determine the influence of various inhomogeneities on the propagation of wedge modes in real structures and their mutual conversion into other wave modes in a solid and, second, in order to analyze the possibilities of using the laws governing the scattering of wedge modes in the design of new acoustoelectronic devices analogous to, e.g., surface-wave devices with reflective gratings. 4 We now report the first results of experiments on the scattering of wedge modes.

The investigated sample was an aluminum prism of height 180 mm with a base in the form of a right isosceles triangle with 80 mm sides (see Fig. 1). Wedge-mode pulses with a duration of 4 μs and a center frequency of 2.1 MHz were excited along the right-angle edge by means of a transversely poled piezoceramic wafer of dimensions 9 × 6 mm², which was bonded acoustically to the end of the wedge through the Plexiglas spacer 1. As in Ref. 9, both antisymmetric and symmetric modes were excited; their velocities are close to the Rayleigh wave velocity in aluminum in the investigated case of a right-angle wedge. For generation of the antisymmetric mode the piezoelectric wafer was oriented with the direction of its vibrations perpendicular to the bisector of the right angle. 5 The symmetric mode was excited by the same wafer rotated through 90°. The center frequency of the wafer was 6 MHz, i.e., the radiator operated away from resonance. A standard SAW wedge transducer containing a longitudinally vibrating piezoceramic wafer of diameter 10 mm and resonance frequency 2.1 MHz was mounted on one face in order to record both the symmetric and the antisymmetric modes. The same transducer was used to record Rayleigh waves.

Preliminary measurements of the wedge mode attenuation showed that the antisymmetric mode scarcely changes with distance traveled, whereas the symmetric mode is characterized by a large attenuation coefficient (≈1.5 dB/cm), i.e., it is clearly a leaky wave. The scattering experiments were therefore conducted with the fundamental antisymmetric mode of the right-angle wedge.

FIG. 1. Investigated sample. 1) Wedge-mode generator; 2) end face of the wedge; 3) edge notch. The arrows indicate the incident and scattered waves schematically.
We first investigated scattering by the right-triangular end 2. The usual procedure (see, e.g., Ref. 10) was used to measure the moduli of the coefficients of reflection (R) and transmission (T) of wedge modes into like wedge modes on the two branching edges of right-angle wedges. The measurements showed that R = 0.5 ± 0.05 and T = 0.4 ± 0.05 (owing to the symmetry of the problem, T has the same value for both branching edges). We also determined the angular scattering diagrams for the scattering of wedge modes into Rayleigh waves $\tilde{u}(\alpha)$ on all three intersecting faces. The results of the measurements at distances of 40 mm from the intersection point are shown in Fig. 2a for: 1) the end face; 2) one of the side faces of the wedge. We note that the scattering diagram for the end face has a near-zero minimum at $\alpha = 45^\circ$ in accordance with symmetry requirements.

We next investigated scattering by a right-angle notch 3 with a nearly flat bottom, which was machine-cut in the middle of the edge (Fig. 1). The width of the notch was 0.5 mm, and its depth $h$ was varied from 0.2 to 2 mm in 0.1-0.15 mm steps. We measured the angular scattering diagrams for the scattering of wedge modes into surface waves $\tilde{u}(\beta)$ for each value of $h$, along with the moduli of the reflection coefficient R and the transmission coefficient T. Typical plots of $\tilde{u}(\beta)$ are shown in Fig. 2b (curves 3-5). The values of R and T as a function of $h/\lambda$, where $\lambda$ is the wavelength of the wedge mode ($\lambda = 0.132$ mm at 2.1 MHz), are shown in Fig. 3. Without discussing the data in detail, we merely note that R depends linearly on $h/\lambda$ for small values of $h/\lambda$, as in the scattering of Rayleigh waves. If we assume that the equation $R = 2C(h/\lambda)\sin(2\pi h/\lambda)$ (see Ref. 6) also holds in this case, we can determine the constant C from Fig. 3. The result $C = 0.72$ is of the same order of magnitude as the corresponding coefficient for Rayleigh waves in aluminum ($C = 0.31$). Thus, the scattering of wedge modes in the given situation is very similar to the scattering of Rayleigh waves, both qualitatively and quantitatively.

The authors are hopeful that the above-reported experimental results on the scattering of acoustic wedge modes will stimulate further research in this direction.

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