Photoelastic Visualisation of Ultrasonic Pulse Interactions
Part 3: SV shear mode interacting on a side drilled hole in a solid

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Keywords: Photoelastic visualisation, ultrasonic
The video to this article can be seen here www.ndt.net/search/docs.php3?id=13777&content=1

1. Introduction

This technical note is Part 3 of a series started in NDT.net. A photoelastic video has been made of an ultrasonic pulse interacting at a boundary. Description of the associated video is provided in this technical note and remarks are made on some of the features seen. In Part 3 we consider the photoelastic visualised pulse from a vertically polarised (SV) shear wave striking a side drilled hole. A similar image was provided using the initial photoelastic system assembled by the author for an earlier document on NDT.net (1).

The SV shear mode is also called the transverse mode. This is the version we get when a compression wave hits a boundary at an angle other than perpendicular incidence. It is the most commonly used mode for NDT weld inspection.

The photoelastic demonstration uses a 12mm diameter 5MHz compression mode probe (made by Xactex) mounted on a refracting wedge made of cross-linked polystyrene. The incident angle of the wedge is configured to produce a shear mode in steel at 45°. This probe was driven using a PCPR100 pulser, tuned at 5MHz with 250V and a 2 cycle square-wave tone-burst. The probe was coupled to a glass sample (soda-lime float glass) using a suitable standard coupling gel (Sonotech SH1001). The photoelastic imaging system was configured to provide an optimised image of the pulse. The illumination strobe delay was then adjusted to observe the pulse move from a point 10mm prior to a side drilled hole to a point approximately 15mm after passing the far side of the side drilled hole (SDH).

The probe placement and approximate pulse start location is indicated in Figure 1.
The block is 65mm high, 19mm thick and 115mm long. The SDH is 5mm diameter and located with its centre at 50mm from the surface the probe is placed on.

2. Comments on the Video
The video starts with the leading edge of the main pulse approximately 10mm from the SDH. A ruled scale has been overlaid in the video to assess dimensions.

Contrast has been added to the original AVI format to allow better visualisation of the fainter pulses. This results in a slightly red-grey background with some granularity. The background is relatively uniform with the exception of the brighter (red) region at the bottom of the glass block. This is a result of pressure from the surface where it is mounted producing a small region of stress that alters the uniformity of the transmitted polarised light. Similar non-uniform regions were seen on previous videos around the corners of notches where residual stresses remain in the glass.

The main phase on the leading edge of the pulse is indicated by a bright red line. Upon interaction with the SDH we see a reversal of phase. Along the same path as the incidence is a dark band leading the arc. Either side of the reflecting shear mode arc we can see a fainter arc. This is the mode converted compression wave. It is seen to have a greater wavelength than the shear mode and its velocity is obviously faster than the shear as it soon separates from the reflecting shear mode arc. The initial evidence of the interaction is illustrated in Figure 2.

As the incident shear mode passes the mid-point of the SDH, several features become apparent. The compression mode is now well separated from the reflected shear. There is an intensity pattern seen in both the reflected shear and compression modes and these patterns are reversed. In a line moving directly back from the incident centre of beam angle, the shear mode is seen to have its maximum intensity over a range of about 15° either side of the incident angle. The intensity of the compression mode is at its minimum on the reflected
centre axis, but its intensity rises to a maximum at approximately 45° either side of the reflection centre axis. This is seen illustrated in Figure 3.

![Figure 3](image)

**Figure 3** Interactions as shear mode moves past the mid-point of the SDH

At a glancing incidence the shear mode satisfies the requirement for the second critical angle and a Rayleigh wave can form. This has the effect of “holding” the wave pulse to the curved surface as the incident shear mode moves past. In addition, there is also a diffraction effect, bending the pulse around the obstruction. This results in a connecting wave front between the incident shear and the Rayleigh wave as it moves around the circumference. The linked wave front can be considered a form of "head wave" and it has the appearance of a spiral. In fact, this spiral head wave can often be seen by operators calibrating an instrument drawing a distance amplitude correction curve. With sufficient gain, the operator will see one or two multiples of the pulse immediately after the peaked direct reflected responses from the SDH.

Figure 4 illustrates the spiral shape as the two Rayleigh waves cross near the initial incident point and the arcs are seen to connect to the incident shear wave pulse. Fainter straight lines can be seen entering the region. These are due to reflections from the shear and compression modes off the edges of the block.
In a paper by Gruber (2), he described an equation that accounted for part of the path in Rayleigh mode and part in shear. The observed time difference between the reflected shear signal and the first arriving multiple was given as

$$\Delta_0 = \left( \frac{\pi}{2\theta} + \frac{1}{c} \right) d_0$$

Where:

- $\Delta_0$ is the time difference between the reflected shear and the first multiple following
- $\pi$ is the constant (3.1159)
- $\theta$ is the Rayleigh velocity
- $c$ is the shear velocity
- $d_0$ is the diameter of the SDH

When we estimate the Rayleigh wave as 90% of the shear velocity ($V_s=3460$ m/s) we can estimate the diameter of the SDH using the delta arrival time (4.0µs as seen on the A-scan used in the setup). This indicates a 5.1mm diameter (within 2% of the measured).

For more information about the photoelastic system see [www.eclipsescientific.com](http://www.eclipsescientific.com).

The video to this article can be seen here [www.ndt.net/search/docs.php3?id=13777&content=1](http://www.ndt.net/search/docs.php3?id=13777&content=1)

**References**

1. E. Ginzel, Video of Photo-Elastic Visualisation of Ultrasound, [http://www.ndt.net/article/v08n05/ginzel/ginzel.htm](http://www.ndt.net/article/v08n05/ginzel/ginzel.htm), NDTnet May 2003, Vol.8, No.05