INTRODUCTION

Surface acoustic waves propagating at the interface between two solids are very important for Non Destructive Evaluation of layered media [1]. Dispersion features and transmission losses of such waves strongly depend upon the elastic constants of the solids as well as the mechanical boundary conditions at the interface between the solids. One particular kind of interface waves is the Stoneley wave, which can exist at the interface between certain specifically combined elastic half-spaces in rigid contact [2]. The acoustic field of this wave, travelling with no loss along the interface, decays away from the interface in each medium (Fig. 1a). Murty studied interface waves in another extreme case, i.e. slip contact [3]. For such type of contact, only the normal stress and displacement components are continuous but shear stresses are cancelled at the interface. In the slip contact case, Murty's study revealed also that the conditions of existence of the Stoneley-like wave are much less rigorous. When material combinations and/or boundary conditions are not satisfied to support the Stoneley-like wave, interface waves may become lossy [3] and radiate acoustic energy through mode conversion into bulk waves (Fig. 1b), like the case of the leaky Rayleigh wave propagating at a solid-liquid interface. Besides, if the presence of a coupling layer between the two half-spaces is taken into account as in most practical conditions, the features of interface waves depends also on the viscoelastic parameters and thickness of the coupling layer[4,5]. Up till now, most of
the investigations involving interface waves are indirect ones using ultrasonic reflection and transmission measurements [6], and some others are related to dispersion measurements using interdigital or wedge transducers [4,5]. Few experiments were reported illustrating the field distribution of interface waves. Claus and Palmer observed the Stoneley wave [7] using an optical interferometer. The wave displacements were only detected by the probe beam focused at the Nickel-Pyrex interface.

We describe in the present paper another optical detection method that not only permits velocity and attenuation measurements but also gives access to the field distribution of interface acoustic waves strains provided the solids are optically transparent. This optical method, combining interferometry with photoelastic interaction, was previously used to measure bulk, Rayleigh and Lamb waves [8-10]. In this work, the interface waves are investigated at the following interfaces: Silica/Silica, Silica/Tungsten, and Silica/Plexiglas. Two limiting boundary conditions corresponding to a slip contact and a rigid bond are basically investigated. The effects of the coupling layer upon interface waves is being also studied.

PRINCIPLE OF OPTICAL DETECTION

Fig. 2 shows schematically the arrangement used to study interface waves. A water wedge transducer is used to generate a Rayleigh wave upon one substrate. When the Rayleigh wave reaches the interface between the two substrates, one part of the incident wave power is converted into interface waves. As shown in Fig. 2, the laser beam crosses normally the acoustic beam inside the transparent solid. Because of the photoelastic effect, the laser beam undergoes an additional phase shift caused by ultrasonic waves. According to a detailed analysis, this optical phase shift induced by guided waves can be related to the acoustic strains by [10]:

![Figure 1 Representation of Stoneley-like wave (a) and leaky interface wave (b) propagating along the interface between two solids.](image)
Here \( \omega, c \) are respectively the angular frequency and the speed of the light, \( L \) is the acoustic beam width, \( \Delta n \) is the mean index of refraction variation, \( n \) is the initial index and \( p_{ij} \) are the photoelastic coefficients. As shown, the induced optical phase shift \( \Delta \Phi \) is proportional to the sum of acoustic strains \( \Delta = S_{xx} + S_{zz} \), that is, the dilatation, or relative change in material volume of the solid. With the help of an heterodyne interferometer, this phase shift is demodulated and calibrated at the output [8, 11], giving the value of the dilatation associated with guided interface waves propagation. By moving the probe beam along the X and Z axes, respectively, the velocity, attenuation and dilatation field of the interface waves can be measured.

In this work, three different material combinations forming the interface waveguide are investigated: Silica/Silica, Silica/Tungsten, Silica/Plexiglass. The slip contact at the interface is realized with a very thin layer of water between the two optically polished substrates. To approach rigid contact condition, the two substrates are bonded by a glue film with a thickness far smaller than the ultrasonic wavelength. Broadband pulses as well as tone bursts are used to generate the Rayleigh wave. The signal received from the probe is sampled and averaged by a digital oscilloscope and then recorded and plotted.

RESULTS AND DISCUSSION

For each combination of materials, the present optical method allows us to measure the wave velocity and the attenuation along the propagation direction, and also to explore the dilatation field distribution in the solids if they are transparent. The first experiment was performed with the Silica/Silica combination which supports theoretically...
a Stoneley wave for the slip contact conditions. The fact that the two solids are transparent allows us to explore the dilatation field on each side of the interface. Figure 3 shows the typical time signals measured on both sides. The measured value of the wave velocity is 3400 m/s, equal, within experimental errors, to that of the Rayleigh wave in Silica predicted by the theory for two identical half-spaces [3]. The two dilatation signals with \( \pi \)-phase shift have the same amplitude because we have identical materials on both sides. This \( \pi \)-phase shift is due to the flexural characteristic of the boundary motion. Figure 4 shows the dilatation field distribution of the Stoneley-like wave measured at different depths from the interface in each solid. This experimental result is in good agreement with the calculated decays of dilatation fields for the Stoneley wave (continuous lines). In the case of the rigid contact, the two identical solids become mechanically a single one and no interface wave can exist. This has been confirmed by measurements using rigidly bonded Silica/Silica interface, in which only a shear bulk wave was detected.

The same investigations were done for the Tungsten/Silica combination. An interface wave, propagating along the interface without measurable loss, is detected for the two boundary conditions. The velocity of the interface wave is 2730 m/s for slip conditions and 2860 m/s for the bonded conditions. These measured velocities are in good agreement with the velocities calculated by Murty [3]. This combination represents the case where a Stoneley wave exists for both slip and bonded conditions.

Silica/Plexiglass corresponds to a material combination that is theoretically unable to support a lossless Stoneley-like wave whatever the boundary conditions are at the interface [3]. Fig. 5 shows dilatation fields of the corresponding interface wave obtained in each medium. Inside Silica, an exponential decay is measured but in Plexiglas little decay is seen. This field distribution looks like that of the Rayleigh wave propagating at the fluid-solid interface: a leaky Rayleigh wave in Silica with a bulk wave radiated in Plexiglas.

When the coupling material becomes viscous and acoustically thick, the properties of interface waves become much more complicated [4-6]. In this experiment, we present only attenuation measurements. A coupling film used for shear transducers is inserted at the Silica/Tungsten interface. Two thicknesses of the coupling film approximately equal to 60 \( \mu \)m and 200 \( \mu \)m are used. The interface wave propagates along the interface with an attenuation due to the presence of the viscous film. The attenuation of these waves is obtained using a spectral analysis method [12]. Figure 6 presents the measured attenuation versus frequency for different coupling thickness. It is seen that the attenuation is higher when the layer of viscous coupling is thicker. The comparison of these preliminary results with theoretical models is in progress.
Figure 3  Dilatation waveforms of the interface wave propagating at the slip interface between two Silica half-spaces measured on both sides of the interface.

Figure 4  Measured dilatation amplitude of an interface wave propagating along the slip interface between two Silica half-spaces. Continuous lines represent the theoretical decays.
Figure 5  Dilatation field distribution of the leaky interface wave propagating at the slip boundary between Plexiglass and Silica.

Figure 6  Measured attenuation of the interface wave propagating at the interface between Silica and Tugsten. The coupling is achieved by a film of viscous coupling of thickness 60 μm and 200 μm
CONCLUSION

An interferometric detection method for acoustic dilatation measurement inside transparent solids has been applied to study the propagation of interface acoustic waves. In addition to velocity and attenuation measurements, the present interferometric method allows us to identify the confined or leaky natures of acoustic waves guided by the interface with slip or rigid contact. The attenuation of interface wave caused by the presence of a coupling viscous film between the solids has been also investigated.

REFERENCES