ARCHIVES OF ACOUSTICS
8, 1, 3-10 (1983)

TRANSMISSION AND REFLECTION OF A SURFACE WAVE AT A CORNER OF TWO PLANES ON AN ISOTROPIC BODY

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This paper reports on an experimental investigation of the diffraction of a Rayleigh wave at a corner of an isotropic solid bounded by two planes forming a dihedral angle with respect to each other.

Application of piezoelectric transducers and their appropriate setting on samples permitted the determination of the coefficient of reflection and transmission of Rayleigh waves at a corner and the directional characteristics of transverse waves, with polarisation in a plane perpendicular to the surface of R propagation, radiated at that time by the corner. The results were compared with the results of papers published in the world literature.

1. Introduction

The problem of reflection and transmission of Rayleigh waves at a corner of a dihedral angle is not easy to be solved theoretically even in the case of an isotropic body. Satisfaction of the complex boundary conditions requires the assumption of a reflected wave which passes onto the other plane and the conversion of part of the energy of a surface wave into that of a bulk wave propagating into the material. Several theoretical and experimental papers [1-4] were devoted to this problem.

In paper [4] HUDSON and KNOPOFF presented a theory of the transmission of a Rayleigh wave from one plane of the dihedral angle θ onto the other in the case of an isotropic body, making a number of simplifying assumptions. As a result of this theory they obtained relations permitting calculation of the coefficients of reflection and transmission of a surface wave as a function of the angle θ and the Poisson ratio σ (Fig. 1). They attempted to confirm the theoretical results experimentally [5]; the values of the coefficients differed greatly from those calculated theoretically. Their investigations were not precise enough, in view, it seems, of the shape of samples and the manner of generating and detecting surface waves. In paper [1] the authors took into account in acoustooptical measurements only surface waves, while bulk waves were accounted for as a complementation of energy balance. These methods did permit more detailed examination of the phenomenon of the transformation of surface waves into bulk ones.

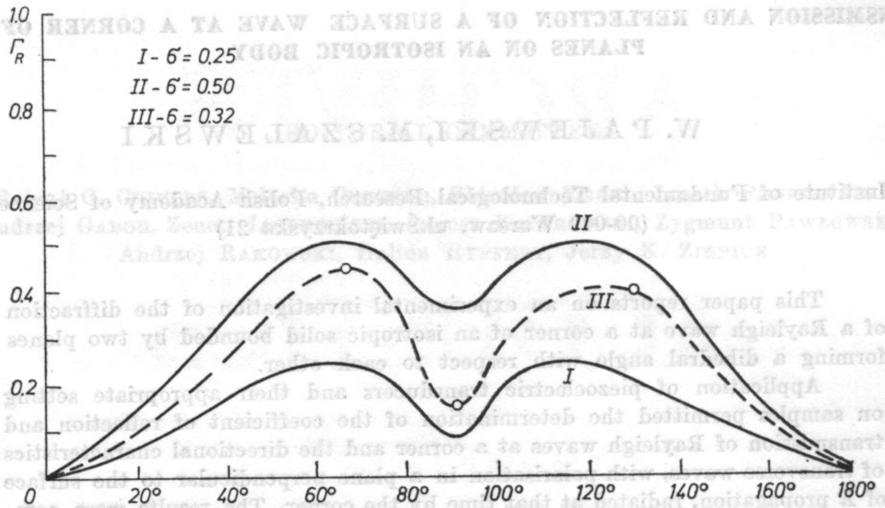

Fig. 1. The reflection coefficient of Rayleigh wave from the edge as a function of the Poisson ratio σ and the dihedral angle θ between the propagation planes [4]. Measurement points are marked on curve *III* $\sigma = 0.32$

In paper [3] Goruk and Stegeman investigated experimentally bulk waves arising at a corner after the passage of Rayleigh waves. Their method can only be used in the case of a transparent body; there are also additional difficulties in visualizing transverse components in optically little active crystals.

The method which permits the measurement of surface and bulk waves, both transverse and longitudinal near the corner, is the method which consists in using piezoelectric transducers with transverse or longitudinal vibration as sources of surface waves and as detectors of surface and bulk waves on samples with appropriate shape.

2. Investigation of the reflection of Rayleigh waves from the corner

The investigations used piezoelectric ceramic material which permitted experiments both with transverse surface waves and Rayleigh waves. The sample used in the investigations had the shape of cylinder sections, with the angle θ being 90, 125, and 65° (Fig. 2). The planes of the dihedral angle of each section were polished so as to obtain minimum attenuation of Rayleigh waves. The Rayleigh wave was excited by a piezoelectric transducer of transverse vibration polarised perpendicularly to the propagation plane. The transducer was set with hardenable resin at the corner of the plane and the cylindrical surface. Thus, the wave propagating along the surface was incident onto the edge of the dihedral angle and subsequently passed onto the other plane or, when reflected, returned to the transmitting transducer. In order to observe transverse waves generated at that time by the edge of the dihedral angle, identical transducers fixed with epoxy resin were set on the cylindrical surface of the section (Fig. 3). Signals detected by transducers were registered using

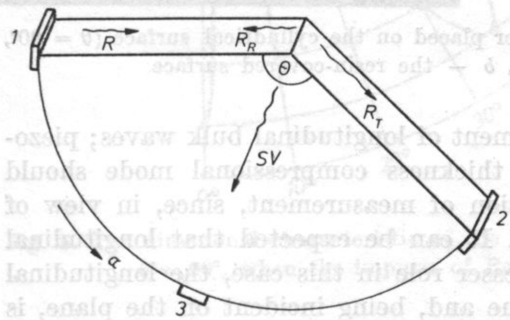

Fig. 2. The transmission of Rayleigh wave at a corner of the dihedral angle θ

1 – the transducer generating the Rayleigh wave and registering the reflected wave; *2-3* – the transducers registering the transmitted wave and the bulk wave SV, R – the incident wave, R_R – the reflected wave, R_T – the transmitted wave, SV – the transverse bulk wave

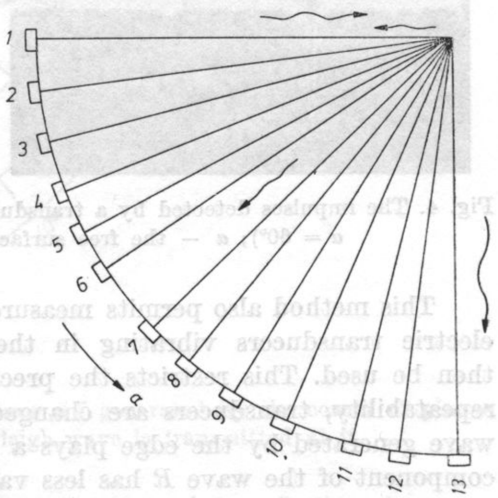

Fig. 3. The position of piezoelectric plate transducers (1-13) for generation and detection of waves in order to observe the phenomenon of the transmission of Rayleigh wave at a corner

an oscilloscope. In this case, the electric signal was proportional to the amplitude of an acoustic impulse. A whole series of oscillograms were thus obtained, on the basis of which it was possible to compare the amplitudes of the impulses of respective waves. It appeared to be quite easy to determine the paths of the impulses, taking into consideration their passage time and the velocity of surface or, alternatively, bulk waves. In the case when a surface wave converts in to a bulk one, part of the path of the impulse is the path over the surface from the transducer to the edge and part is the radius from the edge to the surface of the cylinder. Consideration of different paths and different velocities permits relatively easy identification of the impulses and determination of their amplitude (Fig. 4).

The investigations covered transmitted and reflected surface waves and a transverse bulk wave polarised in the plane perpendicular to the propagation surface.

a b

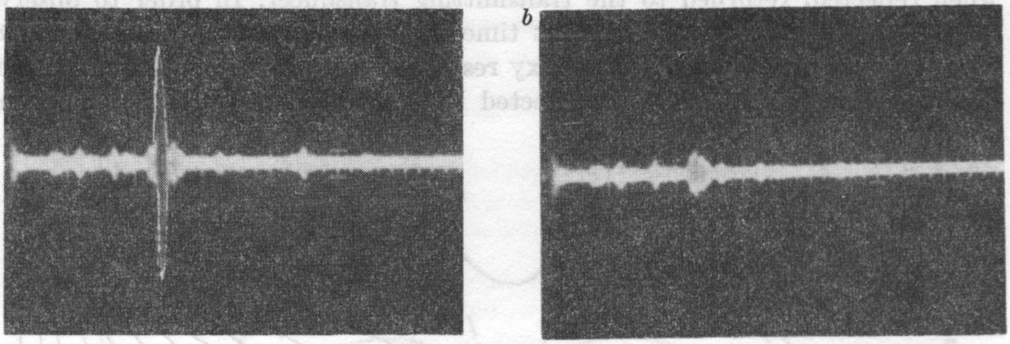

Fig. 4. The impulses detected by a transducer placed on the cylindrical surface ($\theta = 90°$, $a = 60°$); a – the free surface, b – the resin-covered surface

This method also permits measurement of longitudinal bulk waves; piezoelectric transducers vibrating in the thickness compressional mode should then be used. This restricts the precision of measurement, since, in view of repeatability, transducers are changed. It can be expected that longitudinal wave generated by the edge plays a lesser role in this case, the longitudinal component of the wave R has less value and, being incident on the plane, is probably reflected according to the geometrical law of reflection; and, therefore, it should be sought in the respective direction. In the case of the transverse component of displacement of the wave R the reflection conditions are more complicated and geometrical relations are not valid. This problem is not yet clear and requires investigation.

The directional characteristics of the propagation of the bulk wave SV inside the sample (Figs. 5-7) were obtained from measurements. It is interesting to note that in Fig. 5 there are two maxima close to the angles $a \cong 60°$ and $a \cong 30°$ (see Fig. 2), which is in agreement with the results of paper [3] obtained by an acoustooptical method. The results of the investigations were compared with the results in world literature which were obtained using optical methods [1, 3]. The latter results apply to a $LiNbO_3$ crystal with Y-cut and propagation direction z, and to a quartz crystal with X-cut and propagation direction z. In the case of an isotropic body, the results of the reflection of the wave R were obtained by modelling the behaviour of the wave using a computer [2].

The piezoelectric ceramic material can be regarded as an isotropic body, since it was polarised parallel to the propagation surface. It can be seen from

Tables 1 and 2 that the results obtained are quite significantly different from those published in the papers mentioned above. They agree, however, with the results represented by the curve $\sigma = 0.32$ in Fig. 1 (*III*).

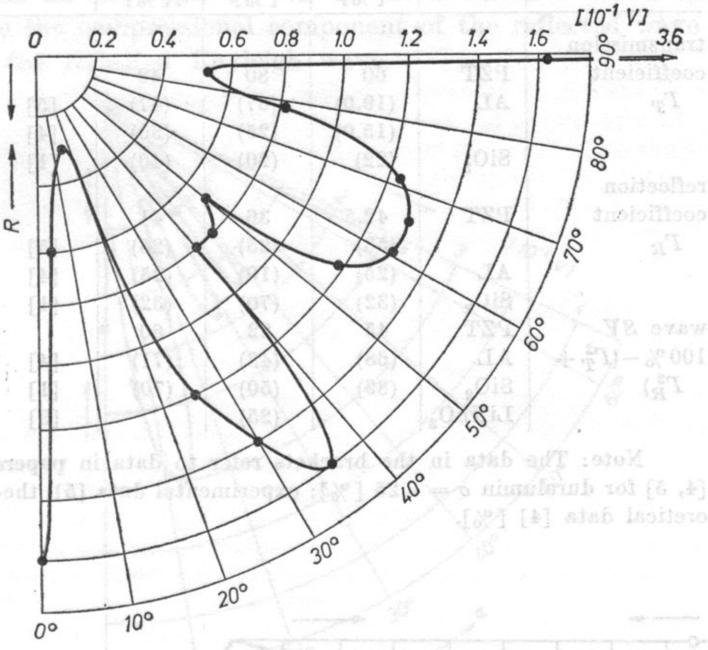

Fig. 5. The directional characteristic of the wave *SV* generated by the corner of planes $\theta = 90°$, when the impulse of Rayleigh wave is transmitted at it

Table 1. Comparison of the results of measurements of the reflection of Rayleigh wave from the corner of a quarter – space ($\theta = 90°$) (power coefficient)

Material kind	Reflected wave [%]	Transmitted surface wave [%]	Bulk wave (*SV*) [%]	Paper
SiO_2 ($y \to x$)	30	50	20	[1]
$LiNbO_3$ ($y \to z$)	23	39	25	[3]
isotropic body	13	41	46	[2]
PZT (isotropic)	13	65	22	

Table 2 confirms the presence of a minimum reflection for the angle $\theta = 90°$ and of maxima corresponding to the angles $\theta = 65°$ and $\theta = 125°$.

These results were obtained applying the conservation rule of energy for the impulses of the waves whose origin is at the corner. However, the energy of longitudinal wave was omitted. A component of this type can readily be found using acoustooptic methods. A closer analysis of the characteristics

Table 2. Comparison of the reflection coefficients of Rayleigh waves from the edge of the angle θ in the case of piezoelectric ceramic material ($\sigma = 0.32$) and other materials

Angle θ		65° [%]	90° [%]	125° [%]	Paper
transmission coefficient Γ_T	PZT	60	80	48	
	AL	(19.0)	(67)	(47)	[5]
		(15.0)	(25)	(50)	[4]
	SiO_2	(22)	(20)	(40)	[1]
reflection coefficient Γ_R	PZT	42.5	36	41	
		(53)	(25)	(26)	[5]
	AL	(25)	(10)	(25)	[4]
	SiO_2	(32)	(70)	(32)	[1]
wave SV $100\% - (\Gamma_T^2 + \Gamma_R^2)$	PZT	45	22	60	
	AL	(68)	(48)	(71)	[4]
	SiO_2	(89)	(50)	(70)	[1]
	$LiNbO_3$		(25)		[3]

Note: The data in the brackets refer to data in papers [4, 5] for duralumin $\sigma = 0.25$ [%]: experimental data [5], theoretical data [4] [%].

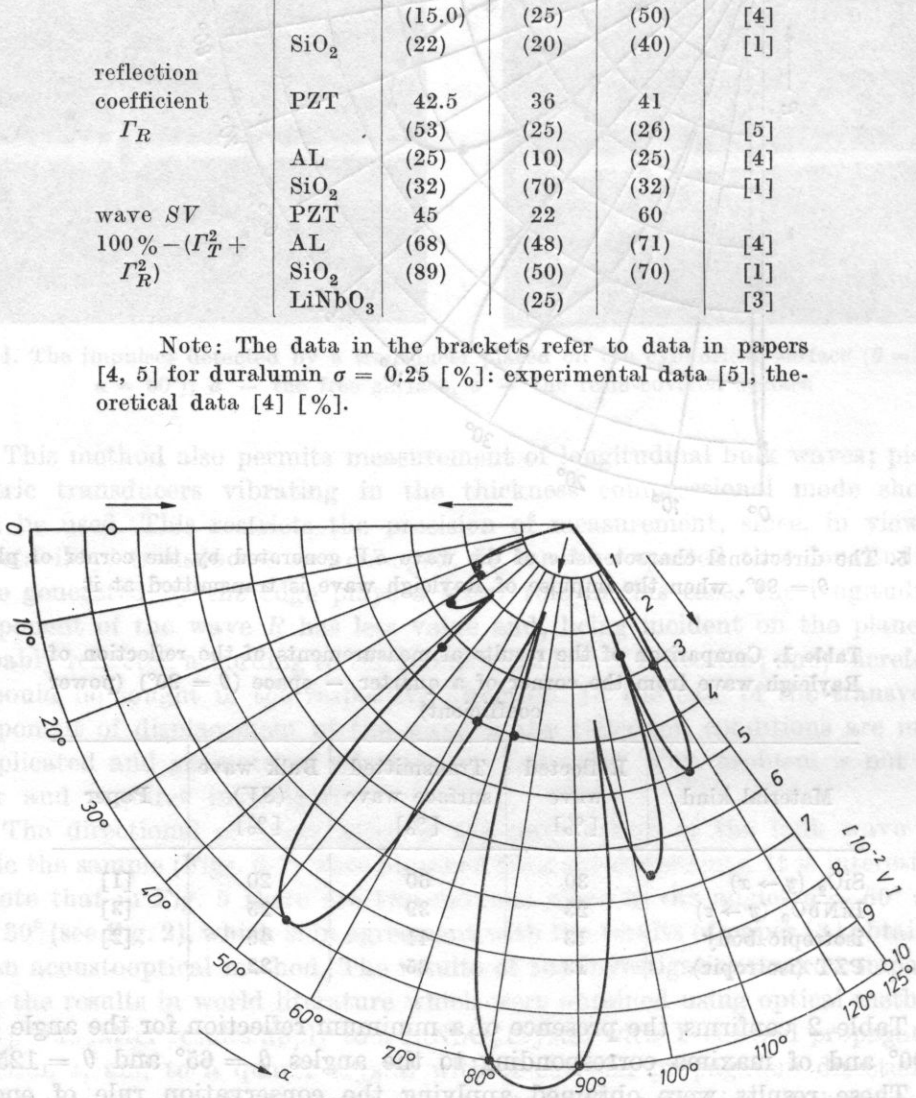

Fig. 6. The directional characteristic of the transverse wave SV for the transmission of Rayleigh wave at the corner $\theta = 125°$

of wave radiation from the edge (Figs. 5-7) and the existing lobes indicates that minima of the amplitude of a transverse bulk wave can be observed in the directions where a reflected longitudinal wave might occur. E.g. for the angle $\theta = 125°$ the lobe of the longitudinal wave should be in the direction $\alpha = 70°$, while for the angle $\theta = 65°$ in the direction $\alpha = 55°$. In the case of a right angle the compressional component of the reflected wave is probably included in the reflected Rayleigh wave.

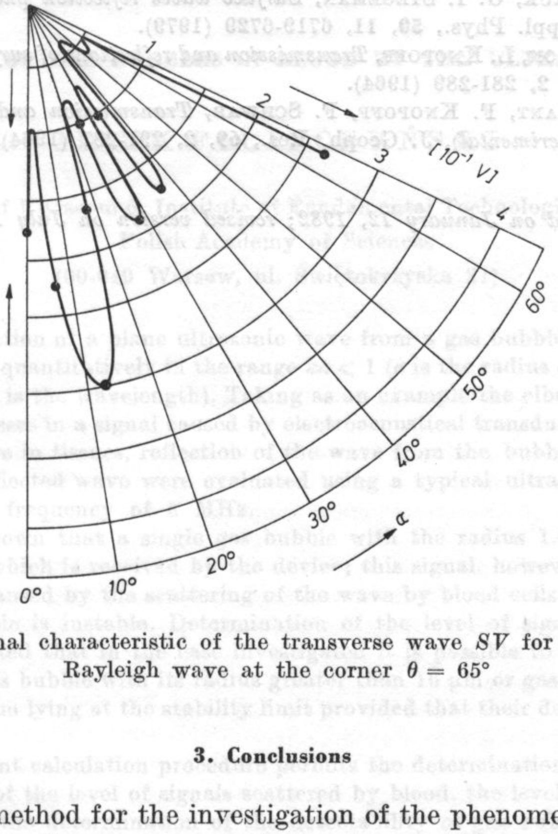

Fig. 7. The directional characteristic of the transverse wave SV for the transmission of Rayleigh wave at the corner $\theta = 65°$

3. Conclusions

The present method for the investigation of the phenomenon of the reflection of waves from the corner gives interesting results and can complement other methods, e.g. optical ones, where these cannot be used. Moreover, it can facilitate the solution of the theoretically difficult problem of the reflection of Rayleigh wave from plane edges, since it permits the determination of the contribution of respective waves to the phenomenon and indicates therefore the possibility of their being neglected in calculation. Finally, the results obtained here contribute to a better understanding of the phenomena involved.

The results obtained also indicate the possibility of using acoustoelectric waves in the construction of piezoelectric resonators – the more convenient reflection of waves can permit greater quality to be obtained in the resonators, without the use of complex reflecting structures.

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Received on January 12, 1982; revised version on July 1, 1982.