The video to this article can be seen here: www.ndt.net/search/docs.php3?id=14584&content=1

Keywords: Photoelastic visualisation, ultrasonic

1. Introduction

This technical note is Part 10 of a series in NDT.net. Description of the associated video is provided in this technical note and remarks are made on some of the features seen. In Part 10 we examine the effects of changing the incident angle of an immersion probe from normal incidence to the second critical angle.

This demonstration is made with a standard immersion-style probe. The probe was 12mm (half inch) diameter 5MHz and equipped with a waterproof UHF connector. The probe was mounted in a manipulator that allowed angulation of the beam in the X and Y planes.

Pulsing of the probe was provided using the USBox (by Lecoeur) with the pulser tuned to provide the optimum output at 2 cycles 255V and pulse-duration tuned to 5MHz.

Figure 1 illustrates the mechanics of the probe motion and the associated wave modes resulting from the changing incident angles. As we have seen in previous parts of this series, the shear mode is not totally absent when the incident angle is 0°. This is due to the spherical divergence of the beam that results in noticeable curvature, especially at the edges of the probe.

Figure 1 Wave modes with varying incident angle (near first critical angle on right)
2. Comments on the Video

The video is in two parts. Part one of the video illustrates the changes due to angulation whilst part two illustrates the effect of the pulse incident at the second critical angle.

In the first part, the pulse is delayed with the incident beam perpendicular to the glass surface. The compression mode in the glass occurs just off the illuminated area to the right side of the screen. With the strobe-light delay fixed, the probe angulator is adjusted to increase the incident angle and the weak compression mode that occurs just off the visible view at about 33mm from the entry surface, begins to move into view. The transverse mode is seen at a depth of 20mm and its strength (relative brightness) increases with increasing angle of incidence.

Using the values of 1500m/s for the velocity in water and compression and transverse velocities in glass at 5800m/s and 3460m/s respectively, we can use Snell’s Law to calculate the refracted angles.

At 10.1° incidence the refracted L-mode should be about 42° and there should be a refracted shear mode present as well. The shear mode nominal refracted angle will be 23.6°. In Figure 2 the IIA (Image Intensity Analysis) software confirms the angles as 42° and 23.7°.

As the incident angle increases, the headwave that connects the bulk transverse wave to the compression wave, can be seen forming (see Figure 3). This occurs due to a portion of the compression mode making glancing incidence along the glass-water interface.
Figure 3  A clearly-formed headwave is seen connecting the transverse and compression waves at the glass-water interface.

Although Snell’s Law indicates that there is a specific incident angle at which the compression wave disappears (the First Critical angle), we can see that due to the spherical shape of the wavefront, this effect is not a sudden event. In Figure 4 the incident angle is seen to be 16° and there is still a compression mode present in the glass; this in spite of the fact that the calculated first critical angle for these conditions is 14.99°. Also visible in Figure 4 is a faint dark line in the water between the probe and glass. This is the reflected compression mode in the water.
When the incident angle has reached 21° there is no longer any evidence of a compression mode in the glass and the refracted transverse wave is at 55.8°, as seen in Figure 5. There we also see the reflected compression mode in the water.

![Figure 5](image)

Figure 5 21° incident angle resulting in 55.8° transverse mode and no compression mode in the glass

Part one of the video ends just as the transverse mode approaches the angle where the refracted wavefront is making a glancing incidence along the glass to water interface. This is the second critical angle as seen in Figure 6. The calculated Second Critical angle for these conditions is 25.69° and the image in Figure 6 is taken at 25.1° incident angle.

![Figure 6](image)

Figure 6 Refracted transverse mode at 25.1° incident angle
Part two of the video uses the strobe-light delay to advance the pulse at the second critical angle. As the pulse advances we can see a slight lag in the wavefront at the glass to water interface (Figure 7). The actual incident angle, 26.6°, is slightly greater than the second critical angle. When the refracted angle of the transverse wave reaches 90° the conditions are set for the generation of the Rayleigh wave which has a slightly slower velocity than the transverse wave.

Figure 7  Formation of Rayleigh wave

The video to this article can be seen here

www.ndt.net/search/docs.php3?id=14584&content=1

For more information about the photoelastic system see www.eclipsescientific.com.