INFLUENCE OF SOLID ELASTIC PROPERTIES ON THE SCATTERING OF

A RAYLEIGH WAVE BY NORMAL DISCONTINUITIES.

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Abstract

A numerical study of the scattering of a surface acoustic wave on edges is presented. New results, concerning the influence of the elastic properties of substrate are given, and they are in good agreement with experiments.

INTRODUCTION.

The study of the Rayleigh wave scattering by normal discontinuities, such as 90° and 270° edges limiting the propagation surface, in an isotropic solid, is a fundamental one, because these types of discontinuities can be regarded as elementary ones.

Indeed, in order to perform surface acoustic wave devices, it is necessary to know the effects of the substrate boundaries.Besides, the knowledge of Rayleigh wave scattering by these elementary discontinuities might allow to imagine more complicated obstacles, made with a linkage of elementary discontinuities, as step, ridge, slot, or chain of steps, ridges, slots, having special properties, such as maximal reflection of surface waves, selective reflection, and so on.The scattering of surface waves by dicontinuities has been studied with some approximations by several authors, [1 2 3] however, as far as we know, no complete analytical solutions has been proposed. We propose here a numerical study of Rayleigh wave scattering by 90° and 270° edges.

NUMERICAL STUDY.

The numerical method used for this study is a finite difference one, with iterations over the time. Such a method has been already successfully used by ALTERMAN and LOEWENTHAL [3] and by MUNASINGHE and FARNELL [4] However, their method used pulses of very particular shapes and durations, with, as consequence, a difficulty to separate the bulk scattered wave components to the surface wave ones, and another difficulty is to obtain experimental results with such a shape of pulses.

In the present work, we have applied the finite difference method to simulate the propagation of a straight crested semi-infinite Rayleigh wave, whose initial particle motions are exactly computed from their known analytical expressions. The interest of using a semi-infinite Rayleigh wave rather than a pulse is double. First, it is numerically possible to determine with a better precision the complex reflection and transmission coefficients, taking into account of the contribution of the bulk scattered wave near the surface. Second, experimentally, a semi-infinite Rayleigh wave being easier to generate than particular pulses, it is possible to obtain experimental confirmations.

Let us consider an isotropic solid bounded by two semi-infinite planes P_1 and P_3 (Fig. 1) in order to shape a 90° edge, or P'_1 and P'_3 (Fig.2) in order to shape a 270° edge. Along the third direction, this solid is unbounded. Along a line source AD or A'D', the numerical values of particle displacement, corresponding to a Rayleigh wave are assigned at positive times. By iterations over the time, the propogation of a semi-infinite Rayleigh wave, is simulated over the surface AB (90° edge) or A'B' (270° edge).

When the stability conditions given by ALTERMAN and LOEWENTHAL [3] are satisfied , the wave propagates along the horizontal surfaces without modification.

After several iterations, the wavefront reaches the edge B or B', where particular boundary conditions are assigned, and iterating again, it is possible to know the behavior of the wave on the edge B, or on the edge B' : A Rayleigh wave is reflected on the incident surface (AB or A'B'), a Rayleigh wave is transmitted on the vertical surface (BC or B'C') and a bulk wave is scattered inside the solid. The simulation is stopped just before the wavefronts of scattered waves reach the limits of the domain. Thus we get the evolution of mechanical displacements with respect to the time.

NUMERICAL RESULTS.

This computation has been carried out for each type of edge, and for a wide range of materials, of which Poisson's ratios values are included between 0.123 and 0,42. The characteristics of scattered waves are determined from the map of displacement amplitudes which gives the interference pattern of all presents modes of propagation. These characteristics depend on elastic properties of the substrate.

The figure 3 shows the reflection and transmission coefficients, expressed in terms of the Poisson's ratio σ of the substrate. These coefficients are more important for the 90° edge than for the 270° one.

The phase ϕ of reflected and transmitted waves are shown in figure 4, as functions of σ .

The figure 5 shows the bulk wave conversion factors. When considering 90° edge, the volumic losses decrease when σ increases. This fact may be related to the surface wave penetration depth. Indeed, the more the penetration depth increase, the more volumic losses decrease. A quite good explanation is certainly to consider the edge neighbourhood as a source, radiating bulk waves as more as the energy is concentrated in a shortest domain. Besides, near the surface, these bulk waves are essentially compressional ones.

EXPERIMENTAL STUDY.

In order to verify some of these numerical results, we have done some experimental measurements of the reflection coefficient of a Rayleigh wave for various materials, with an interferometric probe (Fig. 6).

The measurements were allowed with a quite good level over the noise by introducing in the measurement system, a superheterodyne receiver. That receiver was tuned at the high frequency of the surface wave, and the signal used to produce this surface wave was triggered at a low frequency rate.

The interferometric probe is a Michelson interferometer, in which the substrate takes the place of one of the two minors.

The light signal is received by a photodetector. The output of the photodetector is sent to a two ways filter. The variations of lighting, due to the surface wave, are amplified by the superheterodyne receiver, which gives a signal s related to the amplitude of the normal displacement. Besides, it appears on the second way of the filter a signal S related to the mean lighting. Signals S and s are sent to a xy plotter, and by modifying slowly the order of interference, it is easy to determine the values of S and s corresponding to the maximum of sensibility. This maximum of sensibility occurs when the mean order of interference is $(n+\frac{1}{4})$, where n is an interger. The amplitude of normal displacement at any point of the surface is obtained from the corresponding values of S and s.

The reflection coefficient measurements done with this probe are shown in figure 3. They are in a good agreement with numerical computed values.

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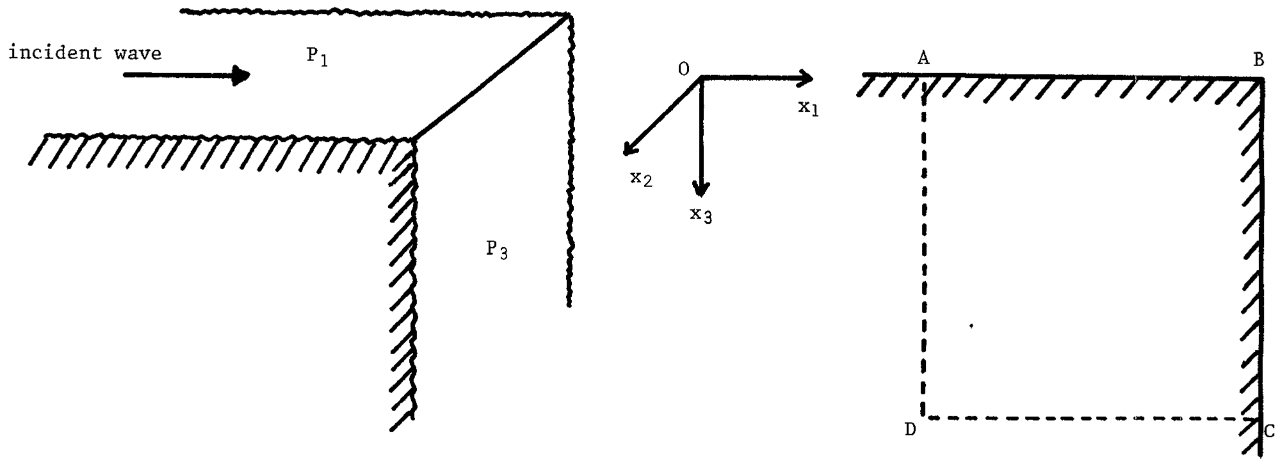


Figure 1 : 90° edge.

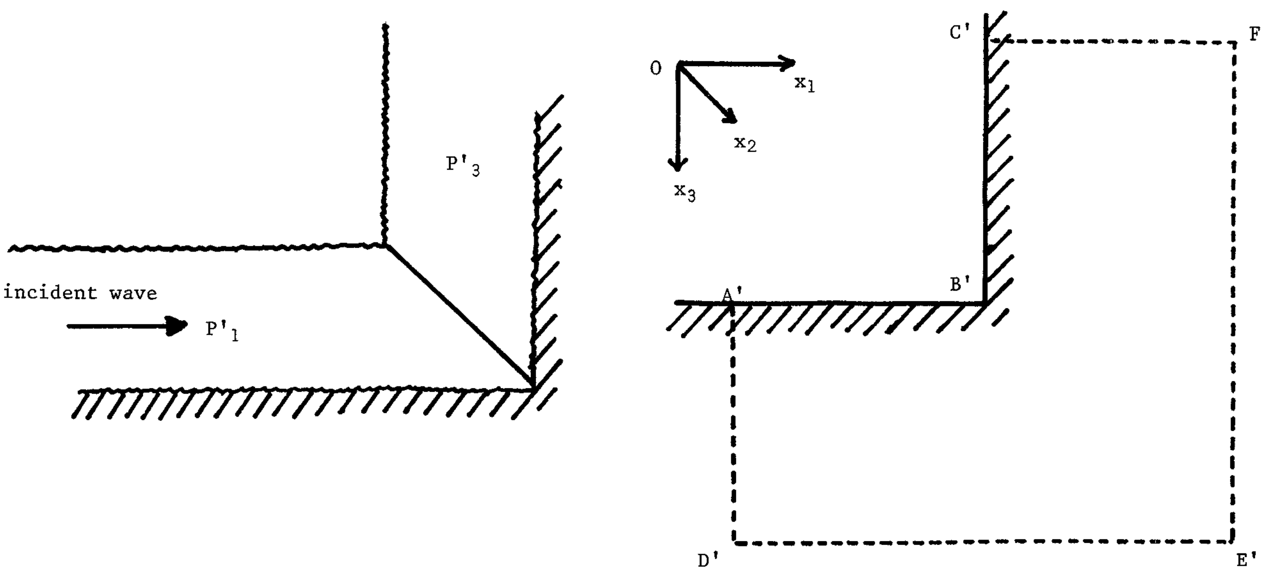
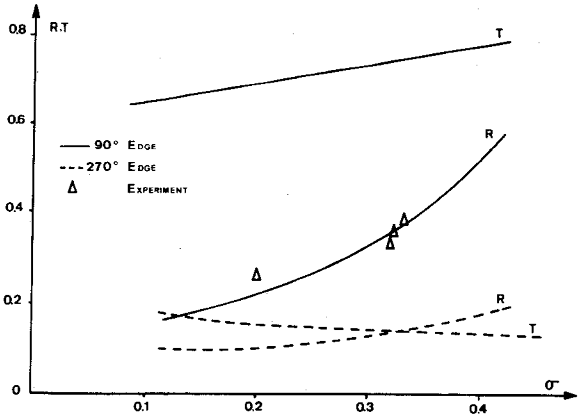
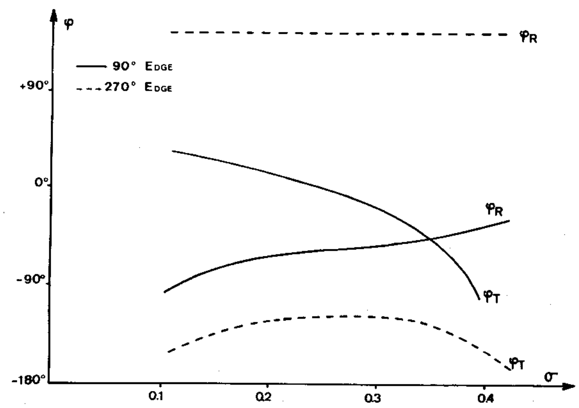


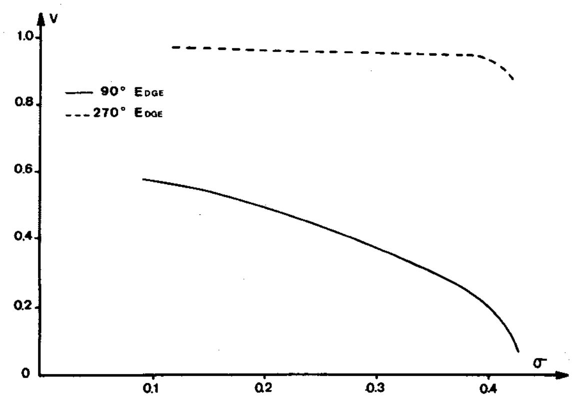
Figure 2 : 270° edge.



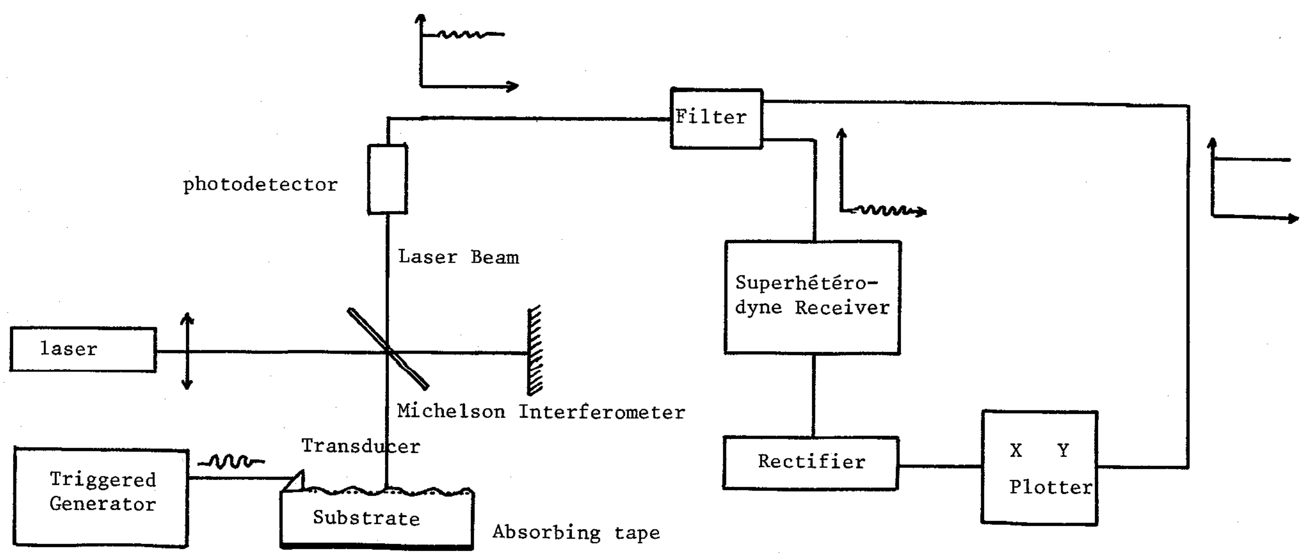
<u>Figure 3</u> : Reflection and transmission cœfficients of Rayleigh wave in terms of Poisson's ratio σ.



<u>Figure 4</u> : Phases of reflected and transmitted waves in terms of Poisson's ratio σ.



<u>Figure 5</u> : Bulk wave conversion factor V, in terms of Poisson's ratio σ.



<u>Figure 6</u> : The interferometric probe.