Photoelastic Visualisation of Ultrasonic Pulse Interactions
Part 5: Effects of pulse tuning on pulse shape and intensity

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The video to this article can be seen here www.ndt.net/search/docs.php?id=13779&content=1

1. Introduction

This technical note is Part 5 of a series started in NDT.net. A photoelastic video has been made of an ultrasonic pulse with essential parameters varied. Description of the associated video is provided in this technical note and remarks are made on some of the features seen. In Part 5 we consider the photoelastic visualised pulse of a transverse mode as the pulser voltage and duration are adjusted.

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. A standard coupling gel (Sonotech SH1001) coupled the probe to a glass sample (soda-lime float glass) using. The photoelastic imaging system was configured to provide an optimised image of the pulse with the illumination strobe delay adjusted to observe the pulse at a point approximately 23mm soundpath into the glass.

In order to illustrate the effects of pulse parameter adjustment, first the voltage was varied for fixed pulse duration and then the voltage was fixed and the pulse duration varied.

The PCPR100 pulser allows the operator to select the parameters of the voltage applied to the piezo element. Options allowed include:

Pulse shape
- Positive uni-polar square wave
- Positive bipolar square wave
- Negative unipolar square wave
- Negative bipolar square wave

Pulse amplitude
- 12 volts then 25 volts to 375 volts in 25 volt increments

Pulse duration
- 25ns to 769ns (20MHz to 0.65MHz)

Number of cycles
- 1 to 8

Ability to select more than a single cycle of the voltage makes the PCPR100 a tone-burst pulser.
Pulse options available are represented in Figures 1-4.

Figure 1  Pulse shape options

Figure 2  Pulse amplitude options

Figure 3  Pulse duration options
By observing the amplitude response from an A-scan display it was determined that the optimum amplitude was obtained using a negative bi-polar pulse tuned to 5MHz with 200V applied voltage. Amplitude difference between the 175V and 200V signal was less than 0.5dB and increasing voltage indicated no noticeable increase in amplitude.

2. Comments on the Video
The video is comprised of two sequences of still captures. In the first sequence the pulse duration is fixed at 5MHz (negative bi-polar 2-cycle) and the voltage increased from 25V to 250V. Voltage adjustments are made in 25volt increments.

In the second sequence the voltage is fixed at 200 volts (negative bi-polar 2-cycle) whilst the pulse duration is varied from 2MHz to 8MHz in (i.e. 3MHz below and above the nominal frequency).

No adjustments have been made to the images to increase contrast as the effects are clearly apparent. Strobe delay was adjusted to image the pulse in a portion of the glass block well away from the probe and any targets.

Pulse voltage adjustments illustrate that pulse shape is unaffected by the applied voltage over the range from 25volts to 250 volts. Visually no perceptible intensity increase is seen in the image after about 150 volts. Figure 5 indicates the resulting images at the lowest and maximum levels with the maximum perceptible level (150V) added to indicate the practical limit for the element used. This indicates that there is no advantage to driving a probe at voltages much over the peak displacement value.
In the second sequence of images it can be seen that, by holding the voltage at 200 Volts and varying the pulse duration, both the shape and intensity of the pulse are changed.

Soda-lime glass has a transverse velocity of the shear mode of 3460m/s. Based on the fundamental equation $\lambda=v/f$, wavelengths for the range of frequencies used can be determined and are tabulated in Table 1.

Table 1 Wavelengths of transverse mode in soda-lime glass

<table>
<thead>
<tr>
<th>Frequency (MHz)</th>
<th>Wavelength (mm) ideal</th>
<th>Measured in IIA (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1.73</td>
<td>0.58 (doubled pulse)</td>
</tr>
<tr>
<td>2.5</td>
<td>1.38</td>
<td>0.54 (doubled pulse)</td>
</tr>
<tr>
<td>3</td>
<td>1.15</td>
<td>1.09</td>
</tr>
<tr>
<td>3.5</td>
<td>0.99</td>
<td>0.96</td>
</tr>
<tr>
<td>4</td>
<td>0.87</td>
<td>0.84</td>
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<tr>
<td>4.5</td>
<td>0.77</td>
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<td>5</td>
<td>0.69</td>
<td>0.67</td>
</tr>
<tr>
<td>5.5</td>
<td>0.63</td>
<td>0.62</td>
</tr>
<tr>
<td>6</td>
<td>0.58</td>
<td>0.60</td>
</tr>
<tr>
<td>6.5</td>
<td>0.53</td>
<td>0.56</td>
</tr>
<tr>
<td>7</td>
<td>0.49</td>
<td>0.53</td>
</tr>
<tr>
<td>7.5</td>
<td>0.46</td>
<td>0.49</td>
</tr>
<tr>
<td>8</td>
<td>0.43</td>
<td>0.49</td>
</tr>
</tbody>
</table>

The ideal wavelengths are noted as well as the values measured using the Image Intensity Analysis software (IIA) whereby the pixels are scaled to a known feature. The scaling to the 10mm notch is illustrated for the condition where the pulse was tuned to 5MHz in Figure 6.
When the pulse used to drive the probe is at 2MHz there is a doubling effect of the pulse pattern as seen in Figure 7. The cursors used to assess the image intensity at two adjacent negative cycles indicate that even though the pulse duration applied is greater than the nominal frequency, the effect is to cause a higher frequency than would be associated with the 2MHz pulse. The appearance of the pulse in glass indicates something of a rattle effect.

From the video images we can see that as we decrease the pulse duration from that of a 2MHz tuning to that required for an 8MHz tuning, the wavelength of the pulse smooths to a simple sinusoidal shape and the wavelengths continue to decrease. Also noted is decrease in image intensity (amplitude) as the tuned frequency moves off the nominal 5MHz.

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

The video to this article can be seen here www.ndt.net/search/docs.php3?id=13779&content=1